ABSTRACT

Title of Dissertation:	The Science of Artistic Expression: Intersections of Piano Pedagogy and Human Neuromechanics
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This dissertation seeks to illuminate the ways in which the scientific field of neuromechanics can inform and improve piano performance and pedagogy resulting in heightened artistic expression. This work represents a beginning to a long-overdue conversation that needs to happen between various fields of study that intersect in the field of piano performance.

Historically, despite over 300 years of treatises and methods, there has been little consensus on the best approaches to the pedagogy of piano performance. Additionally, there seems to be a demonstrable lack of understanding of the impact of physiology, biomechanics and proprioceptive awareness on the pianist as well as the ergonomic considerations of the piano itself. Students having technical or artistic shortcomings are often labeled as untalented without consideration for the efficacy of the pedagogical approaches to which they were exposed. Aspiring and famous pianists continue to accrue injuries. Furthermore, there is the noticeable lack of technological advancement of the instrument itself.

In order to point to ways in which these concerns might be addressed in the future, this dissertation explored several significant areas: 1) historical pedagogy that focused on the development of piano technique, which showed not only the lack of consensus but the general lack of scientific authentication within the approaches of respected pedagogues; 2) scientific texts which focused on motor control in instrumental performance and other tasks, revealing the richness of resources potentially available to piano pedagogy; 3) the impacts of piano technology on piano playing, an area shown to be far-reaching in both the advancement of piano technique and injury prevention.

Another part of the dissertation included several studies into the current experiences of pianists in the field. One study conveyed a significant gap in knowledge but also a desire for better understanding of and more improvement in piano-playing. Another study, a pilot, proposed a way to study the neuromechanical coordination of the fingers and wrists in piano-playing thereby showing a correlation between lateral wrist movement and individual finger strength, speed and control. Crucially, inquiry into linkages between proprioception and piano-playing showed a missing link which could be explored in the future.

THE SCIENCE OF ARTISTIC EXPRESSION: INTERSECTIONS OF PIANO PEDAGOGY AND HUMAN NEUROMECHANICS

by

Dion Alexander Cunningham

Dissertation submitted to the Faculty of the Graduate School of the University of Maryland, College Park, in partial fulfillment of the requirements for the degree of Doctor of Musical Arts
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Preface

Weekend mornings for children in the Bahamas of the 1990s were not the flurry of activity that appear to constitute the lives of many children in the developed world. Options were to either watch the singular local TV channel available, read or go outdoors. I do recall though on one of those TV watching occasions being introduced to the piano through the performances of local musician and teacher, Mr. Francis Fawkes. I was completely amazed at the facility he demonstrated, the sound he produced and the emotions that overtook me as a result of his artistry. Little did I know that it was the beginning of a love affair with music and particularly the piano that continues to this day.

I was driven to pursue this area of research for my dissertation because of my unconventional background in piano playing. From the age of five until the age of seventeen, I did not have the luxury of having access to a grand piano at home or in my lessons. My early training was done on an electronic keyboard. Growing up in the Bahamas, most piano students do not have a lot of options in terms of quality piano teachers. I was fortunate enough to find Dawn Sands, a native of Canada, who had received a diploma in piano. Though reluctant to teach at first, through the persistence of my mother, Edris Cunningham, she agreed to be my piano teacher and I, her first student. Though not trained as a piano teacher, she kept me interested and excited in my formative years about the piano and my overall music education. It is to her I give sole credit to my theoretical and practical foundations as the K-12 institutions I attended gave me very little musically.

When I left the Bahamas for undergraduate studies at Macalester College, I encountered Don Betts, who fundamentally changed the way I approached piano playing.

It was through him I was exposed to the technical studies of composers like Hanon, Liszt and Czerny which enhanced my love for the canon of classical piano works. It was also the first time in my life that I was able to have lessons, practice and perform with regularity on a grand piano. Under his tutelage, I blossomed enough to be able to play complete sonatas and other major works for the first time. I also double-majored in Biology, my other great passion, during those years at Macalester.

I am grateful for every teacher, mentor and medical professional who led me down the path of inquiry and self-discovery - many of whom I will mention later on in this work. Many continue to support me to this day and have played a role in my unconventional way of thinking about music and other areas. Very few fields are as staunchly traditional as instrumental performance and particularly the piano - with its over 300 years of documented history. This work is not meant to be a solution to the challenges of piano-playing and pedagogy. Rather, it represents a beginning to a long overdue conversation that needs to happen between various fields of study that happen to intersect in the field of piano performance.

I ask that readers overlook any conceptual or organizational missteps and look at the bigger picture that I am trying to create. Throughout my future career as an academic and researcher, I hope to better refine my abilities to communicate about this challenging intersection of music and the sciences. Additionally, it is my further hope that other pianists, pedagogues and scientists who will read this this work will bring even further clarity to the concepts and ideas within through writings of their own while also serving as the stimulus for their own novel ideas.

Dedication

To my parents, Deanza and Edris Cunningham and my brother Dominic. Thank you for your endless love and support. I love you more than words can say.

To my inner circle of family, friends, and supporters. Thank you for walking with me for the past 7 years and for reminding during tough times of how far I have already come.

To my 700 islands, the best little country on the planet. I am proud to be Bahamian and to share with the world a piece of who we are.

To my Heavenly Father. It is to You, I give the glory. I will bless Your name forevermore.

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Introduction

Throughout the history of instrumental music, no other instruments have a more developed and expansive repertoire of music written for them than do keyboard instruments.[1] This is especially so for the pianoforte. The importance of an instrument is not simply in its intrinsic nature - but in the literature that has been written for it. The great composers of the world have given the piano a literature that in size and depth and splendor is unmatched by that of any other single instrument.[2]

In addition to this vast repertoire, there exist many pedagogical approaches and methods for the piano, as both teachers and artists aim to achieve musical expression on this instrument. These approaches are vastly varied and are informed by a number of factors. These include the pedagogical lineage of famous performers and composers, the expansion of the complexity of literature and the demands of the instrument as its technology has developed over time.

However, what has not been considered to the same degree is how these various approaches impact human performance and health. There has been, for the most part, not enough regard for the scientific and technological disciplines on which piano playing is based within not only the existing pedagogy but also within the conservatories and academic institutions from where this learning often occurs. Little growth has transpired in our understanding of human physiology and the biomechanics that support existing pedagogy or in the development of new approaches as a result of these findings. Proprioceptive awareness, for example, encourages a greater economy of movement and

[1] Hinson, Guide to the Pianist's Repertoire, preface.
[2] Ortmann, Physiological Mechanics of Piano Technique, xxix.

the prevention and management of injury, yet does not currently exist in our pedagogy. Additionally, there has been virtually no technological or ergonomic advancement in the construction of the modern piano. Sadly, this era of multidisciplinary approaches to study has not yet reached piano performance. The potential of multidisciplinary influences has, to this point, been sacrificed on the altar of so-called 'musical genius,' 'artistic individuality,' and so-called 'prodigious talent.'

This state of affairs has produced many challenges and adverse consequences within our field. Firstly, there exists little consensus on the best approaches to piano performance and pedagogy. While the famous pianists and theorists of the past and present have all attempted to ascend Mt. Parnassus - some with greater vision than others - they have not agreed on the specific road to be used in acquiring a fine interpretative technique.[3] Sadly, there exists today an ocean of pedagogical approaches and methods – too many for even the most diligent of students and teachers to sift through.

The further fallout of this 'pedagogical salad' has also been the labeling of students having technical or artistic shortcomings as untalented without consideration for the efficacy of the pedagogical approaches to which they were exposed. In a graduation speech given in 2016, pianist and professor Awadagin Pratt testified to this fact by recalling a letter given to him by his professor who, for all his musical gifts, brought to light his technical shortcomings. This was after having completed his final jury at the Peabody Conservatory.[4] As a result, he retreated for a time to Canada to work intensively on his technique. Fortunately for him, he emerged from his solitude successfully and now enjoys a career as a performer and academician. While I applaud

[3] Gerig, Famous Pianists and their Technique, 3.
[4] YouTube. Online Video Clip, https://www.youtube.com/watch?v=-1fnKlywbQ8&t=392s

Mr. Pratt for his perseverance, I think a majority of aspiring pianists are working extremely hard to perfect their craft and spending hundreds of thousands of dollars for education over the course of their lifetime - not to mention hundreds of thousands of hours in the solitude of the practice room. But many pianists, for all their loving toil, are without the reward that people like Mr. Pratt are enjoying. Why is it that in this highly scientific and technological age - piano technique largely remains contingent on the 'luck of discovery'?

Secondly, as the number of aspiring pianists continues to increase exponentially, an increasing prevalence of injuries is also being observed. At the age of 16, Leon Fleisher was labeled as the 'pianistic find of the century' and for some 20 years enjoyed the pinnacle of success as a world-class American pianist. A student in the direct pedagogical lineage of Ludwig van Beethoven, he was one of the most gifted pianists of his generation. However, by age 36, he could barely write his name due to the development of a condition that caused the fourth and fifth fingers of his right hand to curl under. This put an immediate halt to his career as a concert pianist.[5] Though Leon Fleisher has since enjoyed success as a conductor and professor at the Peabody Institute of Johns Hopkins, coupled with intermittent returns to the stage as a performer, he continues to fight to regain complete mastery of his right hand to this day.

Such stories amongst past and present pianists are commonplace. Clara and Robert Schumann, Sergei Rachmaninoff, Alexander Scriabin, Glenn Gould, Van Cliburn, Murray Perahia and Richard Goode all come to mind.[6] In addition, there are untold stories of thousands of aspiring pianists who, after sustaining similar injuries, gave up on

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[5] Retrieved from https://www.independent.co.uk/arts-entertainment/music/features/leon-fleisher-my-life-fell-apart-1984408.html.
[6] Mark, Pianists Injuries, 1.

their careers, not only as performers, but in the field of music as a whole. These stories show how even those who are held in high regard as models for piano playing may not be the best models in a physical sense.

Another lauded genius, Lang Lang, for example, is one of the biggest names in classical music today. Arguably having achieved the status of 'superstar concert pianist,' Lang has not only headlined all of the world's great concert halls, but also has had crossover appeal, having played at the live-televised opening ceremonies of the 2008 Beijing Olympics, as well as with *Metallica* at the 2014 Grammy Awards. However, since April 2017, Lang Lang has not been performing due to inflammation in his left arm. His return to performance is expected later in 2018.[7]

Stories like these demonstrate the need for a review not only of the existing approaches to piano pedagogy and those artists we hold in high technical regard, but also the input of scientists and medical professionals. While our field remains captivated by the technical and artistic feats of those who perform at the highest levels in live concerts, the harsh realities of potential injuries should also be highlighted and multidisciplinary approaches to correcting this problem should be encouraged. The fact that these types of safeguards do not currently exist is highly problematic, and most likely due to the cultural stigma of having an injury as a pianist. Injuries typically reflect on not only the pianists themselves, but also on their teachers. As a result, many artists continue their suffering in silence, while their teachers consequently fail to reflect upon how their approaches may be affecting their students. Lang Lang's teacher at the Curtis Institute, Gary Graffman, whose own career had also been curtailed by arm problems is telling. He stated, "Every student gets it. So you don't practice for a while, and it gets better. Lang Lang was the

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[7] Stearns, Lang Lang's Recovery, Retrieved from http://www2.philly.com

first of any of my students where it developed into something that lasted a long time."[8] According to the 2000 Wisconsin Music Teachers Association's statistics, it is estimated that some 20 million Americans play the piano.[9] More incredibly, some 40 million children are learning the piano in China, and this number is growing, according to a 2015 Al Jazeera report.[10] A field with these numbers of participants and practitioners deserves pedagogy that is based upon proven pedagogical concepts authenticated by current physiological and kinesiological information. Otherwise, we could find ourselves on the edge of a statistical epidemic with regard to injuries resulting from piano playing.

Thirdly, the piano's current state of construction as an instrument has rarely been explored as a contributing factor in the performance and health of modern-day pianists. The advancement of the instrument seems to have reached a standstill within the last 100 years, leading many in our field to believe that the instrument itself has reached a state of perfection. However, nothing could be further from the truth. Certainly, the major developers of instruments today are not pushing the envelope in this regard. One of the great pianists of the last century, Vladmir Horowitz, is the greatest example of an artist who was able to demonstrate a great deal of ingenuity, both in his performance as a pianist, as well as in his imaginative approach to the altering of his instrument to better align with his own unique capabilities. Horowitz was also known for having a flat-fingered approach to piano playing. According to Wayne Johnson's sharing of his experience on the Steinway that Horowitz travelled with for concerts,

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[8] Stearns, Lang Lang's Recovery, Retrieved from http://www2.philly.com

[9] How many people in the world play piano? Retrieved from https://www.quora.com/ e

[10] Fawcett, China's Piano Craze Retrieved from https://www.aljazeera.com/news

> "I have never driven a Ferrari, but playing that piano was how I would imagine how it would feel to drive something with so much power and finesse. Horowitz had had the action "doctored" by his technician to his preference so that it was extremely light. It had a bright, bell-like tone, and an incredible dynamic range. *Fortissimos* could be achieved with much less physical power than usual. *Pianissimos* were more problematic, because it was very easy to over-play. I quickly found that using a much less decisive key stroke was the only way to tame the sound. In fact, "stroking" the key instead of "pushing" it gave much more control of soft, slower passages. That was one of Horowitz's quirky techniques as well. And I also quickly found that flatter fingers were needed to avoid a brittle, choppy sound. It was an "aha moment" for me. A light came on as to why and how Horowitz could manipulate the sound of that instrument the way he did."[11]

There are no reports that Horowitz suffered from a performance-related injury during his lifetime. But the context of the 'altered piano' demonstrates how the instrument itself could help the piano play and work *with* an artist's skills and technical capabilities, and thus help prevent injury. The majority of pianists, however, do not have the luxury of altering their instruments to suit their physical and technical needs. The instrument itself is undoubtedly a major cause of pianistic challenges for many.

Upon entering the Peabody Institute, I encountered my third piano teacher, Professor Marian Hahn, who significantly changed my technical approach to the piano. I remember vividly in my first lesson with her that she actually held my fingers while guiding me in how to play single notes on the piano. Her approach differed from my

[11] Retrieved from https://thepianobear.wordpress.com/2017/09/29/vladimir-horowitz-flat-fingers/

previous teachers in the sense that she also encouraged me to read books and articles that discussed piano playing through an understanding of the human body. Additionally, she also encouraged me to get massages to release the tension she observed in my body, as well as yoga and dance classes to assist in my flexibility and rhythmic sensibility. Under her instruction, my playing underwent such a metamorphosis that I was better able to develop control and consistency for the first time. It was under her instruction that I developed enough technically and artistically to win prizes in my first competitions and to be admitted to diploma and doctoral programs at both Peabody and the University of Maryland.

During my second year at Peabody, I held an assistantship with the piano maintenance department where I studied with Mary Schwendeman and her team. It was there that I received my first instruction in piano tuning, in the regulation of the hammers and keys, and in piano moving and cleaning. It was there that my eyes were first opened to the intricacies of the mechanism and how a variation in one aspect impacts not only the overall functioning of the instrument, but also what a musician can execute musically. It also brought me awareness of the sad reality that until this point, I did not understand the instrument on which I had hoped to build my career. This experience became especially valuable to me later on at the University of Maryland, where I was able to fund the first 2.5 years of my education because of my skills in this area.

It was also at Peabody that I was introduced to the Alexander Technique and to my Alexander teacher, Leslie Felbain, with whom I continue to study at the University of Maryland, where she serves as a professor in the School of Theatre, Dance and Performance Studies. Though not a pianist, her instruction has helped me to think about the body and awareness so fundamentally that it has had a positive impact on my playing. She helped me to develop awareness of where my limbs were in space as well as to recognize my muscular tension and where I was 'holding.' Her instruction has guided me to seek an economy of movement as I carry out everyday activities. This training carried over into my approach to piano playing and was especially valuable to me during my years at UMD – particularly when I developed an occupational injury in my right elbow almost 3 years ago from tuning pianos.

In the spring semester of 2015, I was diagnosed with cubital tunnel syndrome – a compression of the ulnar nerve that runs through the elbow joint. This was due to using my elbow as a pivot to manipulate the hammers on the many upright pianos in the School of Music at the University of Maryland. Up to this point in my musical career, I had prided myself on having never experienced a playing-related musculoskeletal disorder like many of my colleagues – though in hindsight, I believe like Horowitz, playing on a keyboard with a lighter action certainly shielded me during my formative years. But the nature of the injury affected me much in the same way as if it had been playing related. I experienced twitching and a lack of control of the middle, ring and little fingers of my right hand. At this point in my doctoral program, I had only completed one of potentially five recitals and was a mere eight weeks away from my second recital. Coupled with the other challenges I was experiencing that year, it was this latest indignity that changed the trajectory of my doctoral studies. The injury literally forced my hand in making my avocation in the sciences the central point of a full dissertation that bridges the gap between the sciences and the arts. Thankfully, I was able to get through my second and third recitals as well as 40+ pages of handwritten comprehensive examination essays. During this period, I also underwent a battery of medical tests and a semester of physical therapy to assist with my recovery. These medical interventions continued until I was no longer eligible due to the discontinuation of my employment within the university and the resulting termination of my medical insurance that covered those costs. I continue to travel down the road toward complete recovery.

Having such radical changes occur in my approach to piano playing, my movements, and my awareness has not been the easiest experience. Then to superimpose a completely unrelated injury on top of that has truly been a test of endurance. In a profession where evaluation is often brutal, short-sighted and dismissive, I have had my fair share of challenging musical experiences in lessons, rehearsals, masterclasses and performance settings. This has often been accompanied by passive and active ridicule at the hands of colleagues, faculty and highly-regarded artists. Though continuing to submit myself to an overhaul in my technical approach has reaped benefits and afforded me increased performance opportunities, it has caused me to ponder the number of aspiring pianists who never realize their full musical potential because of their physical challenges rather than their intellectual ones. How many do not have the resilience, resources or encouragement to pursue the path of inquiry after bad performances, frustration, discomfort, pain or injury?

I believe that not enough regard for the scientific and technological disciplines within piano pedagogy is largely responsible for many of the challenges pianists face, in particular, the physical aspects. This has resulted in a lack of clarity as to the best pedagogical and technical approaches to the piano. As my anecdotal experience suggests, such clarity requires a truly interdisciplinary approach and the inclusion of subjects that have historically been ignored in our discipline. The ability to do cutting edge research with esteemed faculty like Dr. Jae Kun Shim, associate professor in the Kinesiology Department, are significant reasons why I decided to study at UMD – an institution with a particular emphasis on interdisciplinary research. This is in addition to studying with Dr. Cleveland Page, a piano professor who is one of the most respected pedagogues of his generation, and most recently, a collaborative piano professor who has rebuilt the technique of many pianists during her career, Professor Rita Sloan.

Though there are a number of areas that could be discussed, I am choosing to focus on a few key areas in this document that hopefully will shed light on the confusing multiplicity of pedagogical approaches as well as the clear need for multidisciplinary influences. These areas will include:

1) Historical pedagogy that focuses on the development of piano technique
2) Scientific texts that focus on motor control in instrumental performance
3) Impacts of piano technology on piano playing
4) Proprioception in piano playing
5) The current experiences of pianists in the field
6) My pilot study that proposes a way to study the neuromechanical coordination of the fingers and wrists in piano playing.

From my vantage point, science and art should not be mutually exclusive, for surely, any advancement in technical skill is an advancement in the freedom of the musical imagination. Hofmann said it well when he stated that "Technique represents the material side of art, as money represents the material side of life."[12] There cannot be a truly great performance without a masterful physical technique. It becomes the great

[12] Gerig, Famous Pianists and their Technique, 1.

liberating force for the pianist.[13] It is my hope that this document can help to improve the conversation between music and the sciences, since just as no other instrument has such a large repertoire and pedagogy, there are few activities that are as physically complex as piano-playing. On these merits alone, both disciplines stand to become all the richer.

[13] Gerig, Famous Pianists and their Technique, 1.

Part A: Traditional Pedagogical Practices and Philosophies

Chapter 1: Review of Historical Pedagogy

Many books have been written that offer an outline of the entire pedagogical history of the piano. I will not attempt to recount this history, but rather focus on seminal methods, famous teachers and performers, and pedagogues. What I have observed in this review of piano pedagogy is best articulated by the words of Arnold Schultz – Chicago piano teacher and pedagogue of the early 20th century. He states that, "Viewed as a whole, the literature represented not nearly so much a partnership in seeking truth as a competition in proclaiming it, with none of the proclaimers being especially interested in the proclamations of the others."[14] Piano pedagogy was a field where non-consensus reigned supreme, and convergence of ideals was seemingly neither sought after nor encouraged. Not much has changed in modern times, with teachers and pedagogues operating their musical fiefdoms with few truly emerging as lasting or definitive.

Section 1: Common Themes and Concepts

Throughout history, the ultimate aims of piano pedagogy and performance have always been musical ones. As pedagogue and composer Tobias Matthay observes, "Technique means the power of expressing oneself musically."[15] Many pedagogues have spent a lot of time speaking about the mental and aural aspects of performance - oftentimes to the neglect of the physiological requirements of playing the instrument.

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[14] Ortmann, Physiological Mechanics of Piano Technique, xvi.
[15] Gerig, Famous Pianists and their Technique, 1.

Technique was viewed rather a matter of the mind than of the fingers.[16] This is also a feature of the Russian approach, where the emphasis is on *thinking moods* into the fingers and arms. Central to their approach is the concept that a beautiful singing tone must first be conceived mentally.[17] Famed piano teacher Rosina Lhevinne articulated this viewpoint well when she stated that she repeatedly tells students, "You imagine the sound you wish to produce, and then you produce it."[18] Admittedly, she also had famous statements used in lessons used to describe aspects of piano technique. The phrase, "Come to me darling, come to me" used to describe *legato*, comes to mind.

The view that one can learn and develop technique from a score was also common. The music itself was often seen as the best teacher of both interpretation and technique and is best instructed at the keyboard.[19] The implication was that technique does not really change over time, but rather is expanded by the new music of each succeeding generation. Hummel, famed 18th century composer and virtuoso pianist, also championed this viewpoint. He maintained that teachers should accustom the pupil, at all times, to direct his eyes to the notes only, and to find the keys by the feel of the fingers, according to their distance from one another. He stated, "Many pupils, particularly children, endeavor at first to play from memory, by which means they never attain any readiness in reading the notes; if he should observe that the pupil has a committed a piece too much to memory, let him proceed no further with it, but at once give him something new, that he may be compelled to play by note and not by ear." [20] Such an approach continues to be in vogue by many pianists and teachers in modern times.

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[16] Gerig, Famous Pianists and their Technique
[17] Gerig, Famous Pianists and their Technique, 302.
[18] Gerig, Famous Pianists and their Technique 305.
[19] Gerig, Famous Pianists and their Technique, viii.
[20] Gerig, Famous Pianists and their Technique, 70-71

Others advocated playing studies and etudes to develop technique. For pupils of the past, studies like those of Heller were desirable in the cases of students with only moderate technical ability, while the splendid etudes of Chopin were excellent remedies for advanced pupils with tendencies toward hard, rigid playing. To remedy slovenliness, there were the well-known works of Czerny, Cramer or Clementi.[21] Emil von Sauer, famed German pianist and teacher, took this one step further advocating technical development before attempting standard repertoire. "Technic first - then interpretation. The pianist with a bungling, slovenly technic, who at the same time attempts to perform the great masterpieces, reminds me of those persons who attempt to disguise the necessity for soap and water with nauseating perfume."[22]

There was also a view that the piano teacher was the absolute authority. Isabelle Vengerova, famed 20th century Russian pedagogue, for example was the product of an old-fashioned authoritarian European tradition. She expected from most of her pupils an absolute and unquestioning obedience and adherence to her ideas, both technical and musical, which made it difficult for them to grow on their own.[23] As a result, however, students' horizons are restricted; the students' learning achievements usually will not go beyond the limited understanding and provincialisms of their teachers and their other immediate influences. Where his or her resources are excellent, the loss may not appear so great. But even here, a sense of historical perspective will be missing.[24]

Others believed that the concept and even the act of singing is an important aspect of instrumental training. Many believed that among those musicians and composers who in their youth have received instructions in singing, there will generally be found more

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[21] Cooke, Great Pianists on Piano Playing, 240.
[22] Cooke, Great Pianists on Piano Playing, 241.
[23] Schick, The Vengerova System of Piano Playing, 4.
[24] Gerig, Famous Pianists and their Technique, vii

pure, correct, and critical musical feeling, than among such as have only a general and extrinsic idea of melody and good singing.[25]

Many pedagogues and performers also believed in the concept of innate talent connected with teaching. Ossip Gabrilowitsch, Russian born American pianist, emphatically stated,

> "I would earnestly advise all teachers to discourage the efforts of pupils to attain virtuoso heights unless they are convinced beyond the possibility of a doubt that the pupil has marvelous talent. The really great performers seem to be endowed with a "God-given" insight in the matter of technic and touch. They are unquestionably born for it. They possess the right mental and physical capacity for success. No amount of training would make a Normandy dray horse that could compete with a Kentucky thoroughbred on the race course." [26]

The importance of a pupil's ability to concentrate and of a teacher's ability to enforce this continuous concentration has also been emphasized. Many believe that, "Concentration is the vertebrae of musical success. In music, the mind has no time to wander. If a pupil does not have this ability, it is the teacher's responsibility to teach this important skill. There is also the admission that many young students never learn it because it is not innate to them and as a result should cease their music studies. Such students are further dismissed as failures in other endeavors because of their lack of musical concentration."[27]

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[25] Gerig, Famous Pianists and their Technique, 76.
[26] Cooke, Great Pianists on Piano Playing, 129.
[27] Cooke, Great Pianists on Piano Playing, 237.

Section 2: Early Keyboard Methods

The history of piano pedagogy and technique has its roots prior to the invention of the piano. Much of the early methodology for piano was based on its predecessors - the harpsichord, clavichord and organ. These instruments, while similar in the dimension of use of a keyboard, differed substantially not only technologically but in terms of weight and touch.

The action on a harpsichord is one such example. Little force is needed to pluck the string; the action of the fingers is adequate for most of the literature.[28] Some hand and arm movement is needed in chord production, but with no more of the weight of the arms brought to bear than is necessary. Too much force, even with a finger action, is undesirable because of the loss of sensitivity and control and also because of the resulting percussive noises which are more noticeable than those heard in the piano action. The arm needs to be suspended over the keyboard in a weightless manner. It serves as a stationary base for the action of the fingers. The movement of the arm, necessary in controlling horizontal placement of the hand, should be executed in a quiet, graceful and curvilinear manner.[29]

I observe that here even at this early stage in keyboard pedagogy, there are crucial links in the playing apparatus that are not considered – namely the wrist and the back. The wrist is the place from which the fingers branch off and provide the crucial conditions required for effective finger movement. The upper back is the last part of the arm apparatus through its connection through the shoulder joint to the scapula. Contrary

[28] Gerig, Famous Pianists and their Technique, 9.
[29] Gerig, Famous Pianists and their Technique, 9.

to popular belief, the scapula is not connected to the ribcage but is suspended over the ribcage.

The concept of *legato* also varied differently with the reduced resonance and absence of a pedal mechanism. *Legato* is completely controlled by the fingers - the slightest deficiency is immediately evident. The fingers must be held close to the keys and move in as precise a manner as possible.[30] The role of the wrist at this point is still not acknowledged in legato production. The wrist helps to facilitate finger *legato*. Even after the development of the piano, it was thought by many artists that working on older instruments was still vital to developing technique. There are those who believe that pianists today should likewise perfect and discipline their touch, as well as sharpen their listening powers, by working at both the harpsichord and the clavichord.[31]

In a lesson with a piano student, Diruta, 16th century Italian organist and composer, stated, "Because the sonatori who want to play music on the organ, has to observe all the rules I have given about keeping the hands quiet and relaxed, holding the notes, and so forth which are unfamiliar to them; whilst the organist who wishes to play dances can easily make an exception to the rules, especially that about the jumping of the hands and the striking of the keys."[32] If the hands are totally relaxed, as indicated here, it would be impossible to produce sound, as force can only be transmitted across joints if the joints themselves are fixed.

Flexibility of the hands at the instrument was an important consideration. Couperin believed that "People who begin late, they should make their fingers flexible, or get someone else to do it for them, before sitting down to the Harpsichord; that is to say,

[30] Gerig, Famous Pianists and their Technique, 10.
[31] Gerig, Famous Pianists and their Technique, 10.
[32] Gerig, Famous Pianists and their Technique, 12.

they should pull, or get someone to pull their fingers in all directions; that, moreover, will stir up their minds, and they will have a feeling of greater freedom."[33] This is interesting, as Couperin advocates for conditioning of the fingers away from the instrument as a way to improve flexibility. While the merits of such an approach have yet to be determined, it is important to note that Couperin is one of the few pedagogues in history promoting activities away from the piano as being beneficial to piano playing.

Unlike the modern piano, these early instruments were incapable of producing varied dynamics with the fingers. But touch was still an important aspect of keyboard pedagogy. Similar to legato, one's delicacy of touch depends also on holding the fingers as close to the keys as possible.[34] Rameau agreed with this point of view as well. "Perfection of touch results from proper finger action. Any ability can be acquired by simple mechanical practice, cleverly done. The ability to walk or run derives from the flexibility of the knee-joint; the ability to play the harpsichord from the flexibility of the fingers at their roots. A larger movement is only admissible when a smaller is not sufficient." [35]

Such statements are problematic on a variety of fronts – two of which I will address here. Firstly, the notion that the fingers alone are responsible for 'perfection of touch' ignores the other components of the playing apparatus and how 'proper coordination' of these component parts results in perfection of touch. Secondly, I believe that the injuries many aspiring pianists have endured throughout history are due, in large part, to the belief that 'simple mechanical practice' will result in their acquisition of

[33] Gerig, Famous Pianists and their Technique, 15.
[34] Gerig, Famous Pianists and their Technique, 16.
[35] Gerig, Famous Pianists and their Technique, 17.

improved ability. Practice is only one component of developing ability, not only in piano playing, but also in any sphere where skill-building is a component.

Thoughts of velocity and speed were again attributed to diligent practicing. Rameau believed that "velocity and speed are attained only by the practice of regularity." [36] C.P.E. Bach emphasized that all difficulties in passage work should be mastered through repeated practice.[37] Such a notion of increased practice in order to develop velocity, speed and clean passagework, does not take into account matters of proper coordination of the playing apparatus, nor how this repeated practice should be carried out.

> On fingering and finger position, Forkel describes Bach's keyboard technique: "The five fingers are bent so that their points come into a straight line, and so fit the keys, which lie in a plane surface under them, that no single finger has to be drawn nearer when it is wanted, but everyone is ready over the key which it may have to press down. The movement of the fingers should always be under conscious control. No finger must fall upon its key…. but only needs to be placed upon it with a certain consciousness of the internal power and command over the motion."[38]

Forkel further argues that in playing, the fingers should be arched, and the muscles relaxed. The less these two conditions are satisfied, the more attention must be given to them.[39] Those who play with flat, extended fingers suffer from one principle disadvantage: the fingers, because of their length, are too far removed from the thumb,

[36] Gerig, Famous Pianists and their Technique, 18.
[37] Gerig, Famous Pianists and their Technique, 30.
[38] Gerig, Famous Pianists and their Technique, 20.
[39] Gerig, Famous Pianists and their Technique, 27.

which should always remain as close as possible to the hand.[40] From this observation, we can infer that curved fingers were favored. Though I would not want to be accused of quibbling over the technique of the great J.S. Bach, research has shown that in order to maintain curved fingers, simultaneous co-contraction of the flexors and extensors of the fingers must occur, a movement that has unfortunately been correlated with the injuries of the tendons involved. Furthermore, it is impossible for the fingers to be arched and the muscles relaxed; only one of those conditions can exist in a given moment. Arched fingers by their nature require contraction of muscles.

There is even some commentary on the appropriateness of facial expressions and differentiating their varied intention and purpose. "Ugly grimaces, of course, are inappropriate and harmful; but fitting expressions help the listener to understand our meaning." [41] Outside of Hummel, there is little pedagogical commentary on the alignment of facial expressions and keyboard works. Pedagogy surrounding facial expressions is certainly something for pedagogues to consider - particularly given the abundance of expressions in use by pianists today.

Section3: Early Piano Pedagogy - Clementi, Hummel, Czerny

The piano was invented in the early 1700s by Bartolemo Cristofori. Both Haydn and Mozart composed for the new instrument, with the former actually composing for both piano and harpsichord. Mozart, however, composed entirely for the new instrument. And though both composers' music enjoys a celebrated position in the modern pianist's repertoire, it was Clementi who was responsible for the early beginnings of a true

[40] Gerig, Famous Pianists and their Technique, 27.
[41] Gerig, Famous Pianists and their Technique, 30.

pianoforte technique.[42] With Clementi, passagework is naturally played *legato*. In the Mozartian era, it would be played *leggiero*. The posture of legato playing according to Clementi is as follows. "The hand and arm should be held in a horizontal direction; neither depressing nor raising the wrist; the seat should therefore be adjusted accordingly. The fingers and thumb should be placed over the keys, always ready to strike, bending the fingers in, more or less in proportion to their length. All unnecessary motion should be avoided."[43] This is a similar idea to the contracting of the fingertips that was observed in Bach's keyboard approach. However, this means that the longer fingers must contract more in order to hold the fingertips in a straight line.

Clementi deserves credit here for recognizing the importance of a stable wrist orientation in the overall alignment of the playing apparatus. However, it is impossible for the wrist to stay at a given height when executing certain passages of chords and octaves. Therefore, his pedagogy does not account for needed adjustments in alignment which would be commonplace in much of the piano repertoire.

Because of the lightness of touch of the piano's predecessors, Clementi was the first pedagogue to tackle the concept of finger strength and control at the new instrument. It was to that end that he developed his *Gradus ad Parnassum*. It is the equality of finger action and an evenness of tone that Clementi desires to achieve through the practice of these etudes, not to mention the increase of strength and fluency in the hands and fingers.[44] Technical studies and etudes have been passed down to pianists over the years with a belief that repetition of such studies will lead to improved strength, flexibility, etc. What many of these studies do not address; however, is the coordination of the joints

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[42] Gerig, Famous Pianists and their Technique, 59.
[43] Gerig, Famous Pianists and their Technique, 60.
[44] Gerig, Famous Pianists and their Technique, 60.

required to execute such exercises. It is very much akin to someone walking into a gym for the first time without understanding the machinery contained therein. Often, it can be a recipe for certain injury.

Hummel's pedagogical work is also recognized from the same period. He advocated for proper body positioning, stating that the body must be held upright, neither bending forwards nor sideways, and the elbows rather turned toward the body, yet without pressing against it.[45] Here is the first mention of muscles and their role in performance. "The muscles of the arms and hands must act without any stiffness, and with so much force only, as is necessary to move the hands and fingers without languor."[46] Hummel is to be commended for recognizing that muscles facilitate movement. In his description of body positioning, such a description fails to take into account keys that lie in the extreme registers of the instrument. While such a position could be a good starting place, it is impractical in actual performance of many of the great works from his time but particularly afterwards.

The thumb was also an important consideration for Hummel. As it is shorter than the fingers, the pupil must accustom himself to hold it somewhat bent and inclining towards the first finger, that it may always be ready to pass under the fingers but it must not be permitted to touch the fingers, nor be allowed to drop below the keys.[47] The pedagogy of thumb use in piano-playing is one of the most debated points in piano technique. Many still advocate for the passage of the thumb under the other fingers in passagework. Others, however, deride the passage of the thumb under the other fingers

[45] Gerig, Famous Pianists and their Technique, 72.
[46] Gerig, Famous Pianists and their Technique, 72.
[47] Gerig, Famous Pianists and their Technique, 73.

as a source of thumb tension and recommend other alternatives. It is a point that deserves much study.

We also get an indication of hierarchy within Hummel's pedagogy. Of crucial importance is the freedom and quietness of the hand. He states, "In general, to attain the necessary facility, steadiness and certainty in playing, we must avoid every violent movement of the elbows, and the muscles must not be exerted beyond what a free and quiet position of the hand requires. The quickness of motion lies only in the joints of the fingers, which should move with lightness and freedom, and not be lifted up too high from the keys."[48] There is a lot of good terminology present in these statements that most pedagogues would agree with. Hummel, however, couples the words "free" and "quiet" in describing the position of the hand. In order for a given part of the body to be free, it has to be able to move. Conversely, the use of the term 'quiet' suggests that the given part is not moving at all. Non-movement of a body segment is produced by fixation of the surrounding tissues, which inherently results in a lack of freedom.

Concepts of ideal touch are also described. The touch or mode of striking the key must be decisive and equal; all pressure and thumping are to be avoided; neither hands nor fingers should change their naturally bent position, and the keys must be struck forwards rather than backwards on the keyboard, so that the tone may be more powerful, and the passage delivered with more roundness and finish.[49] One of the most sought-after goals of pianists is the complete control of and production of touch. Again here, Hummel uses phrases that many would agree with – namely the "decisive and equal" touch of the key which would result in evenness of tone. However, he does advocate for

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[48] Gerig, Famous Pianists and their Technique, 73.
[49] Gerig, Famous Pianists and their Technique, 73.

the keys to be "struck" and for this to be done in a forward direction. Both of these points deserve much study in order to be authenticated.

Hummel also discusses the importance of the ability to exercise absolute control of finger movements. He states,

> "To arrive at a correct and beautiful style of performance, it is requisite that the player should be master of his fingers - that is, that they should be capable of every possible gradation of touch. This can be effected only by the finest internal sensibility in the fingers themselves, extending to their very tips, by which they are rendered capable of increasing their pressure on the keys, from the most delicate contact to the utmost degree of power. Consequently, the fingers must obey the player in the gentlest touch and in the most natural and easy position of the hand, equally as in the finest stroke, and in the most extended state of the muscles."[50]

Hummel here describes the technical goal of virtually every aspiring pianist. How this is to be achieved however remains elusive, and in fact, almost mystical, since it requires musicians to possess the "finest internal sensibility in the fingers themselves."

Czerny, a student of Beethoven, is widely regarded today for his contributions to piano technique. His Opus 500, *The Complete Theoretical and Practical Piano Forte School*, along with other works, remains a significant part of the practice diet of piano students everywhere. Throughout the three volumes, while acknowledging the necessity of freedom of movement, Czerny emphasizes a quiet, restrained keyboard approach.[51] This is similar to Hummel's concept of the same hand condition and thus runs into the

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[50] Gerig, Famous Pianists and their Technique, 77.
[51] Gerig, Famous Pianists and their Technique, 111.

same problems of using incompatible terms. Closeness to the key is also emphasized by Czerny. "As each finger, previous to its being used, must be held very near to its key (without however touching it); so, after the stroke it must again return to its previous situation."[52] This concept of playing very close to the key is a debatable one and there are as many supporters of this concept as there are dissenters. Much research is required to authenticate claims in these dimensions.

What the above discussion of the early pedagogues sought to highlight was that, even at this early stage of pedagogical development, there were troubling signs in the development of formal pedagogy. The fact that early pedagogues were advocating vastly differing philosophies and practical approaches to piano playing is already problematic. But the fact that even at this early stage, pedagogues did not see the need to engage with differing viewpoints nor to build consensus with their colleagues around the use of new instrument is truly bewildering. It really forecasts the confusion that was to come from highly regarded composer-pianists as well as modern pedagogues.

[52] Gerig, Famous Pianists and their Technique, 111-112.

Chapter 2: Important Composer-Pianists on Piano Playing and Pedagogy - From Mozart to Brahms

Though the great pianists of the past may not have written about their own methods, their playing served as a model for those who did. These accounts were passed down by private students of the composer-pianists as well as those who would have observed these pianists in recital and in masterclasses. They continue to live on through students and teachers who can directly trace their training back to a particular musician. Many pianists still try to emulate these anecdotal accounts in modern times. But what can be observed is the further progressive divergence and continued non-consensus of pedagogical approaches.

From anecdotal accounts of J.S. Bach's keyboard technique, we see the finger-centered approach in full effect. Bach is said to have played with such an easy and small motion of the fingers that the movements were hardly perceptible. Only the first joints of the fingers were in motion; the hand retained its rounded form even in the most difficult passages; the fingers rose very little from the keys.[53] In fairness to Bach, he never composed for the piano as it was only recently invented toward the end of his lifetime. Despite this, it is his approach that later pianists and pedagogues attempted to transfer to the modern piano. We observe this in accounts of Wolfgang Amadeus Mozart's technique. "Surely it was Mozart who defined the ideal Viennese piano technique in superlative fashion: an extremely smooth-flowing touch - *leggiero*, immaculate, clear: a tone quality that was always refined and cantabile in melody passages; a physical

[53] Gerig, Famous Pianists and their Technique, 21.

approach that ruled out all affectation and unnecessary movement - still largely the finger and hand technique of the harpsichord."[54] Admittedly, the instrument of Mozart's age was closer to that of a harpsichord – particularly in terms of size and range.

In Ludwig Van Beethoven, we see that the music necessitated the development of something new in terms of technique. The pianoforte became a means to an end in expressing the deepest human emotions, so the previous rules and traditions of piano technique meant nothing if they in any way hampered Beethoven's innermost feelings when he was at the keyboard. Here is the first major pianist directly to oppose the finger-centered approach and its harpsichord ancestry. According to Czerny, a student of Beethoven and a pedagogue in his own right stated, "The man, who struggled intensely with the mundane while creating the most sublime, who could show the deepest sympathy and kindness and then again vast ill will, simply had to play the piano with his entire physical body."[55] Czerny also realized that both Beethoven's playing and his compositions were far ahead of his time, and that the pianos before 1810 "still extremely weak and imperfect, could not endure his gigantic style of performance."[56] In his teaching, Beethoven was working for fullness of tone and was concerned that the power of the arm should back up the fingers.[57]

While Carl Czerny's account of Beethoven shows a radical departure from that of Bach and Mozart, some elements of the 'quiet' approach in Beethoven's playing remained. Schindler, an associate and secretary of Beethoven, stated that Beethoven's "hands and the upper portion of his body were held quiet. His notes were sustained, and his accentuation was always very distinctive."

[54] Gerig, Famous Pianists and their Technique, 52.
[55] Gerig, Famous Pianists and their Technique, 81.
[56] Gerig, Famous Pianists and their Technique, 87.
[57] Gerig, Famous Pianists and their Technique, 91

In Frederic Chopin, we see the beginnings of a more 'romantic' approach to technique which the repertoire of the Romantic Era seemingly demanded. Chopin's technical dexterity was described as complete; his physical coordination and freedom were of the highest quality. The touch was smooth and even, perfectly articulated with the greatest of refinement and elegance, somewhat in the Hummel tradition.[58] His meagre physical means made it imperative for him to exploit the *pianissimo* range of the piano. In his younger days when he had greater physical strength, he did not hesitate to make use of a solid forte sound, but he never "thumped."[59]

We observe finger substitutions as part of Chopin's technique. Alfred Hipkins, a student of Chopin and a champion of his works, stated, "He changed fingers upon a key as often as an organ player."[60] In his approach to teaching piano, Chopin did not begin with the key of C. Rather Chopin made his pupils begin with the B major scale, very slowly without stiffness. Suppleness was his great object according to Dubois, another student of Chopin.[61] He stated, "It is useless to begin to learn scales with that in C major. While it is the easiest to read, it is the most difficult for the hands since it contains no purchase points." What concerned Chopin most at the commencement of his instruction was to free the pupil from every stiffness and convulsive, cramped movement of the hand, and to give him thus the first condition of a beautiful style of playing.[62]

Chopin also seemed to advocate for wrist development. To his students, he recommended the bending of the wrist inward and outward, the repeated touch from the wrist, the extending of the fingers, but all this with an earnest warning against over-

[58] Gerig, Famous Pianists and their Technique, 160.
[59] Gerig, Famous Pianists and their Technique, 160.
[60] Gerig, Famous Pianists and their Technique, 163.
[61] Gerig, Famous Pianists and their Technique, 165.
[62] Gerig, Famous Pianists and their Technique, 165.

fatigue.[63] The evenness of the scales, he believed, depended not merely on the utmost equal strengthening of all fingers by means of five-finger exercises and on a thumb entirely free at the passing under and over, but rather on a lateral movement (with the elbow hanging quite down and always easy) of the hand, not by jerks, but continuously and evenly flowing. Within Chopin's description of scales lies a concept that I believe is absent in pedagogy today – lateral movement of the hand as controlled by the wrist. I believe it to be important not only in even execution of scales and other passagework, but also to be the crucial link in individual finger speed, strength and control.

Franz Liszt also made contributions in the area of pedagogy, having taught many of the late 19th and early 20th century virtuosi. Liszt's contribution to the historical development of piano technique is immense. His manner of playing was directly related to Chopin's free, elegant, yet natural technique, but he expanded the dimensions of that freedom.[64] Chopin freed piano technique completely from the fetters of the quiet hand, stiff-finger school, and his superb bodily mechanism, controlled by a near perfect coordination, fully served his musical objectives.[65] Liszt, however, offered a noteworthy lack of technical explanation entirely, caring little for technical analysis at all. He achieved his transcendent musical interpretations without becoming so preoccupied with the nuts and bolts of developing piano technique. In contrast, his teaching dwelt almost entirely on the aesthetic side of performance - particularly in his maturity. But the theorists, as well as the many aspiring pianists of his day, were greatly intrigued by what they saw and heard. Thus Liszt became the model of the best of piano technique. Probably no other pianist's influence has been so great.[66] It is interesting that even

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[63] Gerig, Famous Pianists and their Technique, 165
[64] Gerig, Famous Pianists and their Technique, 180.
[65] Gerig, Famous Pianists and their Technique, 180.
[66] Gerig, Famous Pianists and their Technique, 180.

during this period and without commentary from Liszt himself, pianists and pedagogues believed they could glean elements of Liszt's piano technique from mere observation. We will see that this philosophy continues to be shared by many important modern pedagogues. They will be discussed in the next chapter.

We also get glimpses of Liszt's pedagogical approach through the lens of Boissier, a former student of his. "You must give more time to octave practice. Your hands are rather weak. In order to strengthen them, I want you to drop your wrists every day, striking octaves on the same note while lifting the hand high. Start slowly. Hands and wrist must remain relaxed without the slightest contraction or cramping up."[67] Concerning touch, Liszt stated that "One must play from the wrist, using what is called "la main morte" (dead hand) without interference from the arm, the hand falling onto the keys in a motion of total elasticity."[68] Liszt believed in the inequality of fingers and that listening was key: "The fourth finger is naturally weak and sometimes also the third," he said, "so we must listen attentively and correct them with great care."[69] Unlike Chopin, Liszt was more concerned with the vertical movement of the wrist than the lateral movement, and that such movement was crucial to strengthening the hand. However, such vigorous flexion and extension is bound to put pressure on the tendons that pass through the wrist. Research is needed to evaluate the physical costs of such a technical approach on the hands and fingers. Liszt also failed to give an explanation on how 'listening' would help to correct inequalities in tone from 'weaker' fingers.

Strangely, we also see Liszt's reluctance in addressing technique in his students. In fingering, he advocated the thumb frequently passing over the fingers as well as under.

[67] Gerig, Famous Pianists and their Technique, 181.
[68] Gerig, Famous Pianists and their Technique, 183.
[69] Gerig, Famous Pianists and their Technique, 183.

He gave technical advice when he felt he needed to do so. But as a rule, he would only work with those pianists whose technique was already advanced and well formed.[70] This philosophy was expressed by Friedheim, a pupil of Liszt. "To be sure, he expected technique, a very fine technique, of any student who approached him. He would show considerable indignation if anyone presumed to come to him insufficiently trained. To such hapless students, he displayed scant consideration."[71] Amy Fay, an American pianist who had taken some lessons with Liszt for a period, also stated, "He doesn't tell you anything about the technique. That you must work out for yourself."[72] Such a view on teaching piano is unfortunate and continues to be practiced by many teachers and faculty. Sadly, many aspiring pianists today continue to shoulder the weight of the burden of correcting their technical challenges without any resources to assist them in doing so suitably and efficiently.

To the aesthetic side of piano playing however, Liszt waxed eloquently. "He (the virtuoso) is called upon to make emotion speak, and weep, and sing, and sigh - to bring it to life in his consciousness. He creates, as the composer himself created, for he himself must live the passions he will call to light in all their brilliance. He breathes life into the lethargic body, infuses it with fire, enlivens it with the pulse of grace and charm."[73] It is fine to wax poetically on what the pianists should be able to do when one already has a finely-tuned technique. This certainly appeared be the case with Liszt. However, many aspiring pianists are not as fortunate technically, so this type of teaching ignores the practical reality in which piano-playing is based.

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[70] Gerig, Famous Pianists and their Technique, 185.
[71] Gerig, Famous Pianists and their Technique, 188.
[72] Gerig, Famous Pianists and their Technique, 192.
[73] Gerig, Famous Pianists and their Technique, 193.

Similar to Liszt, Felix Mendelssohn did not deal with technical analysis, but rather outsourced it to his junior teachers: "Upon questions of simple technique, he rarely touched except, as in the case of our first precious lesson upon the chord of D minor, with regard to the rendering of certain special passages. But the members of his pianoforte classes were expected to study these matters, on other days of the week, under Herren Plaidy, or Wenzel, professors of high repute, who had made the training of the fingers and wrist their specialty."[74] It left Mendelssohn free to direct the undivided attention of his pupils to the higher branches of art.[75]

Frederic Wieck, father-in-law of Robert Schumann, is also mentioned here, due to the success of his daughter Clara Wieck, who eventually married Schumann. Wieck stressed the importance of bringing out a fine *legato* tone with loose and quiet fingers and a yielding moveable wrist, without the assistance of the arm.[76] He also believed in the relaxation of the wrist as a crucial factor. "The tones which are produced with a loose wrist are always more tender and more attractive, have a fuller sound, and permit more delicate shading than the start tones, without body, which are thrown or fired off or tapped out with unendurable rigidity by the aid of the arm and forearm."[77] Wieck also acknowledged the individuality of pianistic approaches to wrist movement. "It must after all depend upon individual peculiarities whether the pupil can learn better and more quickly to play such passages thus or with a loose wrist."[78] While the best use and condition of the wrist needs further investigation as stated previously, Wieck here demonstrates something that we have not seen yet in piano pedagogy so far – *the need to*

[74] Gerig, Famous Pianists and their Technique, 201.
[75] Gerig, Famous Pianists and their Technique, 201.
[76] Gerig, Famous Pianists and their Technique, 208.
[77] Gerig, Famous Pianists and their Technique, 208.
[78] Gerig, Famous Pianists and their Technique, 208.

tailor technique to the innate characteristics of an individual's playing apparatus. This applies not just to the size of the component parts, but also the ratios of parts to each other and their ranges of motion.

Here, we get an indication of chord techniques from summaries of Clara Schumann's playing as left behind by Franklin Taylor. "Chords were grasped from the wrist rather than struck from the elbow. She founded her technique upon the principle laid down by her father…. that 'the touch should never be audible, but only the musical sound."[79]

Johannes Brahms also made contributions to piano pedagogy. Here Eugenie Schumann, the daughter of Clara and Robert, compares her experience of being taught by her mother as compared to Brahms. "Also, he took a great deal of trouble in the training of my fingers. He had thought about such training and about technique in general much more than my mother, who had surmounted all technical difficulties at an age when one is not yet conscious of them."[80] I believe that this last statement here unfortunately describes the kind of faculty that seems to exist in most of the great conservatories and schools of music. These teachers, while amazing role models, are oftentimes not equipped enough to be training the next generation of performers and teachers.

Brahms' view of the wrist coordination with the thumb bears special mentioning. "He gave special attention to the training of the thumb, which as many will remember, was given a very prominent part in his own playing. When the thumb had to begin a passage, he flung it on the key with the other fingers clenched. As he kept his wrist loose at the same time, the tone remained full and round even in a fortissimo."[81] As discussed

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[79] Gerig, Famous Pianists and their Technique, 208.
[80] Gerig, Famous Pianists and their Technique, 222.
[81] Gerig, Famous Pianists and their Technique, 222.

before, the thumb deserves special research in terms of the best approach to training in the context of piano playing. The fact that Brahms considered it important enough to be trained deserves special commendation.

Even amongst the great pianists and composers of the Western musical tradition mentioned here, there is little consensus on how pianists should approach piano-playing. There is no agreement on what constitutes the important concepts in piano-playing. Many only offer a technical philosophy, while others flat out refuse to grapple with technique and focus on the "higher ideals" of artistry. Remarkably today, there are still teachers and pianists who proclaim their pedagogical lineages back to many of these great pianists and composers as a badge of honor. They believe that to declare they hail from the pedagogical lineage of Beethoven or Schumann brings authenticity to both their own piano technique and their approaches to teaching. Sadly, this does little to bring clarity to the important parameters of piano-playing and only serves to further create factions in our field.

Chapter 3: Analysis of Important Pedagogues and their Approaches

The beginnings of the modern technical methodology that we depend upon today began in the 19th century. It was within this period that the piano as an instrument became sturdier, with the action of the keys becoming heavier, and the lightweight wooden instrument now incorporating iron within its construction. As the piano in the early nineteenth century began gradually to augment its power, piano technique, however, did not evolve as naturally to meet the new demands placed upon it.[82] In spite of this, there ensued a flowering of pedagogical works.

Section 1: Theodore Leschetizky

Theodore Leschetizky was a Polish pianist, composer and teacher who lived in the 19th and early 20th century. Famed as a teacher in Vienna, he created one of the most eminent private piano schools there. Some of his students included Jan Paderewski, Artur Schnabel and Ossip Gabrilowitsch. The account of Leschetizky's pedagogical approach has been handed down via secondary sources - the most comprehensive of which is that of another student of his, Malwine Bree, and the only one to which he gave his approval. Entitled ***The Groundwork of the Leschetizky Method***, it begins with a description of what a piano hand should look and feel like over time when properly trained. It claims that a *thoroughly trained 'piano-hand'* becomes broader, supple in the wrist, and

[82] Gerig, Famous Pianists and their Technique, 229.

muscular, with broad fingertips.[83] Later though, he does admit that large and small hands have their advantages, and that there are pianists of the highest rank with large hands and with small hands.[84]

Throughout Leschetizky's pedagogical approach, the wrist plays a prominent role in every concept and exercise. His view of the arrangement of the wrist-to-knuckle relationship was that the wrist must be held somewhat lower than the knuckles, and the fingers so curved that the tip-joints fall vertically on the keys, which are touched by the tips of the fingers only.[85] No justification is given as to why this position is advantageous to another. It is rather a statement of fact.

FIG. 2. How to Hold the Left Hand

FIG. 1. How to Hold the Right Hand

i. Hand positions for wrist exercises

[83] Bree, The Groundwork of the Leschetizky Method, 2.
[84] Bree, The Groundwork of the Leschetizky Method, 2.
[85] Bree, The Groundwork of the Leschetizky Method, 3.

Leschetizky then proceeds to give us initial exercises for the wrists.

> "As soon as the posture of the hand is quite under control, press rather firmly on the five white keys and lower and raise the wrist slowly and repeatedly, taking care:
>
> 1. that the hand remains rounded upward
> 2. that the fingers retain their position
> 3. that on raising the wrist it does not rise higher than its original position and
> 4. the upper arm does not follow the wrist-motion.[86]"

After two or three days, Leschetizky says that one may try to get more tone, always endeavoring to play evenly (with equal strength of tone) with all the fingers. This, he claims, is accomplished by an unequal exertion of pressure on the keys in conforming with the unequal length and muscular strength of the fingers. Special care should be given to the 4th finger. He states, "We must on the contrary, exert the strongest pressure on it, to remedy its inequality."[87]

ii. Hand positions for single finger exercises

From his initial exercises, we observe a heavily finger-oriented and muscular approach. While four fingers hold the whole notes, one finger plays the quarter notes. This exercise is to be continued with the 4th and 5th fingers. These two fingers must, however, be raised as high as possible, so that the hampered 4th finger may acquire more independence and the 5th more strength. During these five-finger exercises, students are

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[86] Bree, The Groundwork of the Leschetizky Method, 4.
[87] Bree, The Groundwork of the Leschetizky Method, 4-5.

reminded continually to make sure that the wrist is loose.[88] There are many challenges with this approach to playing. The lowered wrist for one does not allow for weight of the rest of the arm to be involved leaving only the fingers as the major generator of force. Secondly, the lifting of the fingers without assistance from the rest of the arm puts an incredible amount of pressure on the intrinsic muscles of the hand as well as the tendons. The concept of weak and strong fingers is also problematic, as the 4th and 5th fingers are equally as capable of producing force when properly leveraged with proper wrist and arm orientation.

iii. Score of single finger exercises

In his discussion of preparatory exercises for scales, Leschetizky brings attention to the fingers used before and after the thumb. Both in these exercises and the following ones, the fingers coming just before and after the thumb should strike rather stronger than the others, going either upward or downward so that the turning-under and turning-over may not be noticeable.[89] The wrist also features prominently in these exercises. Students are to take care in all these exercises to keep the hand quiet, and the wrist loose but unmoved; neither must the elbow rise when the thumb passes under.[90] The 2nd, 3rd and 4th fingers hold the whole notes, the thumb leaping as in the former similar exercise, without describing too high a curve. The wrist may now turn a trifle in the direction in which the hand is moving, when the thumb strikes its key.[91] In scale playing, take care that when the thumb turns under, the arm is not thrust forward with a jerk but follows the movement of the hand evenly and horizontally, gliding along much like a car on rails.

[88] Bree, The Groundwork of the Leschetizky Method, 9.
[89] Bree, The Groundwork of the Leschetizky Method, 14.
[90] Bree, The Groundwork of the Leschetizky Method, 14.
[91] Bree, The Groundwork of the Leschetizky Method, 15.

Furthermore, hold the wrist loosely, without moving it up or down.[92] It is impossible to keep the wrist simultaneously loose and unmoved as Leschetizky advocates. The act of keeping a part of the body unmoved necessitates tension in the surrounding muscles.

Leschetizky gives the wrist an important role in chromatic scales. In the chromatic exercise, the wrist remains quiet and loose but should be held a little higher than for the diatonic scale, so that the thumb strikes the key more with the tip.[93] The wrist's importance in broken chords is also mentioned. Students are to hold down the whole notes as long as the quarter-notes are played, keeping the hand arched and the fingers curved. Students are to move the wrist up and down without interrupting the playing.[94] In repeated notes, the wrist is held loosely and rather higher, allowing the hand to follow the movement of the fingers by turning slightly outward.[95] A lot of directives are given here, but again without explanation. Why for instance is it important for the thumb to strike the key more with the tip in a chromatic scale and not in other instances?

Leschetitzky views the wrist as important to executing what he refers to as the different *touch styles*. For instance, when a strong, full tone is to be brought out *legato* in a Cantilena, the strength of the fingers does not suffice, but must be reinforced by *wrist-pressure* in the following way: Touch the key lightly and force the finger to press it down deep (without losing contact with it) by means of a swift upward movement of the wrist; at this instant, wrist and finger-joints must be firm. The same effect may also be obtained by a rapid down-stroke of the wrist. Immediately after striking the tone, the wrist must return to its normal position, while the finger holds the key lightly. In the *wrist-staccato*,

92 Bree, The Groundwork of the Leschetizky Method, 18.
93 Bree, The Groundwork of the Leschetizky Method, 21.
94 Bree, The Groundwork of the Leschetizky Method, 22.
95 Bree, The Groundwork of the Leschetizky Method, 27.

the bent finger is thrown upon the key without further ceremony, striking it smartly, and being instantly withdrawn by the wrist.[96]

Another short kind of touch Leschetitzky recommends is the *'lifted' tone*. For this, the wrist is loose, while the finger joints are firm in a state of tension. The bent finger touches the key lightly and noiselessly, presses it down with a swift, short stroke, and is instantly lifted from the key by the flying-back of the hand from the wrist.[97] There are many clarifications that need to be made here. What exactly is the normal position of the wrist? What does it mean to *throw the finger* upon the key? Also, it is physiologically impossible to have a firm finger with a loose wrist, as the very tendon that contributes to the firmness of the finger passes through the wrist-joint.

In executing octaves, Leschetitzky states that students should play in the style of *wrist-staccato*, taking care that the width of the stretch between the 1st and 5th fingers does not change when the hand is lifted, so that the octave may be struck squarely and clean. Students are told to play *forte* and *fortissimo* octaves with a firm wrist held high, as it is absolutely impossible to bring them out with a loose wrist.[98] Octaves that are played legato are done so with a moved, but not stiff, wrist, and with fingers gliding close over the keys."[99] While physiologically, playing forte octaves with a firm wrist is desirable to transmit enough force to the key, why Leschetizky advocates maintaining tension in the hand by keeping the width between the first and fifth finger the same after the octave has already been played is curious. It is an unnecessary expenditure of muscular tension and fatigue will certainly accelerate with such an approach.

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[96] Bree, The Groundwork of the Leschetizky Method, 29.
[97] Bree, The Groundwork of the Leschetizky Method, 30.
[98] Bree, The Groundwork of the Leschetizky Method, 32.
[99] Bree, The Groundwork of the Leschetizky Method, 33.

In the principles related to chord playing, Leschetizky believes the hand should be arched as far as the stretch permits. The fingers are to remain curved and the fingertips and wrist should remain firm during the stroke which is affected by a wrist movement upward or downward. In a slow succession of chords, either wrist movement may be utilized; in a rapid succession, only the upward movement. For playing chords *forte* or *fortissimo*, the wrist movement must be greater and more vehement for piano chords less extended and slower.[100] In order that chord playing may not tire one too soon, it is indispensable not to hold the chords with a stiff wrist after striking them. Relax the wrist instantly after the stroke; then it will be unnecessary to expend more strength than is requisite simply to hold the keys down.[101] When chords follow each other slowly, hold the fingers of the uplifted hand easily, after striking, in the shape of a fist, so that the muscles may rest. Such was Rubinstein's habit. [102] In order to hold any note after it has been played, tension must be maintained in the playing finger and by extension the wrist. This is especially so in chord-playing. It is impossible to completely relax the wrist and hold the notes at the same time. However, Leschetizky is correct in advocating for relaxation between the chords, though to relax by making a fist is curious, as doing so requires tension in the muscles of the hand and forearm.

In *arpeggio-playing*, the quick "turn of the hand" implies a lateral wrist movement. Leschetizky advocates that while the first three fingers are pressing their keys, students are to give the hand a quick turn toward the 5th finger, so that the latter strikes its key. This turn of the hand somewhat resembles the twist of unlocking with a key.[103] In playing *double thirds*, again, the swinging of the hand suggests an implied

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[100] Bree, The Groundwork of the Leschetizky Method, 33.
[101] Bree, The Groundwork of the Leschetizky Method, 34.
[102] Bree, The Groundwork of the Leschetizky Method, 35.
[103] Bree, The Groundwork of the Leschetizky Method, 48.

wrist movement. In "turning over" in third-playing, students are to take the next-following third, for the 1st and 3rd fingers, with wrist high and a swift swing sideways. Then, they are to take this swinging movement of the hand backwards, so as to turn over the 2nd and 4th or 1st and 3rd fingers, respectively, in order to take the initial third. As a point of support for this swinging movement, students should use the 4th or 5th finger going up, and the thumb going down (in the left hand the reverse).[104]

Leschetizky emphasizes the use of the wrist in voicing chords. When playing, he believes the wrist should support the finger bearing the theme by not exercising equal pressure on all the fingers, but rather bearing down on the one in question. Bind the highest part as far as possible and let go of the middle parts directly after striking, with a gently lift of the wrist.[105] More explanation is needed on how the wrist "bearing down" on the finger playing the theme in a chord is achieved.

In executing dynamics, Leschetitzky believes that music possesses only three prime colors: *piano, forte* and the *accent*. He claims that out of these, the rich color-scheme of the musical picture must be built up. The realization of these colors is achieved by a frequent alternation of the prime colors and by transition from one to the other. *Forte* and *fortissimo* cannot be brought out by the unaided strength of the fingers; the wrist must be brought into play. The fingertips must be firm, and the wrist should be loose. In *piano* passages, the wrist should be held loose; but the fingertips must be held firm, for yielding fingertips can bring out only a *piano* lacking in tone and here and there a tone may fail to sound. In quick tempo, the fingers are thrown with a loose wrist.[106] An *accent* may be more or less strong or weak and is obtained with firm fingers and firm

[104] Bree, The Groundwork of the Leschetizky Method, 51.
[105] Bree, The Groundwork of the Leschetizky Method, 56.
[106] Bree, The Groundwork of the Leschetizky Method, 60.

wrist. When the tone is to be prolonged, the finger holds the key down and the wrist is relaxed. For making a crescendo, the pianist should begin with a loose wrist, gradually increasing the wrist-tension. For a *diminuendo*, the action is reversed, the tense wrist gradual relaxing.[107] Again, Leschetizky advocates for a biological impossibility throughout - the firm fingers with a loose wrist.

In the section covering the movements of the hand and arm, Leschetizky discourages movement beyond that of the wrist and hand. He states, "These are fancy tricks not wholly devoid of piquancy and may be viewed with indulgence when accompanying virtuoso performance. In contrast to these are the necessary movements of the wrist, which serve to facilitate the execution of phrases to support the rhythm, or to rest the hand after the tension of forte-playing by relaxation of the joint."[108] To not involve any other part of the arm outside of the fingers and wrist is one of the biggest errors in the Leschetizky approach. The forearm, elbow, upper arm, shoulder joint and back are capable of contributing an immense amount of force and ease to piano-playing.

Leschetizky believed that skill in wrist movement is attributed in part to talent. Talented students, he believes, will instinctively find the proper employment of the wrist and how to accommodate it to the varying position of the hand; others must acquire it by practice, whence arises a sort of 'preparatory technics' for the promotion of an easy and sonorous execution.[109] In other words, it is ultimately up to the piano student to figure out the proper movements of the wrist that will lead to good piano technique.

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[107] Bree, The Groundwork of the Leschetizky Method, 61.
[108] Bree, The Groundwork of the Leschetizky Method, 78.
[109] Bree, The Groundwork of the Leschetizky Method, 79.

Section 2: Isabelle Vengerova

Isabelle Vengerova was a Russian-American pianist and music teacher who made her career in the United States. A student of Leschetizky, she was a founder of the Curtis Institute and was also a teacher at Mannes College in New York City. Some of her students included Samuel Barber, Leonard Bernstein, Gary Graffman and Menahem Pressler. Like Leschetitzky, we see the importance of the wrist in her pedagogical approach.

In her approach to piano-playing, Vengerova advocated for a *non-percussive touch*. She argued that fingers are to be close to the keys and in contact with them before playing.[110] Also central to her system is the importance of a flexible wrist. The flexibility and power of the wrist must be developed.[111] Like her teacher, we also observe that the upper arm is not involved in her pedagogy. At no time is the upper arm used directly in the production of an accent. When playing an accent, the power comes from the application to the key of pressure from the finger and wrist.[112] Proper hand position is also integral to Vengerova's pedagogy. The knuckles are arched, and the hand is held level so that it does not tilt toward either the thumb or fifth finger.[113] While the non-percussive approach is a unique feature of her approach, she makes the same grave error in limiting her pedagogy to the wrist and fingers. Also, grand statements are made without explanation or reasoning.

In her approach, Vengerova developed a system of exercises based on production of accents and their gradual removal. To play an accent, she states that the wrist is to be raised as high as possible without losing the curvature of the fingers. The fingertip then

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110 Schick, The Vengerova System of Piano Playing, 12.
111 Schick, The Vengerova System of Piano Playing, 12.
112 Schick, The Vengerova System of Piano Playing, 12.
113 Schick, The Vengerova System of Piano Playing, 22.

presses firmly into the key and the wrist drives down sharply and quickly at the same time in a strictly vertical plane.[114] The wrist motion continues past the moment when the sound is produced. After playing an accent, the wrist and the fingertip which has just depressed the key will be lower. However, the hand and the fingers must maintain the same shape - the hand cupped and the fingers curved - throughout the process of playing an accent. Otherwise, they would be unable to function as a firm unit when transferring the weight and strength of the wrist and forearm to the keys.[115] The performer's wrist moves in a *down-up, down-up* motion as it goes from note to note. Vengerova maintains further that there are only two speeds for the motions, a faster one for all of the *"downs"* and a slower one for all of the *"ups."* The *"up"* movement should be a relaxed one since it produces no sound of its own.[116] Unfortunately like Leschetizky, Vengerova believes that a lowered-wrist joint as opposed to a fixed-wrist joint is capable of transferring weight to the keyboard. Secondly, the fact that Vengerova advocates for the extreme raising and lowering of the wrist is bound to put undue pressure on the nerves and tendons passing through the wrist by constriction of the carpel tunnel through which these tissues pass. Additionally, using words "sharp" and "driving" to describe this extreme vertical movement of the wrist is the kind of pedagogical concept that could be misapplied by pianists to their physical detriment.

Vengerova believed that wrist should turn when using the thumb in scale playing. In contrast to Leschetizky, Vengerova does not encourage lateral wrist movement in scale playing. She states, "The wrist should not turn to help the thumb. If it did, the motion

[114] Schick, The Vengerova System of Piano Playing, 22.
[115] Schick, The Vengerova System of Piano Playing, 23.
[116] Schick, The Vengerova System of Piano Playing, 24.

would have to be repeated twice in an octave…. which would make it impossible to develop speed in scale playing."[117]

Unlike Leschetizky, we see a slightly different perspective on hand and finger position at the piano. Vengerova believes that the fingers should point inward and at a slight angle to the keys. This is particularly important in fast tempo. The hand also should not tilt much, if at all, toward the fifth finger.[118] This differs from Leschetizky's concept on the positioning of the fingers on each key.

In the discussion of practicing Vengerova's exercises, it is recommended that all exercises be practiced within the context of the Vengerova technique, and in particular with a flexible wrist.[119] Also, Vengerova's concept of weight transfer is that the hand should follow the fingers so that the weight is transferred from one fingertip to the next.[120] This description sounds very close to the lateral movement of the wrist so that the hand is centered behind each finger to provide weight. This correct application of balance behind each finger is undone however by continuous avocation of a flexible wrist, rendering any possible weight transfer impossible.

iv. Score for 'accent exercises'

[117] Schick, The Vengerova System of Piano Playing, 25.
[118] Schick, The Vengerova System of Piano Playing, 26.
[119] Schick, The Vengerova System of Piano Playing, 30.
[120] Schick, The Vengerova System of Piano Playing, 38.

Vengerova's favorite exercises fell into three main categories: one group strengthened the fingers, another increased the power and flexibility of the wrist, and a third helped focus the arm weight into the fingers within a given hand position when practiced within her system of technique.[121] Vengerova advocated these exercises to be used for the development of finger-wrist coordination, as she believed them not only excellent for developing the coordination between the fingertip and the wrist, but also for developing the strength of the fingers when playing in thirds or in other specific hand positions.[122]

In applying the technique to music, Vengerova claims that the wrist is the initiator of all melody. She states that "The melodic accent of a melody…is played with a drop of the wrist."[123] The importance of lateral wrist movement in supporting the weaker fingers is also emphasized. Between the first and the fourth sixteenth-notes the wrist and the hand will swing somewhat to the right, thus shifting the weight in that direction also, and into the fourth finger which might otherwise sound weaker the rest.[124] She uses the left-hand figuration from Chopin's *Fantasie-Impromptu* to provide an illustration of how the hand follow the fingers. Here the wrist will swing freely to the right as the musical figure approaches the thumb, and then back to the left when it returns.[125] Rather than have the wrist move to the right and then returned in the same plane, it is better to have it make some sort of circular motion so that it can move continuously and not have to stop at the end of each pattern.[126]

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[121] Schick, The Vengerova System of Piano Playing, 31.
[122] Schick, The Vengerova System of Piano Playing, 31.
[123] Schick, The Vengerova System of Piano Playing, 37.
[124] Schick, The Vengerova System of Piano Playing, 38.
[125] Schick, The Vengerova System of Piano Playing, 39.
[126] Schick, The Vengerova System of Piano Playing, 40.

The importance of the hand tilt in projecting a fifth-finger melody is also discussed. Vengerova would tilt the hand toward that finger, making it lower than the rest of the hand so that more weight goes into the fifth finger.[127] Combining lateral wrist movement with the tilt of the hand is also a component of producing a singing tone and said that one could swing the wrist - either from *left to right*, or *right to left* - in addition to tilting to help get the weight into the melody note.[128] Also, there is a belief in the connection between the wrist's descent and the richness of sound. She also suggested practicing scales in "ones" with a singing tone - in this case, not with the usual *forte* accent, but with one produced by a slower descent of a firm wrist - to help each finger acquire the ability to produce a warm rich sound.[129]

Vengerova advocates for a parallel relationship of the wrist and forearm to the keyboard in playing *arpeggios*. Pianists should keep the forearm and wrist at the same angle to the keyboard throughout a long arpeggio, at least until an extreme register of the piano is reached. Any appreciable motion at the inside of the wrist could result in a serious loss of speed. One need not straighten out the hand to facilitate the thumb reach. To do so would result in a sharp turn at the inside of the wrist, which would slow pianists down.[130] There are many challenges with this approach to playing arpeggios. It would be very difficult to maintain legato without some assistance from the wrist joint – especially when going over the thumb or under the other fingers. Such an approach would be especially disadvantageous to pianists with smaller hands. Additionally, maintaining a parallel relationship between the wrist and forearms would mean that movement in a long

[127] Schick, The Vengerova System of Piano Playing, 46.
[128] Schick, The Vengerova System of Piano Playing, 47.
[129] Schick, The Vengerova System of Piano Playing, 47.
[130] Schick, The Vengerova System of Piano Playing, 53.

arpeggio would be facilitated by the torso, which could be even more of a serious loss of speed than any movement of the wrist joint.

Vengerova uses the wrist in both the *percussive* and *non-percussive* touches. In describing the *non-percussive* touch, she argues that after the depression of the keys with the fingertips, pianists are to snap the hand away from the keyboard while bending at the wrist, thus pulling the fingertips from the keys.[131] The *percussive touch* is described as moving the hand as a unit from the wrist and directing a relatively fixed and firm finger onto the key.[132] The "snapping" of the fingers away from the keys does not contribute anything to the sound as this occurs after sound has already been produced. This renders this motion useless at best and harmful and injurious at worst.

Vengerova also offers an explanation of the wrist movement in octave-playing. Pianists are to play octaves with a bounce of the hand from the wrist, allowing the fingertips to hit the keys percussively.[133] She also believes that good wrist movement can help decrease the need for "inventive fingerings." In describing the technique of Vengerova's students, Schick states, "Her students did not rely only on finger articulation, which more elaborate fingerings tend to emphasize, but could achieve many affects by proper relaxation, adjustments of hand position and the wrist, and differing applications of weight.[134] She chose to have the whole hand cover as many notes as possible, thus avoiding finger crossings and making it easier to achieve the needed speed."[135]

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[131] Schick, The Vengerova System of Piano Playing, 66.
[132] Schick, The Vengerova System of Piano Playing, 66.
[133] Schick, The Vengerova System of Piano Playing, 68.
[134] Schick, The Vengerova System of Piano Playing, 73.
[135] Schick, The Vengerova System of Piano Playing, 74.

Section 3: Tobias Matthay

One of the most widely-known piano pedagogues is Tobias Matthay – an English pianist, teacher and composer. His many piano students, including Myra Hess, York Bowen and Arnold Bax, defined a school of important English pianism in the early 20th century. A writer of many books on piano technique, his most famous treatise arguably was *The Visible and Invisible in Piano Technique* – a text still highly regarded in modern times. Penned by the author himself, we observe that the physical and mental processes are equally as important in his approach. He states, **"**To acquire technique therefore implies that you must induce and enforce a particular mental-muscular association and cooperation for every possible musical effect."[136] Pianoforte technique, he believed, is therefore essentially an act of aiming or timing the right activities of the limb at the musically right moment during key-descent.[137] Mastery of technique and mastery of interpretation alike rest on the same basis - a basis of rhythmic impulse and control.[138]

Matthay provides us a mechanical explanation of the parameters involved in the descent of the piano key and its subsequent tone production. Good tone, ease in production and control of tone can only be obtained by gradually pressing the piano key into motion.[139] Only in this way can pianists obtain perfect control over tone, good singing tone, and good quality of tone.[140] One cannot control tone and cannot play musically unless you succeed in acquiring this way of managing key-descent.[141] Matthay makes the distinction between *moving to a key* and *with it* to produce sound. He admonishes pianists to always realize that the action of moving to a key and the action of

[136] Matthay, The Visible and Invisible in Pianoforte Technique, 3.
[137] Matthay, The Visible and Invisible in Pianoforte Technique, 4.
[138] Matthay, The Visible and Invisible in Pianoforte Technique, 4.
[139] Matthay, The Visible and Invisible in Pianoforte Technique, 7.
[140] Matthay, The Visible and Invisible in Pianoforte Technique, 6.
[141] Matthay, The Visible and Invisible in Pianoforte Technique, 8.

subsequently moving with that key during its descent, should always be two quite distinct things.[142] *Tone-production,* he claims, is always in the nature of a "follow-on" pressure upon the key after it is reached, and during key-depression. This tone-producing pressure must increase in intensity during key-descent.[143]

Contrary to other pedagogues, he disagrees with the notion of some pedagogues that tone is produced by the finger alone. He states, "There is practically no such thing as tone-production sole by exertion of the finger. It must always be finger-exertion plus hand and arm, in some form or other."[144] Matthay here arrives on a seminal aspect of piano pedagogy – that piano-playing always integrates various parts of the limb and should never be thought of or practiced in isolation. Failure to do so has often led to injury, as the physical work of piano-playing should be shared and supported by the larger bones and muscles of the playing apparatus.

Matthay also differentiates between the muscular effort expended at different key speeds. To move the key quickly, the total amount of work has to be concentrated during a shorter space of time, hence the muscles feel the resulting strain more severely the quicker the work is done, and it is this difference in the resulting muscular-sensation of which we can become aware if we attend to the key as we should through our muscular sense, key-resistance sense or 'key-sense.'[145] Matthay also discusses the physiological challenges of piano-playing from a mechanical standpoint. The movements which accompany touch give but little (or even illusionary and misleading) indications of those hidden and invisible stresses - exertions and relaxations of limb, which are the real cause

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[142] Matthay, The Visible and Invisible in Pianoforte Technique, 17.
[143] Matthay, The Visible and Invisible in Pianoforte Technique, 18.
[144] Matthay, The Visible and Invisible in Pianoforte Technique, 19.
[145] Matthay, The Visible and Invisible in Pianoforte Technique, 12.

of desirable and undesirable effects.[146] He maintains pianists need to understand, "what particular stresses and relaxations are required of the various portions of our playing-limb - which parts of the limb to exert and which to leave passive."[147] The functions of each component of the playing limb as an integrated member is a crucially underexplored area in pedagogy and Matthay is to be commended for shedding light on this. What is not present in his explanation, however, is its practical application. It is largely left to the pianist and teacher to apply these concepts he articulates.

Matthay emphasizes the need for having a bank of physical sensations to call upon to differentiate between good and bad playing. He argues that only by the sensations thus experienced can we realize which limb conditions correspond to both good and bad piano-playing from a performance standpoint. By recalling such sensations, we can then reproduce the effects and can develop the habits that we can then teach others to acquire.[148] He also lamented the fact that those pianists who are best at recalling the sensations are the least equipped to teach. Those few gifted ones who instinctively stumble upon the right physical movements are usually precisely the ones least likely to be good at self-analysis. The greater their temperamental, emotional and musically-imaginative gifts, the more likely are they to be disinclined, opposed and even resentful towards any exercise of self-analysis, mechanically and physically.[149]

I would agree that such remains the case today. Matthay claims here that a large part of what constitutes good and bad playing is based in a pianist's recollection of good and bad movements and their ability to duplicate these movements in practice and performance. Indeed, it is a pianist's *movements* and the condition of their playing

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146 Matthay, The Visible and Invisible in Pianoforte Technique, 14.
147 Matthay, The Visible and Invisible in Pianoforte Technique, 15.
148 Matthay, The Visible and Invisible in Pianoforte Technique, 16.
149 Matthay, The Visible and Invisible in Pianoforte Technique, 16.

apparatus that leads to better expression and musical success. Sadly, many piano teachers and institutions at the elite level are either ill-equipped or willfully reject the need to teach what is really a critical foundational aspect of instrumental success choosing rather to focus on more aural and artistic attributes.

Matthay also believed that the only way to get your body to act properly is to get your mind to lead the process: "You cannot teach your limbs or your muscles to act. All you can do is teach your mind to direct the required limb conditions of activity and inactivity."[150] I think this statement is problematic on a few levels. While neurologically, it is common knowledge that the brain directs the muscles and bones to move, his statement presupposes that the movements initiated will serve the best outcomes for piano playing physically and musically. Pianists have shown, however, that musical and physical outcomes do not always correlate, as demonstrated by the physical costs to pianists' bodies as well as the unmusical playing that is perhaps more physically efficient. A baby's brain, for example, does not know how to direct the limbs of the lower extremities to walk. But through physical trial and error, a baby acquires the skill of walking, which the brain recalls with increased assurance as they mature. I believe that in piano playing, one's ability to 'teach' the limbs to act is crucial.

Matthay also introduces the notion that the *exertions* of piano-playing are often non-observable to the naked eye. He maintains that most of the exertions and relaxations required in playing are not revealed by corresponding movements - they are invisible.[151] If such is the case, how then does a teacher assist a student in producing the correct exertions to produce musical and biomechanically efficient performances – especially

[150] Matthay, The Visible and Invisible in Pianoforte Technique, 16.
[151] Matthay, The Visible and Invisible in Pianoforte Technique, 19.

with the invisibility of much of it? Today, this remains a critical defect in existing piano pedagogy that needs to be addressed. I believe that an understanding of 'inner exertions' could be transformative to our field when teachers have available tools at their disposal to observe these exertions.

In reference to the arm, Matthay distinguishes between the arm's *condition* versus its *movement*. He believes it is therefore of extreme importance that one understands this radical distinction. Namely, the condition of the finger, hand and arm during the action of touch and its relationship to the movements that may optionally accompany such changes of condition in a muscular sense.[152] I agree with Matthay on the importance of this distinction. We cannot, for example, observe from the motion of the fingers at the piano the amount of tension in the forearm. However, yet again, pianists and piano teachers do not yet have the skills to analyze this distinction and thus help the piano-playing of their students and themselves.

Matthay describes two possible movements of the fingers in piano-playing. Though the description is different from previous pedagogues explored, one can see similarities with previously described touches:

a. One can see it in a *folding-in* direction, as in everyday life, when grasping anything. Matthay believed it to be the best and advocated its action at the piano.

b. One can use it in the opposite direction, as an *unfolding* or *opening-out* of the finger.[153]

With ***a***, the finger when raised, is in a somewhat flattened-out position, and that it folds in when descending towards and with the key. Whereas with ***b***, the finger when

[152] Matthay, The Visible and Invisible in Pianoforte Technique, 20.
[153] Matthay, The Visible and Invisible in Pianoforte Technique, 22.

raised is considerably bent, or even full bent into an arch, and in this case the finger opens out when descending towards the and with the key.[154]

Matthay also discusses the fact that both types of movements can be produced using two totally different sets of muscles. He claims that both these movements or exertions of the finger can be provided in two quite distinct ways muscularly. That is, one can produce the action of the finger either by exertion of its *small muscles* only or exertion also of its *strong muscles.* The small flexing muscles of the finger are situated on the inside of the hand, whereas the finger's strong flexing muscles are situated in the forearm.[155] He advocates that we use both methods in tandem. It is this second way of exerting the finger which one must employ in sounding the notes, whereas the first way suffices to hold the notes down once they are sounded.[156] Matthay is to be commended for laying out a description of the pianistic movement of not only the fingers, but also the musculature involved. I stand in agreement with his belief that both sets of muscles should be used in tandem, as such muscular cooperation shares the load of piano-playing more equally as opposed to straining one set of muscles. The application of *how* exactly to use these muscles in tandem, however, is left to pianists and teachers to divine.

Matthay continues to explain further the need for a *stable base* from which to operate a *moving part* of the playing apparatus. It is clear that without such help from the *hand,* there is no foundation for the *finger* to work against - for one cannot apply the strong muscles of the finger without also exerting the hand, and without such hand-help, finger action alone is too uncertain and feeble.[157] The basis for the finger should be provided at the right moment by a downward exertion of the hand - at the knuckle joint.

[154] Matthay, The Visible and Invisible in Pianoforte Technique, 22-23.
[155] Matthay, The Visible and Invisible in Pianoforte Technique, 23.
[156] Matthay, The Visible and Invisible in Pianoforte Technique, 23-24.
[157] Matthay, The Visible and Invisible in Pianoforte Technique, 25.

This exertion of the hand must be precisely timed along with the exertion of the finger itself, during the movement of key-depression.[158] The hand also needs its own proper basis during the moment of tone-production, else the wrist-joint will be driven-up by reaction or recoil, and power and accuracy of tonal-result again lost.[159] Here lies a real distinction in Matthay's view of the wrist in comparison to Leschetizky and Vengerova. Rather than being a point of *flexibility*, it is a *base* from which tone production can happen.

With this skeletomuscular combination, there two movements available.

1. *A movement of the finger alone* - while the exertion of the hand remains invisible, or,

2. *A movement of the hand* - while the exertion of the finger may here remain quite hidden from view.[160]

Matthay here reinforces how the neighboring parts of the playing-limb work in tandem with the part that is actively moving. This is a concept that we will see later in other pedagogues.

Matthay warns of the dangers of adding too much *arm-weight*. Arm-weight, he believed, that is allowed to rest too heavily upon the keyboard in between the sounding of the notes, inevitably does infinite harm both technically and musically.[161] As Matthay already insisted, weight can but form the basis for the activities of the finger and hand, but it cannot really produce a tone.[162] Rather, "The function of weight in playing is solely that of basis, whether it moves or not; that is, its function always is but to form a

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[158] Matthay, The Visible and Invisible in Pianoforte Technique, 20.
[159] Matthay, The Visible and Invisible in Pianoforte Technique, 21.
[160] Matthay, The Visible and Invisible in Pianoforte Technique, 25.
[161] Matthay, The Visible and Invisible in Pianoforte Technique, 34.
[162] Matthay, The Visible and Invisible in Pianoforte Technique, 41.

stable foundation, sufficient to resist the reactions of finger and hand exertions, so that these can be effectively applied to the key."[163] This argument about weight not producing tone is controversial, as many modern pedagogues, some of whom will be explored here, believe that weight is absolutely necessary to good tone production. It would seem that if weight could substitute for individual muscular exertions, that it would not only be more efficient, but, in turn, be preferable to preventing injury.

Additionally, Matthay mentions the importance of *forearm rotation* in playing. He states that it is applied without any outward indication whatever of presence or absence. The *forearm rotation* element applies all through one's playing and either makes or mars it.[164] Matthay believed that understanding and mastery of rotation is usually the solution of most 'fingerwork' troubles.[165] Of all the forms of *arm-use* or *conditions* enumerated, Matthay believed *forearm rotation* to be the most important.[166] His concept of forearm rotation was not previously discussed by other pedagogues and Matthay is to be commended for this. Forearm rotation has slowly but progressively become part of modern pedagogy, even though its practical application is left wanting in many cases – particularly on its execution as a technique and its application to repertoire.

Matthay emphasizes that an understanding of *forearm rotation* is crucial to piano technique. Success or failure technically depends on a clear understanding and due mastery of these invisible forearm rotatory-adjustments.[167] He then gives a detailed explanation of the execution of *forearm rotation*. The direction of rotatory help is always from the finger last used, and towards the finger being used - and you must always supply

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[163] Matthay, The Visible and Invisible in Pianoforte Technique, 42.
[164] Matthay, The Visible and Invisible in Pianoforte Technique, 30.
[165] Matthay, The Visible and Invisible in Pianoforte Technique, 31.
[166] Matthay, The Visible and Invisible in Pianoforte Technique, 31.
[167] Matthay, The Visible and Invisible in Pianoforte Technique, 50.

such rotatory help with perfect freedom. When a passage moves melodically alternatively upwards and downwards, the rotational stresses are alternately inwards and outwards. When the melodic movement proceeds in the same direction, as in *five finger exercises,* then you must repeat your rotary stresses in the direction of the passage instead of alternating them.[168] Taken slowly, one can show these stresses by actual rotatory movements each time, as directed. The hand, in this case, turns back before each rotatory-movement and then turns again in the direction of the next finger played.[169] At higher velocities, Matthay emphasizes the invisible and ‘felt’ aspects of rotation. In a quick passage, however, such rotatory movements cannot be attempted - there is not time for them. Instead, the rotational stresses are here completely dissuaded, hidden and replaced by finger movements. Nevertheless, pianists must supply the necessary help individually for each note by invisible forearm rotation exertions or relaxations. Matthay is to be commended for giving us a practical application of forearm rotation to music, though for all his emphasis on the invisible aspects of this technique, the application of what he has presented would certainly be visible at the outset. Furthermore, there is no explanation on the execution of *invisible forearm rotation,* which Matthay views as important at higher velocities.

Matthay is careful to remind us, however, that rotation is not a replacement for the ‘work’ of the fingers. He reminds us, “Do not forget to exert the fingers themselves”[170] but simultaneously warns against finger lifting stating that to teach finger-lifting so as to be able to strike better was one of the worst fallacies and superstitions of the teachers of the past.[171] He also discusses the application of rotation to score study, as such

[168] Matthay, The Visible and Invisible in Pianoforte Technique, 56.
[169] Matthay, The Visible and Invisible in Pianoforte Technique, 57.
[170] Matthay, The Visible and Invisible in Pianoforte Technique, 59.
[171] Matthay, The Visible and Invisible in Pianoforte Technique, 66.

antagonistic action is, however, very likely to arise in passages where the two hands move by similar motion melodically.[172] Coordination between forearm rotation and fingers should first be studied in passages needing a reversal, rotationally, each time from note to note; and when the hands are first played together, passages should be chosen so far as possible, which need the rotational help in similar direction in both hands, and which therefore, move melodically by contrary motion.[173]

I do take some exception to Matthay's admonition to *exert the fingers*. The use of the fingers in his explanation of rotation seemed an after-thought, and no practical explanation is given to 'exerting' the fingers within the context of forearm rotation. Matthay also comments extensively about the position of the playing limb, and special attention is given to the hands and wrists in *scale* and *arpeggio* playing. If one's upper arm hangs straight down from the shoulder or even slants backwards, its weight cannot become available, he believes. Rather, he thinks it best to sit sufficiently far away to allow the elbow to be moved in front of the body, so that one can easily reach the extreme limits of the keyboard. The best elbow position is therefore with the upper-arm more or less sloping forward. Thus, the free-set upper-arm weight can exert a pull on the fingers when needed.[174] Unfortunately, Matthay demonstrates a misunderstanding of the principles of physics here. The greater the angle of extension of a joint, the more weight can be transferred across it. The lesser the angle, the more muscular work has to be done to produce force across the joint. Movements like *standing* versus *walking* attest to these principles.

[172] Matthay, The Visible and Invisible in Pianoforte Technique, 59.
[173] Matthay, The Visible and Invisible in Pianoforte Technique, 60.
[174] Matthay, The Visible and Invisible in Pianoforte Technique, 105.

Matthay also advocates that piano technique should be relegated to the *subconscious*, providing that it has been properly studied. He maintains that when piano techniques have been learned consciously, they must be forgotten. That is, having purposefully learnt to obey all these physical and physiological laws involved, they must be relegated to the realm of the *sub-conscious* before they can truly help you in purposeful musical performance.[175] While an element of this idea of the 'technical subconscience' is valid, especially in a performance setting, this viewpoint presupposes an arrival point at which a pianist is an 'expert' in piano technique. Such a notion is misguided, as the body is never static. There are always areas in which musicians and pianists in particular can be more efficient. The prevalence of injuries proves this point – especially as injuries are often correlated with the length of time that a person has played. Hence, I think piano technique should never be relegated to the subconscious mind, as there is always some area in which improvements can be made.

Matthay emphasizes the need for clarity in teaching piano technique. He believed that definite statements are needed here: as to which portions of a limb to leave passive or supported, and which to exert. That alone will help us. Whereas, to merely name the point where the limb must be immobile during the act of touch, does not in the least inform us how to produce such immobility or a stable foundation from which to exert our limb effectively.[176] Again I stand in agreement with Matthay. Pianists and teachers need to understand the physical tools which they use for piano-playing. I believe that a lack of awareness of the physiological aspects of piano-playing is to blame for the damages to musicianship and health experienced by many piano students.

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[175] Matthay, The Visible and Invisible in Pianoforte Technique, 46.
[176] Matthay, The Visible and Invisible in Pianoforte Technique, 24.

Matthay talks about the importance of having an established nomenclature to discuss the various movements involved in piano-playing. “To prevent confusion, I had to retain the already accepted terms, but I also had to add new terms to designate the new knowledge of the casual facts.”[177] Matthay believed that many teachers are likely to assume that the pupil understands such labeling, but this belief is misplaced, as the student often does not have the same background knowledge. Hence a wise precaution, Matthay argues, is constantly to re-explain what terms and phrases really signify; else one may find, later on, that the pupil has attached a totally wrong meaning to them.[178] On this point, I agree with Matthay and would state further, that even today, teachers do not use similar terms to describe identical aspects of piano-playing.

Matthay advocates for every pianist to have some understanding of human physiology and biomechanics. He maintains that to comprehend the movements of piano-playing, the student certainly needs some knowledge of the mechanics of his own limbs. This includes skeletal knowledge, the understanding of the actions, reactions and interactions of the upper arm, forearm, hand and finger levers which form his or her playing outfit. They must also understand that in order to produce a desired movement, a pianist must call into activity each of the attached muscles to recognize the dual muscular apparatus we possess for most actions in the hands and arms. That way, Matthay believes that “by their being able to notice the sensation of tension across a joint, a pianist can learn both to avoid the unrequited stresses, and to provide the right ones.”[179]

Matthay stops short, however, of advocating for experimental research in this area, believing that experiments made on the living body are not only unreliable and

[177] Matthay, The Visible and Invisible in Pianoforte Technique, 114.
[178] Matthay, The Visible and Invisible in Pianoforte Technique, 118.
[179] Matthay, The Visible and Invisible in Pianoforte Technique, 156.

misleading, but are often even impossible to attempt. Mechanical tests of the tension or laxity of muscles and tendons during the actual performance of a sufficiently competent artist suffer from the grave disadvantage an uncertainty that the player is quite unlikely to 'be himself' under such ordeal.'[180] In this mindset, Matthay reveals the 'datedness' of his pedagogy. Modern science research is certainly capable of achieving what Matthay believes to be impossible. And lest we forget, many a 'sufficiently competent artist' has suffered from the very physical ailments that experimental research could assist in treating and preventing.

Matthay urges the need to do away with incorrect approaches and concepts in order to move piano pedagogy forward. He notes that,

> "It has been claimed that a reconciliation can be effected between the old explored technical teachings and our present-day knowledge of the facts. Such obviously puerile proposition hardly needs serious refutation. One cannot reconcile truth and untruth as to the facts of pianistic physics and physiology. Either these facts are understood or they are not! It would be like trying to reconcile…the ancient idea that the sun rotates around the earth and recognition of the fact that it is the earth that rotates around the sun. You cannot subscribe to both notions!"[181]

I agree with Matthay's assertion as there are many incongruences in existing pedagogy. We need to strive to resolve these and have the courage to admit when a given pedagogy is refuted by modern research.

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[180] Matthay, The Visible and Invisible in Pianoforte Technique, 157.
[181] Matthay, The Visible and Invisible in Pianoforte Technique, 166.

Section 4: Ludwig Deppe

With the technical teachings of Ludwig Deppe, we come to the true beginnings of the modern era of piano technique. A German pianist, composer, conductor and teacher, he is credited with contributing to the transition from a *finger-based* approach to a *weight-based* approach. Deppe, unfortunately, never left behind any published pedagogical materials outside of an article. Therefore, his approach is articulated by his many students, including Elizabeth Caland and Amy Fay. Their accounts reveal that Deppe was a figure of genuine musical stature, one who is very much concerned about sensitive tone production while realizing that the whole body in all its complexity must be involved in an adequate technical system.[182]

In his 1885 article entitled ***Arm Ailments of the Pianist***, Deppe bemoaned the low level of musical performance and the lack of standards in piano pedagogy which helped the student avoid strains and tensions.[183] This remains the case today. Amy Fay recounts that in a lesson, Deppe once stated, "In piano-playing no particular way of doing anything had ever been decided upon, and recognized as the true method, as has been the case in singing, and in playing the violin. But when it comes to the piano, there are no fixed laws, and each teacher goes his own way. Now there is no reason why there should not be a logically developed system for forming a fine piano technique, which, if rightly followed out will enable the player to obtain the results he aims at."[184] Over 100 years after Deppe made these statements, this 'logically-developed system' has yet to be developed.

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[182] Gerig, Famous Pianists and their Technique, 254.
[183] Gerig, Famous Pianists and their Technique, 252.
[184] Gerig, Famous Pianists and their Technique, 252.

In his commentary on seat height, Deppe argued that a principal reason for frequently occurring arm strain in pianists is that the piano bench is too high. The pianist should sit so that the forearm from the elbow to the wrist will be slightly raised - in this way, the hand will remain free from any oppressive influence of the elbow.[185] This belief in the benefits of the lower seat height is interesting, as the lower the seat height, the more muscular work is involved in sound production due to the increased angle of joint flexion at the elbow. Deppe does not go into explanation as to what kind of 'arm strain' he is referring to. Hence, we are left with a lack of clarity or any ability to judge the merits of a lower seat height.

Throughout his pedagogical accounts, Deppe appears to have employed an analytic approach to teaching piano works. One of his students' recounts that Deppe, instead of saying, "Oh, you'll get this after years of practice," would show me how to conquer the difficulty on the spot. "He took a piece, and while he played it with the most wonderful fineness of conception, he cold-bloodedly dissects the mechanical elements of it, separates them, and tells you how to use your hand so as to grasp them one after the other. In short, he makes the technique and the conception identical as of course they ought to be but I never had any other master who trained his pupils to attempt it."[186] Deppe's approach to piano-playing seemed based on the *scientific method*, and as a result he could help his students extremely effectively because he was leaving them not with a *solution* to technical challenges, but an *approach* to solving their own problems.

Deppe placed a strong emphasis upon the fundamental importance of proper functioning upper arm and shoulder muscles, a topic which many early piano methods

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[185] Gerig, Famous Pianists and their Technique, 252-253.
[186] Gerig, Famous Pianists and their Technique, 255.

and pedagogues scarcely addressed. These muscles were not only involved in the exercising of *free-falling arm weight*, but also in holding back that weight when the situation warranted it. Students were encouraged to function in total harmony with the muscles of finger and forearm - these smaller muscles which had been so overworked by the *high-finger school* and had been made to assume much of the upper arm's rightful activity. No aspect of the playing limb was to engage in isolated activity.[187] Elisabeth Caland in her book, *Artistic Piano Playing as Taught by Ludwig Deppe*, called this condition *muscular synergy*, the keystone in the Deppe approach. She stated, "When we have to make an exertion of strength, *muscular synergy* is requisite in order to avoid fatigue. Not only to spare ourselves, in this way, a painful sensation of strained effort, but we actually develop more real energy."[188] This concept of muscular synergy seems a reasonable conceptual framework for distributing the *work of piano-playin*g equitably between the smaller and larger muscles of the playing limb. No other method or pedagogy to this point had attempted such an explanation on the balance of muscles involved in piano-playing.

In most aspects of piano-playing, and particularly in passagework, Deppe continually emphasized that the elbow must lead and the wrist be like a feather. This 'feather-light hand' was to be carried about and supported by the arm, with much of that support centered in the large upper arm and shoulder muscles.[189] The total integration of the arm was one of the chief aims in Deppe's approach. He believed that though the hand is necessarily sustained by the wrist, the wrist by the forearm, and that in turn, by the upper arm, yet in none of these members should there be any exertion of independent

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[187] Gerig, Famous Pianists and their Technique, 255-256.
[188] Gerig, Famous Pianists and their Technique, 256.
[189] Gerig, Famous Pianists and their Technique, 256.

activity. The upper arm, he argued, must be in a state of complete rest and passivity, and simply allow itself to be guided as a whole throughout the prescribed motions.[190] The integration of the playing limb is an important consideration in piano-playing and Deppe was the first to really attempt to articulate this idea. However, it is impossible for the upper arm to be in 'a state of complete rest' – especially as the elbow, in his approach, is leading. This in turn necessitates muscular activity in the upper arm.

Deppe believed the angles of the fingers in relation to the forearm was extremely important. A distinguishing feature of Deppe's position was that the line formed by the fifth finger, the outside of the hand, and the forearm, should be a straight one. In other words, the hand is turned slightly inward at the wrist. Elisabeth Caland, a student of Deppe, mentioned three immediate advantages achieved by this position:

1. Owing to the straight line running through the hand and arm, the muscular connection between the two becomes of the most direct and positive kind. When the hand is allowed to turn out at the wrist, this rapport is summarily broken at that point, and the fourth and fifth fingers -- no longer lying parallel with the keys but stretched diagonally across them -- suffer a proportionate loss of freedom and power.
2. The very important muscles which lie along the under or inner side of the forearm are now brought into exactly that position which is most favorable to their free and unhampered cooperation with the muscles of the upper arm; hence follows a notable increase in their strength and stability.
3. Through the agency of this 'hand position,' the fingers are effectually aided in attaining complete independence and equality of power.[191]

[190] Gerig, Famous Pianists and their Technique, 257.
[191] Gerig, Famous Pianists and their Technique, 258.

Without using the word, Deppe is bringing to light the concept of *alignment* – both amongst the parts of the playing limb and the playing limb with the piano. While the 'turning-in' of the hand was mentioned before as part of technical execution of scales, Deppe advocates for this alignment as an approach to all aspects of piano-playing. Deppe's advocacy for focusing on alignment, although not voiced as such, is important, because alignment is an area not explored enough in piano pedagogy, and research into the concept could lead to not only improved piano-playing, but also a decrease in injury. My own preliminary studies show how changes in alignment lead to changes in strength, speed and control of the individual finger. I will discuss these studies in chapter 9.

Deppe objected most strenuously to any fast practice until every "detail of phrasing and execution can be subjected to strong and perpetual control, and the movement forms characteristic of each particular composition firmly impressed on the memory." He argued that with enough of this kind of practice, the control became a spontaneous, instinctive thing.[192] I cannot completely agree with Deppe on this front – particularly as it relates to fast practice. When a pianist in this case is 'ready' to play '*a tempo*,' this will lead to changes in the established biomechanics developed at the slower speed. Such an approach to learning repertoire will in turn render any 'memory' that has been impressed, in technical and musical respects, null. In athletics, a sprinter does not 'walk' to practice 'running,' as the mechanics are completely different. I contend that the same is the case in piano-playing. Deppe is correct in much of what he claims except that 'fast practice' must be established from the outset so that one establishes similar biomechanics to what will be used in performance.

[192] Gerig, Famous Pianists and their Technique, 260.

Deppe's description of the movements involved in scale playing involves the concept of *lateral wrist movement*. He advocates that while the fingers take the first three keys, the hand is carried, by a *lateral and progressive movement of the wrist*, so far to the right that the passing under of the thumb, as it sinks on F, is barely perceptible to the eye.[193] The third finger, Deppe believes, by virtue of its position as a regulator for the straight line, must always be imagined as running through the hand and forearm. By using his concept of alignment in approach to scale playing, Deppe provides us with a potential solution to the vexing challenge of thumb crossings in not only scale playing but all passagework. Biomechanically, the thumb in piano-playing traditionally involves more co-contractions than the other fingers because of its position. Such an approach as advocated here would negate the need to contract the interphalangeal joints of the thumb, which would reduce tension in the surrounding muscles. Besides, the wrist joint, which assists here, is the most inherently flexible joint of all the parts of the playing arm.

Notwithstanding the mechanical aspects of playing, Deppe was also greatly concerned about the aesthetic element in physical movement at the piano and its relationship to beauty of performance. The fusion of the beauty of movement and beauty of tone was to him a law of primary importance in the aesthetics of musical performance. Deppe claimed that all movements on the keyboard could be shaped in such a way that *beauty of tone* would be the natural consequence of *beauty of movement*.[194] It was his desire that this movement, which involved the full arm, should always be *curvilinear* and as simple, direct, and purposeful as possible. Each movement should truly be a natural

[193] Gerig, Famous Pianists and their Technique, 261.
[194] Gerig, Famous Pianists and their Technique, 263

outgrowth of the music itself. It was Deppe's desire that even the simplest piece should be performed "with such artistic grace and finish as to turn it into a masterpiece." [195]

In fact, Deppe believed that a musical work could be conceived in terms of *pure movement* and this movement should be informed by the music. He maintains that movement is always continuous from the first to the last note of a piece. "It is unsurpassed as a means where a composition may be rendered in most compact and perfect form; for since all meaningless and superfluous motions are avoided, the movement adapts itself with the utmost nicety to the varying demands of the music," recalls Caland.[196] This concept is also a feature of Abby Whiteside's pedagogy, who will be discussed later. Even in modern pedagogy, movement is valued as secondary to the aural experience. I believe that movement should be valued at least as the aural experience, for it is from movement that the aural experience is generated. This not only applies to piano but to all instruments.

Deppe's focus on the wrist joint is crucial to initiating the curvilinear movement he championed. He emphasized the importance of making every movement a curved one, for it is only by an awkward and angular movement that one can lay the hand flat upon the keys, and the inevitable consequence thereof is a hard, unmusical tone. But the placing of the hand, with wrist well raised upon the keys is the beginning of a curvilinear movement. The movement continues through the pliant downward and outward motion with which the wrist returns the hand to the normal position. It finds further expression as the wrist rises again, with an equally flexible, yet controlled, movement and thus prepares the hand for a new descending curve. In this manner, the hand describes, at each

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[195] Gerig, Famous Pianists and their Technique, 264.
[196] Gerig, Famous Pianists and their Technique, 264.

successive displacement, a curve which joins itself to the one following next; thus, the movement becomes an uninterrupted one, because the hand is meanwhile carried over the keys by the same continuous movement that enchains the separate curves.[197]

Deppe also believed that the integration of the wrist joint with the other parts of the playing limb makes piano technique more efficient. He advocates that when this combination movement of wrist, hand and arm has been made one's own, then will come the realization that this movement lends itself with equal readiness to the performance of runs, thirds, sixths, arpeggios, chords, octaves, trills and staccato passages.[198] Deppe encouraged musicians to imagine the curved lines that the music creates - both musically and physically. The player, he contends, should always endeavor to create for himself a mental picture of a composition, in which these various arpeggios and runs, chords and octaves figure as entwining ropes of pearls; he should follow in imagination the curving lines formed by the execution of such passages.[199]

In promoting the curvilinear movement, Deppe calls into question the usefulness of 'rectangular movement' at the piano – both in a physical and musical sense. He states, "Just as a beautiful form is never born from the straight line and the square alone, so harmony -- which is to tone what geometry is to forms -- can never give rise to the ever-changing melody of passion unless each sentiment has its curve, its climax, its aim and its measure." Deppe is the first and only pedagogue of those I will discuss who has hinted at the challenges of piano technique at the intersection of the instrument's construction and the resulting movements it encourages. This is a central point in chapter 6 of this dissertation.

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[197] Gerig, Famous Pianists and their Technique, 265.
[198] Gerig, Famous Pianists and their Technique, 265.
[199] Gerig, Famous Pianists and their Technique, 265.

Deppe's teachings prepared the way for the ***Weight School of Piano-Playing*** which was to appear shortly and unfortunately, in its excesses, was to repudiate his teachings to a large degree. But seen in perspective from the present day, Deppe is remarkable in that he anticipated many of the views of several modern-day theorists. Certainly, he put appropriate emphasis on the vital role of the arm in the total development of piano technique. Fortunately, Deppe was such a fine, aesthetically-minded musician that he clothed technique in the artistic language in vogue of his day. [200]

Section 5: Rudolf Maria Breithaupt

Rudolf Maria Breithaupt was an early 20th century German pianist and pedagogue. Appointed professor at the former Stern Conservatory in Berlin, he published a number of works and articles on piano-playing. Breithaupt confronted the problem of the weight of the piano key by advocating the use of the whole arm in all playing. Piano-playing in his approach was almost entirely arm activity, free falling weight, and super-relaxation.[201] Although his material is not without some merit, it is continually clouded by statements that are not completely valid nor clear. Of his work, Schultz stated, "Mr. Breithaupt's method pushed to a logical, if absurd extreme the growing tendency at the end of the last century actively to employ the mass of the arm in piano playing."[202] Breithaupt advocated for a lower seat at the piano in order to strengthen the shoulder muscles. He aimed to make the joints supple, maintain relaxation of the muscles of the arm, accustom the arm to retain a position of passive suspension and develop the shoulder muscles.[203] It is true that the shoulder muscles work harder as the arm is lifted

[200] Gerig, Famous Pianists and their Technique, 267.
[201] Gerig, Famous Pianists and their Technique, 329.
[202] Schultz, The Riddle of the Pianist's Finger, 266.
[203] Gerig, Famous Pianists and their Technique, 338.

toward a horizontal plane, and that they are therefore strengthened more when a low rather than a high seat is used. But for the same reason, the arm must then tend, if anything, to be less relaxed, and its joints less supple.[204]

Breithaupt believed that the function of the hand is to support *arm-weight* and *arm-pressure*. In his approach, he believed the chief function of the *hand* was to support the weight of the *arm*. By extension, he rejected any concept of 'hand position,' believing that there are as many hand positions as there are technical forms.[205] While there is some merit to the hand being flexible enough to occupy many positions, to claim that there are as many hand positions as there are technical forms is an exaggeration.

On broken DIP joints (nail joints), Breithaupt argued that they were inconsequential in his approach, stating that the "bending-in of the first joint is no absolutely objectionable feature, provided the middle joint is sufficiently firm. Liszt and Chopin almost constantly played with a more or less flat touch and with the first joints bent in, as the case required, and as the execution suited the fingers."[206] Saying that a broken nail-joint constitutes 'no absolutely objectionable feature, provided the middle-joint is sufficiently firm' flies in the face of the fact that a firm nail-joint has been a dogma in practically every technical system.[207] Additionally, with a little experimentation, Breithaupt would have realized that the less extended a joint is, the less it is able to transfer the very weight that is the cornerstone of his approach.

Breithaupt further advocates, in his discussion of the finger joints, that the PIP joint (middle finger joint) should always be lower than the hand-knuckle to ensure proper weight transfer. A curved-finger raised so that the PIP joint is higher than the hand-

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[204] Schultz, The Riddle of the Pianist's Finger, 268
[205] Schultz, The Riddle of the Pianist's Finger, 268.
[206]Gerig, Famous Pianists and their Technique, 342.
[207] Schultz, The Riddle of the Pianist's Finger, 269.

knuckle joint, Mr. Breithaupt condemns as "absolutely wrong" from the point of view of "free-weight produced touch." This "full-cock" finger represents exaggerated tension and "besides the bending-in of the fingers would destroy the bridge and hand-arch and thus render transmission of weight impossible."[208] Breithaupt is correct that the finger coordination is to be rejected on the ground of exaggerated tension - which causes one to wonder why he was willing to permit the 'bridge' to the fingertips to be disrupted by a broken DIP joint. Mr. Breithaupt's second reason, however, is plainly untrue, as it is both mechanically and physiologically possible to transmit the weight of the arm to the key with the first finger-phalanx higher than its joint.[209]

Breithaupt's concept of piano technique, as previously mentioned, is fundamentally 'weight-centered.' He stated, "The full utilization of the massive weight of the arm (which differs as to quantity and quality with each individual) when combined with the elastic muscular tension of the whole physical apparatus set in motion constitutes the fundamental elements of piano technique."[210] Surely weight is not so exciting a factor in technique to lead a theorist to incoherence, or to the fantastic statement that arm-weight differed qualitatively from player to player.

Breithaupt believed in having a loose and relaxed playing limb at all points. He maintains that every movement must be supple, perfectly free from muscular contraction or stiffness, every joint, muscle and sinew of the limb being relaxed.[211] If Breithaupt is employing the words "relaxed" and "loose" in their absolute sense, he cannot have the arm in a position to oscillate. A truly relaxed arm hangs inert at the side of the body. On the other hand, he is equally mistaken if he uses the word relaxed in the sense that it has

[208] Schultz, The Riddle of the Pianist's Finger, 270.
[209] Schultz, The Riddle of the Pianist's Finger, 270.
[210] Schultz, The Riddle of the Pianist's Finger, 271.
[211] Gerig, Famous Pianists and their Technique, 343.

taken on throughout much of modern pedagogy - the absence of fixation. The fact that a joint shows movement does not mean that the antagonistic muscles which pass over it are not simultaneously contracted.[212]

Breithaupt outlined two types of arm movements in his system. The *high fall* and *low fall* are how they are referred to in his system. In contrast to pedagogues up to this point, finger movement or touch does not exist believing that technic is in reality not much more than alternate 'up-swing' (*high fall*) and 'down-swing' (*low fall*) of the weight.[213] Unfortunately, Breithaupt ignores the fact that in *high fall,* the force of an activated lever (the upper arm exerted forward) is already involved, that weight, in the definitive sense of the word, is employed only during *low fall.* Neither mechanically nor physiologically is the *high fall* an inversion of the *low fall*. Whereas in *low fall* the weight of the arm is falling through the wrist-joint, in *high fall* the upper arm is being pushed forward by ***muscular contraction***, this forward push being only partially resisted at the wrist-joint.[214]

In his chapter covering "Extension of Forearm," Breithaupt here surprisingly shows an absolute disregard for the premises of weight in his system he initially set up. He stated, "The extension of the forearm is equivalent to stretching out in the elbow joint. The important object of this action is in the first place to remove the habitual stiffness and limber the elbow-joint. In the second place, and this is the experimentum cruces - an absolute relaxation of the wrist-joint is a certain consequence of the action."[215] If the wrist is absolutely loose, of course, no tone can be produced, any more than a baseball bat, hinged in the middle can have an appreciable effect upon a ball. And aside from this,

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[212] Schultz, The Riddle of the Pianist's Finger, 273.
[213] Schultz, The Riddle of the Pianist's Finger, 275.
[214] Schultz, The Riddle of the Pianist's Finger, 275.
[215] Gerig, Famous Pianists and their Technique, 346.

the movement of the forearm, whether by weight or by muscular contraction, is not a determinant of the muscular condition at the wrist.[216]

Breithaupt believes that the *arm fall*, combined with rotary turns of the arm, can execute a series of pitches. Termed *Rollung,* he argues, in reference to playing a five-note scale, that instead of executing five swinging and falling movements, one rotation of the forearm in the elbow joint suffices to cause the weight of the hand and arm to bear, or rock upon the five participating fingers, or upon the five keys.[217] However, a single rotary turn, in the absence of finger-movement, cannot possibly get a group of keys down as a series unless it occurs in its entirety while the arm is moving from the key-surfaces to the key-beds. In other, words, the rotary turn, instead of being the agent of key-depression, serves only to distribute the real agent, arm-force.[218] Mr. Breithaupt's execution of scales and arpeggio, obviously intended as a radical departure in piano technique, is nothing more than weight transference by finger movement with rotary adjustment of the released weight over the playing fingers.[219]

Breithaupt discussed the role of the upper arm in forearm rotation. In describing *Rollung*, he stated, "The arm describes a very arched curve, backwards, like a sower casting seed, or a mower's backward movement of the right hand. This back curve of the arm is essential, especially in very rapid passages, to secure a purling, liquid flow and elegance of form, and affords the most natural solution of many a difficult passage, etc. Physiologically this form of movement is nothing more than a combination of upper and forearm rolling."[220] One is, of course, grateful to Mr. Breithaupt for having observed the

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[216] Schultz, The Riddle of the Pianist's Finger, 276.
[217] Gerig, Famous Pianists and their Technique, 349.
[218] Schultz, The Riddle of the Pianist's Finger, 278.
[219] Schultz, The Riddle of the Pianist's Finger, 280.
[220] Gerig, Famous Pianists and their Technique, 350.

fact that upper-arm movement has a bearing upon forearm rotation: most theorists have assumed that all turns of the forearm must take place in the radio-ulnar joints. He failed to understand, however, that the upper-arm movement is properly to be considered an alternative rather than an aid to movement in the radio-ulnar joints.[221] Rotation by itself is incapable of getting the keys of a roulade down; in other words, both key release and key-descent must result from finger movement. Breithaupt, accordingly, is speaking without reference to easily ascertainable facts when he says: "All conscious pressing with the fingers…exhausts energy, strength, wastes time, and is therefore wrong."

Breithaupt believed the arm to be an elastic body and that elasticity has a role to play in piano-playing. He states, "When an elastic body falls to the ground, it rebounds i.e. it is thrown back in the reverse direction, until the power of impulsion is exhausted. If we let the arm descend, with a free swing upon the keyboard and rebound naturally, we obtain a tonal effect corresponding to a sharp and short martellato sound. Hence the tonal effect which we call staccato, is, mechanically speaking, nothing more nor less than the rebound of the striking mass."[222] It is indeed true that, upon falling to hard ground, an elastic body (regarded in the popular rather than in the scientific sense) rebounds. It is not true however, that the arm is such an elastic body. A sharp reversal of a rapid, extensive movement ordinarily requires the contraction of the antagonistic muscles before the movement is completed. That is, if a short tone is to be produced by a sudden descent of the arm, the muscles which lift the arm are contracted before the descent is finished.[223]

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[221] Schultz, The Riddle of the Pianist's Finger, 281.
[222] Gerig, Famous Pianists and their Technique, 352.
[223] Schultz, The Riddle of the Pianist's Finger, 283.

Breithaupt believed that nature has a role in predisposing us to certain movements at the piano. Behind his use of the word *natural* is the hypothesis that nature provides a strong tendency in favor of certain arm movements and that she does not intend all the possible movements to be used.[224] Any attempt to choose the movements of piano technique on the assumption that the arm has a marked, inherent predisposition toward a restricted sphere of movement is foredoomed to failure because such a predisposition does not exist.[225] Schutlz stated, "The piano was made for man, not man for the piano. Even if strong natural predispositions toward certain movement-types existed, we might expect piano-playing to involve an artificial rather than a natural behavior of the various unit of the arm."[226] While Breithaupt uncovered many truths in his pedagogical approach, "his work, however, was swathed at most of its dubious points with references to a word confused in meaning and assigned with an almost magical potency for the pianist, weight."[227]

Section 6: Otto Ortmann

Otto Ortmann was an American pianist, music researcher and educator. A graduate of the Peabody Conservatory, Ortmann served as a professor and established the former Peabody Conservatory Research Lab that was devoted to the scientific exploration of piano-playing**.** A radical departure from the pedagogues so far discussed, he was the first to subject the processes of piano technique to laboratory analysis. He is known for his groundbreaking work, ***The Physiological Mechanics of Piano Technique***, which applied the laws of mechanics and physiology to piano technique.

[224] Schultz, The Riddle of the Pianist's Finger, 286.
[225] Schultz, The Riddle of the Pianist's Finger, 287.
[226] Schultz, The Riddle of the Pianist's Finger, 287.
[227] Schultz, The Riddle of the Pianist's Finger, 289.

We firstly observe this departure in Ortmann's use of scientific vocabulary used to describe piano technique. His discussion of the nature of Robert Schumann's injury serves to emphasize this point. "He (Robert Schumann) lamed himself permanently as a pianist pursuing a dubious objective, for the deep problem in the fourth finger is independence, not strength. It lacks independence cause of the *vinculae* that attached between its *extensor tendon* and the tendons of the adjacent fingers, a disadvantage of physiological structure that additional strength might ameliorate, but never eradicate."[228] This level of discussion of the mechanisms and function of the playing limbs does not exist in our field. I believe this lack of detailed understanding is a major contributing factor to misguided technical approaches of many teachers consequently which can cause discomfort and injury.

Ortmann further argued that one of the predominant problems in the field of piano pedagogy is the lack of sharing ideas and theories amongst pedagogues. Thus, the existing pedagogy in the field has not gone through the kind of rigor and testing that is standard in fields of science and engineering. He stated, "The theorists of piano technique, both new and old, not only ignored one another's ideas, they seemed actually ignorant of them."[229] One of the benefits of sharing information from overlapping fields like science and engineering is that such rigor ultimately leads to consensus and improvements in the field overall. Piano pedagogy, and ultimately much of instrumental pedagogy, I maintain, has yet to develop such a culture. Rather, the field is like an archipelago, existing in close proximity to the others, but without boats or bridges to connect them, or even to help them become at all aware of each other's existence.

[228] Ortmann, Physiological Mechanics of Piano Technique, xv.
[229] Ortmann, Physiological Mechanics of Piano Technique, xvi.

Toward this end, Ortmann set forth how, given the laws of mechanics and of physiology, the piano must be played if it is to be played well, and also how, when measured by laboratory instruments, the piano actually is played by artists of great skill. He begins with a survey of mechanical and physiological facts in a level of detail that immediately sets his work apart from that of all of his forerunners. To accomplish his second aim, Ortmann set up a laboratory where he tested the living performances of expert pianists with a variety of lab instruments, some of which he invented himself. It was the pointer-readings of these instruments that he reported on in his study, not his personal judgements. All of this is to say that Ortmann approached the problems of piano technique as a music teacher looking for scientific facts.[230] Of Ortmann's approach, Schultz stated, "Nothing in our time, of course, is more highly honored than science, and it thus comes about that if something a musician happens to believe on personal grounds is seconded by science, he welcomes it as a benediction."[231]

Ortmann's grounds his concepts of piano technique in the objective terms and scientific laws that exist in the fields of physics, physiology and mechanics. He believed that if pianists are going to think about technique at all, we must think about it objectively. If there is no way out of conceiving piano-playing without considering technique, Ortmann believes we might as well conceive of technique boldly. According to Ortmann, the units of the body with which we play the piano are essentially levers of the third class, and thus obey the laws of lever systems. The muscles are complex engines that move the levers according to certain laws pertaining to their structure. Additionally, the muscles attachments to the skeletal parts, and the interaction of the

[230] Ortmann, Physiological Mechanics of Piano Technique, xvii.
[231] Ortmann, Physiological Mechanics of Piano Technique, xvii.

body's movements against the resistance of the piano keys proceeds according to strict mechanical laws.[232] Contrary to those who disagree with a scientific approach to music, Ortmann maintained that this work in pedagogy is one of artistic merit. Scientific techniques can be learned, and there are many who have learned them, but the discovery of how to apply them is itself a creative act.[233] One of the benefits of Ortmann's application of the concepts and terminology of other fields to piano-playing is that he is building the very consensus outside the field that does not exist within piano pedagogy. Secondly, Ortmann is giving related fields the opportunity to contribute to the development of modern pedagogy. In my opinion, this interdisciplinary approach is way overdue, as piano-playing is, inherently, an interdisciplinary activity.

In his initial chapters, Ortmann discusses the playing apparatus from the viewpoint of a system of levers and analysis of the various joints of the playing unit. He emphasizes the concept of *coordinated rotation of the forearm* with *vertical and lateral movements of the wrists* in order to produce finger movement. Without the radio-ulnar joint, forearm rotation, upon which the important pianistic motions depend, would not be possible with any amount of freedom. The fingers, as appendages of the hand, can thus, without movement of their own joints, be made to descend and to ascend. This concept harkens back to that first articulated by Matthay, who discussed the importance of the coordination of the playing limb. However, in this case, Ortmann goes a step further to specifically describe the areas of the playing limb crucial to such coordination.

Ortmann goes on to describe these specifics. Since the axis of rotation passes through the fourth finger, the thumb will describe the greatest arc, because it is furthest

[232] Ortmann, Physiological Mechanics of Piano Technique, xviii.
[233] Ortmann, Physiological Mechanics of Piano Technique, xix.

removed from the axis of rotation, and the fifth finger, the smallest arc.[234] Flexion and extension at the wrist may occur through an arc of 150 degrees or more, with marked individual variation. On the other hand, *abduction* and *adduction* of the hand - a sideways bending at the wrist used in arpeggiated-chord figures, polyphonic and double note passages occurs through 60 or 70 degrees. This lateral movement is greater on the outer side (toward the fifth finger) than on the inner side (toward the thumb).[235] The movement however, need not be restricted to the thumb and fifth finger for as soon as the wrist is turned laterally, the axis no longer passes through the fourth finger, and any finger may be shifted out of the line of the axis of rotation and hence receive vertical displacement when the forearm turns at the radio-ulnar joint. As a result of this motion, the fingers can receive a vertical stroke equivalent in height to the finger-stroke itself.[236] Here Ortmann provides us a practical guide in executing the concepts of forearm rotation with lateral wrist movement to produce finger movement. This explanation of combining lateral wrist movement with forearm rotation gives pianists and pedagogues a legitimate alternative to finger movement and serves to highlight the inherent redundancy that exists in piano-playing.

Ortmann further emphasizes the importance of lateral movement in the wrist joint. Lateral wrist movement is important on account of the effect it has upon changing the axis of rotation of the forearm. By turning the hand outward slightly at the wrist, the forearm axis which, in the unturned hand passes through the fourth finger, may be shifted to the third finger, thus dividing the hand more symmetrically. A further lateral turn at the wrist will shift the axis still further toward the thumb side of the hand.[237] It is

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[234] Ortmann, Physiological Mechanics of Piano Technique, 16.
[235] Ortmann, Physiological Mechanics of Piano Technique, 17
[236] Ortmann, Physiological Mechanics of Piano Technique, 22-23.
[237] Ortmann, Physiological Mechanics of Piano Technique, 31.

important to note here that the form of rotation that Ortmann is discussing here is a *visible form* and not the *invisible stresses* that Matthay articulated in his approach. Ortmann argues that *curved movements* should form a centerpiece of piano-playing, maintaining that all smooth, steady movements in the whole field of mechanics, that involve more than one direction, are movements in curves. The principles of all machines, from the mechanism of a watch to that of a turbine, are based upon rotation. Physiological mechanics are no exception to this rule. It is impossible to make a steady movement in more than one plane any other way than in a curve. It is in partial, though not complete conflict with the "fixed position" school of piano pedagogy.[238] *Curvilinear movement* was also a feature of Deppe's approach, and Ortmann here supports these earlier claims.

Ortmann also discusses muscles of the playing apparatus involved in rotation of the forearm and demonstrates the inherent inequalities in muscular strength. The muscles of *supination*, he maintains are much stronger than those of *pronation*, a difference utilized in the direction (to the right) in which a screwdriver is turned.[239] Additionally, Ortmann believes that players with more arm and finger strength can more easily distribute their energy more efficiently to manage how fatigue is manifested. If the player possesses sufficient strength in their fingers and arms, he can distribute this in any of several economic ways. The player with weak fingers and arms, on the contrary, will have to be satisfied either with less pronounced dynamic effects, or with the utilization of the shoulder and back muscles, a coordination that does not always facilitate the technical demands of the particular passage. Ortmann here demonstrates the benefits of the

[238] Ortmann, Physiological Mechanics of Piano Technique, 30.
[239] Ortmann, Physiological Mechanics of Piano Technique, 43.

inherent redundancy that exists in piano-playing while also implying the need for developing muscular strength. He does not, however, expand on how a pianist can improve strength applicable for the piano.

Ortmann contends that similar conditions hold for compositions demanding sustained finger-work. If the fingers be sufficiently strong, the required dynamic gradations may be made without calling into play the larger muscle-groups of the arm.[240] Ortmann draws the correlation between muscular fatigue and relaxation, claiming that the earliest onset of muscular fatigue affects the relaxation, but not the contraction rate of the muscle. The next effect of fatigue shows in the degree of contraction.[241] The relaxation rate of muscles also has implications for finger speed, just as the rate of key-descent correlates to the 'release' of the finger just used. Contraction in one of the intrinsic muscles decreases the available energy of the other fingers.

Ortmann also discusses what happens to the nerves and to blood circulation while playing, and he is the first of the pedagogues to do so. He argues that *accuracy*, measured here by spacing and dynamic control, likewise depends upon the sensitivity of the touch-organs and other kinesthetic stimuli. This is the function of the nerves, which can only transmit the impulse they have received. If the latter is deficient, the transmission will be deficient. Any harmless device that will increase the circulation is useful.[242] The efficiency of muscular reaction is bound up intimately with the circulation in the body.[243] Ortmann strongly advocates for teachers to have knowledge of the neural and circulatory systems which innervate the playing apparatus. The real teachers, of whom there are, unfortunately, relatively few, will not rest content with a casual "that

240 Ortmann, Physiological Mechanics of Piano Technique, 55.
241 Ortmann, Physiological Mechanics of Piano Technique, 56.
242 Ortmann, Physiological Mechanics of Piano Technique, 69.
243 Ortmann, Physiological Mechanics of Piano Technique, 70.

pupil is not talented," but will seek to find the causes of the defective playing. This he can do only if he thoroughly knows his tools, and these include the elements of circulation and nerves as well as the bones and muscles.[244] Unfortunately, many teachers still have little knowledge of these very elements for which he advocates. And the reason for this has to do with the lack of emphasis of these areas in music institutions at all levels.

The discussion of rotation is expanded in Ortmann's work to include all joints in the playing apparatus - not just the forearm as emphasized by earlier pedagogues. He reminds us that 'rotation' describes the movements of all joints involved in piano-playing and that motion at a joint demands muscular coordination. *Movements in straight lines* therefore, since they involve the coordination of motion at several joints, are physiologically more complex than *movements in the arc of a circle* caused by one joint. A straight descent of the fingertip in a finger-stroke is mechanically more complex than the curved stroke resulting from a fully extended flat finger. Any movement in a straight line, means that several joints are participating in generating this movement.[245] This is a common misconception not just in movements involved in piano-playing but in movement in general. And to further extend the concept, the more joints participating in a movement, the more energy is expended and hence the more quickly fatigue can occur.

Ortmann described the *change in direction of motion* as a chief component in piano-playing. He stated, "The chief geometric characteristic of piano technique is change in the direction of motion. And physiologically, this probably constitutes the biggest problem of technique. A change in direction may be abrupt or gradual. In the

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[244] Ortmann, Physiological Mechanics of Piano Technique, 70-71.
[245] Ortmann, Physiological Mechanics of Piano Technique, 77.

first case an angle will be formed; in the second case, a curved line."[246] Here we observe another argument for curvilinear movement as being superior to angular movement. In discussing the types of muscles potentially used in piano-playing, Ortmann advocates for a coordinated combination of the larger and smaller muscles. He maintains that by adding a *slow movement* of larger muscles to the *rapidly repeated movement*, the player changes the movement from one of *absolute repletion*, to one of *relative repetition*. With this, he eliminates absolute muscular repletion, and consequently, in the case of rapid movements, reduces the danger of early fatigue."[247]

Coordinated movement is an important consideration to Ortmann. A *coordinated movement* is considered as one in which the body parts involved act using the best mechanical advantage to achieve a desired force or intensity. As the force of a movement increases, the directional-relationships of the various parts of the body change. In piano-playing, the mechanical aim of all movements is the descent of the piano-key at the proper time and place of a force sufficient to produce the desired tonal intensity.[248] This explanation of coordinated movement also supports an argument against *slow-practice* as eventually the force or speed will change the relationship of the various body parts that has been built up.

Ortmann interestingly extends the definition of 'talent' to one's muscular ability, much in the same way we speak of athletes today. He contends that most movements of piano technique involve rapid contraction followed by periods of relaxation. Ortmann is inclined to believe that the readiness with which relaxation sets in between movements of

[246] Ortmann, Physiological Mechanics of Piano Technique, 78.
[247] Ortmann, Physiological Mechanics of Piano Technique, 79.
[248] Ortmann, Physiological Mechanics of Piano Technique, 99.

the playing apparatus is a fair index of kinesthetic talent as applied to the piano. He states,

> "I have always found, in watching the playing of technically talented, though pianistically untrained students, that a very nicely adjusted relaxation is always present immediately after tone production. The opposite of this is an accepted fact: The sustained contraction (useless stiffness) of untalented pupils is pianistically undesirable. But the relaxation following tone-production has frequently but erroneously been supposed to exist during tone-production as well and has given rise to a pedagogy of tone production that robs the player's style of much force, velocity and brilliance."[249]

He is the first piano pedagogue to attribute talent to one's muscular control and this, I believe, is an area of study that deserves attention. Perhaps an improvement in our understanding of this 'adjusted relaxation' is a concept around which a pedagogy can be developed.

Ortmann discussed the concept of *weight* in playing and its addition and removal. He examined commonly held beliefs about position and weight transfer and demystifies this through experimentation. The nearer the shoulder is over the elbow, the less arm-weight can be directed to the key. *The best position for directing the maximum amount of arm weight into the key is that shown at B*, where the wrist is high and the upper arm at a small descending angle. This requires a slight incline of the trunk away from the keyboard.[250]

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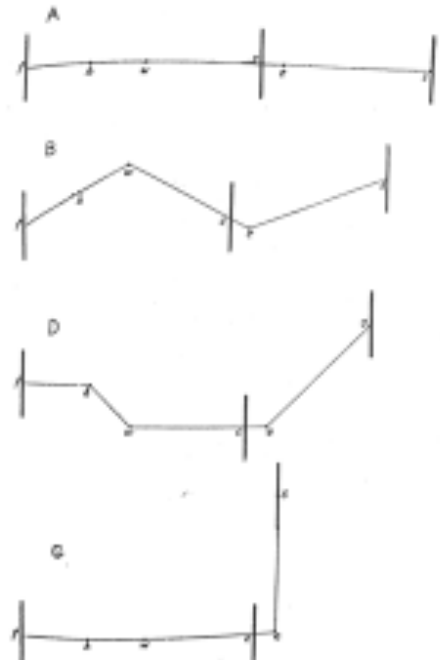
[249] Ortmann, Physiological Mechanics of Piano Technique, 120.
[250] Ortmann, Physiological Mechanics of Piano Technique, 130.

The conditions change, however, when *force is exerted by muscular forc*e. In G, the lever arm is considerably shorter. For that reason, position G becomes decidedly superior. G is the typical "learning forward" position accepted as the standard by most performers and teachers. This acceptance in itself is proof that an *arm-stroke*, not *arm-weight* is normally used in piano-playing,.[251] Today, this concept of how *arm-weight* is directed onto the keyboard continues to be misunderstood, in spite of Ortmann's research findings on the matter.



v. Diagram for arm orientation and force into the key.

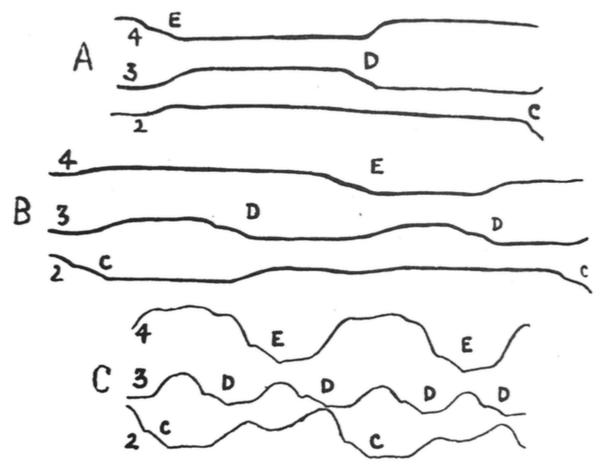
Inertia, in all complex piano passages, is of extraordinary importance, and its reduction to a minimum is most desirable. Ortmann believed that such a reduction is secured by bringing the shoulder forward more nearly over the keys. The purpose of this position is not to add the weight of the upper relaxed arm, but actually to remove the weight. He argues that for speed and dexterity, the mass of the playing-unit must be reduced to a minimum. This requires a degree of fixation that makes impossible the relaxed arm necessary for arm-weight.[252] He negates the notion that one can have *maximum weight and speed*. He states, "As the intensity (dynamics) increases, the number of key strokes in a given time decreases and the fluctuations in the transfer of weight increase, so that when we get to the *forte* degrees, there is a noticeable reduction

[251] Ortmann, Physiological Mechanics of Piano Technique, 131.
[252] Ortmann, Physiological Mechanics of Piano Technique, 132.

in finger-speed and noticeable fluctuations in the transfer of weight from finger to finger."[253] It would do well for pianists to understand this inverse relationship between weight and speed. Many invite strain and tension in their misguided attempts to achieve maximum weight and speed rather than seeking an equilibrium between the two.

Ortmann is critical of the concept that the *muscular coordination* of a given musical passage is the same regardless of tempo. He argues against the notion that slow practice will assist in playing fast passages more accurately. Ortmann supports this viewpoint graphically with curves that represent direct tracings of the finger movement itself in a descending three-note passage.

In A, the motion of each finger is, in point of time, an isolated movement, the two other fingers remaining at rest while the third moved. In B in the descending passage, the third finger is lifting as preparation for its down-stroke while the fourth finger is still descending. The plateaus noticeable in A are here shortened. In C, no sign of a fixed position remains. The three fingers are here in constant motion, shown by the absence of any horizontal lines. The mechanics and the coordination have thus changed completely. The muscular coordination in turn, must differ with the speed. The question of the extent to which slow practice is necessary for ultimate speed, when with every change in speed we change the



vi. Diagram for finger coordination at various speeds

[253]Ortmann, Physiological Mechanics of Piano Technique, 136.

muscular reaction is an important one for the psychologist, and its answer awaits an adequate experimental investigation.[254] This viewpoint is a provocative one and flies in the face of most approaches to practicing in particular. I do believe, however that practicing with the exact muscular coordination that will be used in performance is critical to physical and psychological confidence as well as memory.

Ortmann also discusses the fallacy of *relaxation* correlating to increased transfer of *arm-weight*. He maintains that not only can there be no fully relaxed joint in any usable arm-position, but also only a part of the arm weight, and usually only a small part can be transferred to the finger in any condition. The shoulder continues to support the remainder, regardless of relaxation.[255] In order to throw more weight into the finger-tip, some intervening joints must be fixed. And if the entire arm-weight were to be transferred, the fixation of the whole arm between fingertip and shoulder would be necessary. The fixation of all intervening joints is diametrically opposed to the whole doctrine of weight-transfer, which demands a relaxed arm as a necessary physiological condition of this transfer. He argues that exactly the opposite is mechanically true: weight transfer demands fixation of the joints, not relaxation.[256] This is a point that I shared in opposition to previous approaches, based on its applications in sports and other activities. Here, Ortmann has explained it using the playing mechanism.

Ortmann also commented on the complexity and subtlety of individual differences in musical talents. He suggested that these differences “begin in the physiological variations of the gross physiological organism: the size of the hand, length of the fingers or arm, weight of the arm, and range of movements.” He also supports the work of recent

[254] Ortmann, Physiological Mechanics of Piano Technique, 140-141.
[255] Ortmann, Physiological Mechanics of Piano Technique, 147.
[256] Ortmann, Physiological Mechanics of Piano Technique, 148.

researchers who have affirmed that *joint mobility* and *finger spans*, rather than *hand size*, are significant factors that impact piano performance. On the other hand, *finger mass* does not seem to play an important role in tone production. Ortmann noted that pianists with *tapered fingertips*, who played with a 'light, delicate touch,' or pianists with a chubbier finger type, who produced a more massive tone, both had sufficient touch control and dexterity to produce the desired tones.[257] Again this is in opposition to some commonly held beliefs regarding the determining physical factors in musical talent in piano-playing. Sadly, there are many who hold on to these beliefs much to the discouragement of many aspiring pianists.

In contrast to Breithaupt, Ortmann's findings reveal that *differences in intensity* are the only variations which a piano tone can show as opposed to *qualitative differences* in tone. He states, "Qualitative changes in tone actually occur, but these changes are concomitant with variations in intensity. That is to say, each gradation in the intensity of a given tone possesses its own inalterable quality." This viewpoint needs to be understood by every pianist and teacher in addition to the fact that those variations in tone intensity are determined only by the *speed of the piano-key's descent*. Pianists' varying abilities to affect changes in tone are correlated to their varying degrees of control of the speed in key descent.

Ortmann regrets the attitude held by most pianists that a knowledge of science is irrelevant and believes that the serious pianists will meet the challenge. He states, "He (The pianist) still believes that a knowledge of the action of muscles and of the laws of the lever are of no value in his work. That is the typical attitude. This attitude is to be regretted. It has served to keep obscure a field of great theoretical interest and practical

[257] Lee, Hand Biomechanics in Skilled Pianists, 1.

importance - the borderland where science meet art." Ortmann also leaves a scathing rebuke of piano teachers. "The concert artist, if he so chooses, may work as he will, remaining his own problem, or, perhaps, finding his own solution; but the teacher, selling lessons in physiological mechanics hour after hour, day after day, should at least know the tools with which he works. But, too often he does not; and since he constantly uses his arms and fingers, he usually resents the assertion that he does not know how they are used."[258] Ortmann is articulating a state of affairs in the field of piano-playing and pedagogy that, since his writings and research, has not changed much. It is my hope that my work in the field will spur the kind of changes that Ortmann hoped for almost 100 years earlier. Ortmann's work, while a difficult read for non-scientists, deserves study by all involved in the performance and teaching of not only piano-playing but all instruments.

Section 7: Arnold Schultz

Arnold Schultz was a piano pedagogue and a respected authority on piano technique in the 20th century. A contemporary of Ortmann, he had the utmost respect for his colleague and even wrote the Introduction to the 1962 rewrite of Ortmann's book ***Physiological Mechanics***. His own pedagogical treatise, ***The Riddle of the Pianist's Finger***, is a self-proclaimed balance between Ortmann and Matthay's pedagogical approaches.

Schultz begins by discussing the challenges of science and art and debunks the myth that they cannot coexist. He states, "It is one thing to say that scientific curiosity is

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[258] Ortmann, Physiological Mechanics of Piano Technique, xxxi.

vastly different from subjective sensibility, and quite another to imply that an extreme curiosity and an abundant sensibility cannot coexist in the same personality. If one's own intuitions do not rebel, then the facts of history afford the proof against too facile thinking."[259] Schultz goes on to describe the engineering prowess of Da Vinci and his formulation of lever laws, Goethe's contributions to botany and anatomy and Borodin's in chemistry.

Of pianists and teachers, Schultz laments, "At times they have groped uncertainly for truths which have been understood for centuries in the fields of physiology, anatomy, and mechanics; some of their most serious blunders, in fact, might have been avoided had they frankly repaired to these sciences. Yet an open invocation of these sciences breeds immediately a dread that music itself is to be turned into a science."[260] In this regard, Schultz recommends schools of music to have courses in physiological mechanics and champions Ortmann as important to review in such courses. Of Ortmann's contributions, he states, "The study of Mr. Ortmann's laboratory records on various *touch-forms* would serve to raise the whole study of technique from its present level of personal conjecture and loose opinion to a stage of relatively clear and ascertained fact. Such study would produce a purely intellectual grasp of technical theory which seems to me quite as essential in the training of pianists as are courses in harmony and counterpoint in the training of a composer."[261] These 'blunders' sadly continue in the field today and most conservatories and schools of music still do not have these courses for which Schultz advocates.

[259] Schultz, The Riddle of the Pianist's Finger, vii.
[260] Schultz, The Riddle of the Pianist's Finger, ix.
[261] Schultz, The Riddle of the Pianist's Finger, xii.

In the opening chapters, Schultz discusses the mechanics of key descent and the involved skeletomuscular components. He then discusses the all-important *playing unit* and its importance in piano-playing. The playing unit is that group of *arm-levers* which depresses the key. If the various joints within a playing unit do not support the descending force, they will collapse, and the force intended for the piano key will not reach it. To remedy this, Schultz discusses the need for a *supporting contraction* - the contraction of a muscle which is just great enough to keep a joint from breaking through without causing movement in the opposite direction.[262] It is amazing how many pianists and teachers continue to search for solutions to collapsing finger joints that knowledge of Schultz's findings would certainly remedy. However, because of the lack of consensus within the field, such nuggets of wisdom continue to escape many.

Schultz comments on two sources of the force which moves the playing apparatus into the key. The force which moves the *playing unit* into the key is derived from one of two sources - from the *gravity of the earth (weight)* or from *muscular contraction*. Weight is a constant force, assisting muscular contraction in all downward movements of the playing units - given special recognition only when it is the sole force producing the movement of the playing unit.[263]

Schultz describes a series of movements and conditions of the arm that could be used in piano-playing. His newly minted vocabulary advocates that *contra-fixation* and *trans-fixation* movements are the best for *legato*. Contra-fixation movements are described as the isolation of finger movements from the pressure or weight of the arm to depress piano keys. It is preferred by Schultz when compared to *contra-weight* – where

[262] Schultz, The Riddle of the Pianist's Finger, 32.
[263] Schultz, The Riddle of the Pianist's Finger, 32.

the force needed to play is supplied by gravity, and *contra-pressure* - where the force is supplied by muscular contraction. Fixation represents a means of eliminating separate voluntary force-adjustments for separate tones. Here, the antagonistic muscles stiffen the various joints of the base so it is welded as if into a single piece with the body.[264] Contra-fixation movements can produce legato with either the *whole arm* or the *finger* as the playing-unit. The movements of the fingers are by far the best touch to produce legato when the rate of a tone succession exceeds that which one of the arm-touches can produce.[265] Such comparisons, Schultz argues, serve to emphasize more than ever that the finest legato in conjunction with the subtlest control of intensity can only be achieved by contra-fixation movements of the fingers. Yet the touch-form, at least when its mechanics are defined, is almost universally barred by modern pedagogy. All first-rate pianists, of course, employ it, but in doing so, they are flatly disobeying the sovereign theories of traditional technique.[266]

Contra-fixation movements of the fingers also have a *velocity advantage* over *contra-weight* movements. With contra-fixation, a finger may arise from the keybed immediately after key depression without waiting for the next finger to assume the support of the base. This is an advantage of special importance when great velocity is required.[267] Additionally, it has an advantage in the *control of intensity*. Of the three types of movement in which the base does not move, we see the contra-fixation movement is at an advantage for velocity and for the control of intensity, and that is at no disadvantage for legato. While its range of intensity with the smaller playing-units is less

[264]Schultz, The Riddle of the Pianist's Finger, 63.
[265] Schultz, The Riddle of the Pianist's Finger, 76.
[266] Schultz, The Riddle of the Pianist's Finger, 78-79.
[267] Schultz, The Riddle of the Pianist's Finger, 79.

than that of the other two types, its force is nevertheless adequate for the playing of most piano music."[268]

Schultz describes three conditions that a *contra-fixation* movement must fulfill:

1. The joint in which the playing-unit swings, in other words the base, must show no movement, either up or down, during the movement of the playing-unit.
2. The playing-unit must not support the base during key descent, nor after key descent.
3. The antagonistic muscles which fix the base must not contract in excess of the degree required to withstand the reaction of the playing-unit. If they do, energy is wasted and endurance is needlessly decreased.[269]

Trans-fixation movements are necessary as a compromise mechanism for the execution of passages in which the degree of velocity and the degree of tonal intensity are both relatively high.[270] According to Schultz, *trans-fixation* movements are to be employed in preference to *trans-weight* or *trans-pressure* movements wherever the music score demands that combination of velocity and tonal volume.[271] In *trans-fixation* movements, the base returns to its original position without resting upon the playing unit. Its return is caused by those muscles engaged in the fixation which depress the arm.[272] Because the base returns more rapidly, a series of tones can be connected by this touch at a faster tempo.[273] Such movements which involve the return of the base simultaneously with the release of the keys are, accordingly, admirably suited to the production of

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268 Schultz, The Riddle of the Pianist's Finger, 81.
269 Schultz, The Riddle of the Pianist's Finger, 135.
270 Schultz, The Riddle of the Pianist's Finger, 83.
271 Schultz, The Riddle of the Pianist's Finger, 94.
272 Schultz, The Riddle of the Pianist's Finger, 94-95.
273 Schultz, The Riddle of the Pianist's Finger, 96.

staccato, for if the base is returned as soon as the tone is sounded, the playing-unit arises from the keys a very short moment after tone production.[274]

Schultz argues that "provided that *contra-fixation* movements have already been well-learned, no pedagogical problem whatsoever is encountered in *trans-fixation* movements."[275] All that is needed to change a *contra-fixation* movement into a *trans-fixation* movement is an increase in the contraction of the muscles operating the playing-unit. The distinguishing feature of the *trans-fixation* touch is the speed with which the base returns to position. The whole movement is little more than a vibration.[276] Schultz's concept of *fixation conditions* and *fixation movements* deserve laboratory study of pianists. Physiologically, his theories seem logical, though it would be interesting to see how many elite pianists already execute the movements he has labeled. I do have a concern however about this approach as it places the playing arm – particularly the upper arm muscles, in a state of constant contraction. Though it very well may be effective from a tone production standpoint, such a muscular approach does take a tremendous energy toll, which in turn may lead to tension and strain.

For control of *tonal intensity*, Schultz argues that it is best to use *only the small muscles of the hand*. Though he describes four other coordinations of intrinsic and extrinsic muscles available to pianists, he believes that the finger is ever more sensitive to key-resistance, and therefore never more capable of fine control over intensities, than when it is operated by the *small muscles alone*. With the small muscles as the sole operators of the finger, the piano-key feels heavy and the finger small - a situation which, he believes, makes for ease in planning the speed of each key descent. This is interesting

[274] Schultz, The Riddle of the Pianist's Finger, 96-97.
[275] Schultz, The Riddle of the Pianist's Finger, 169
[276] Schultz, The Riddle of the Pianist's Finger, 170.

that Schultz believes that sensing the *heaviness* of the piano key is a key to fine control. Many modern pianists actually see such a heaviness as a weakness to overcome and expend much effort in developing compensatory strength in the muscles of the hand.

In discussing finger movement, Schultz admits both the *bent-finger* and *flat-finger* approaches are useful and necessary. However, he advocates that the *flat-finger* approach be learned first and argues that the *bent-finger* movement is of little assistance in learning the more complicated *flat-finger movement*. The reverse is rather true, that after *flat-finger* movements have been mastered, little new difficulty is encountered in learning the bent.[277]

In contrast to many of the previous pedagogues studied so far, *rotation* for Schutz is a minor factor in piano-playing. Schultz states, "That the movements signified by the phrase *forearm rotation*, serve a useful purpose in balancing the weight over the supporting finger during arm-touches has already been seen. That they are of value for certain tremolo figures which involve the thumb along with either the fourth or the fifth fingers will be conceded before this chapter closes. But that they are of practically no help to the pianist beyond these two rather self-apparent functions can be, I think, definitely demonstrated."[278] Schultz later does discuss the possibility of combining finger movement with rotation in order to improve tonal intensity but leaves no practical explanation. He simply states, that "The combination of forearm rotation with independent finger movement is, accordingly, often justifiable, especially when finger strength alone is incapable of producing the required degree of tonal intensity."[279]

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[277] Schultz, The Riddle of the Pianist's Finger, 163.
[278] Schultz, The Riddle of the Pianist's Finger, 180.
[279]Schultz, The Riddle of the Pianist's Finger, 188.

The only aspect of rotation Schultz discusses in detail is from the standpoint of *vibrato coordination (tremolo)*. But here, he discusses something I think that has implications beyond a tremolo to all piano pedagogy – ***the importance of shifting that axis through lateral movement of the wrist to accommodate fingers that are at a disadvantage***. During a given rotation, a finger which lies close to the axis moves through a smaller distance than one which is farther removed. Therefore, a more extensive rotation of the arm is required to depress a key with a finger which is close to the axis than with a finger which is farther removed. Because the axis of the forearm passes through the fourth finger, only one pair of fingers, the third and fifth, satisfy the requirement of the vibrato coordination to the effect that the opposite movements be equal. The third and fifth fingers, however, fail to satisfy the requirement that the movements be relatively small. They lie immediately on either side of the axis, and the forearm must pass through relatively wide rotary arcs to depress either of them - arcs which in fact are much too wide to permit a vibrato.[280]

If, however, the hand is abducted in the wrist-joint, the hand-knuckle of the third finger may take the position formerly occupied by the hand-knuckle of the fourth finger, the axis being transferred, accordingly to a line approximately midway between the thumb and the fifth finger. The important advantage of the new arrangement is that the thumb and fifth finger satisfy both of the requirements of a rotary vibrato. Not only is the degree of pronation which depresses the thumb equal to the degree of supination which depresses the fifth finger, but both motions are of a minimal extensiveness. The second and fourth fingers, however, are still unavailable for velocity. They describe equal arcs, but their closeness to the axis demands wider rotary turns than the vibrato coordination

[280]Schultz, The Riddle of the Pianist’s Finger, 186.

can produce.[281] Though Schultz's discussion of lateral wrist movement is geared towards executing an effective tremolo, I believe the lateral movement of the wrist is able to assist the fingers in more significant ways than providing an equal arc for vibrato coordination. Providing balance as well as biomechanical efficiency through the alignment of each finger with the forearm when used in piano-playing is one such application.

Section 8: Abby Whiteside

Abby Whiteside was an American piano teacher of the early and mid 20th century. She follows in the tradition of Ortmann and Schultz in their analytical approach to piano technique. While possessing a high regard for Ortmann and his analytical research, Whiteside made her own observations not in the science laboratory but throughout the world of nature - wherever physical skills were in evidence. A student of anatomy and body mechanics; she observed carefully the graceful, skilled movements of athletes in many fields: dancers, jugglers, musicians and anyone else so engaged.[282] From such observation, she developed the piano pedagogy for which she is now known and respected.

Whiteside believed in the importance of rhythm as a foundation for technique. She affirms that a vital all-encompassing rhythm is the basic coordinating factor involved in building an effective technique and must serve as the basis for musical continuity and beauty of interpretation. Such a rhythm will also express itself in physical continuity of movement and flow.[283] She believed in this concept so much that she expressed that '*ear training'* more than '*music reading'* was crucial in the beginning stages of establishing a

[281]Schultz, The Riddle of the Pianist's Finger, 187.
[282] Gerig, Famous Pianists and their Technique, 469.
[283] Gerig, Famous Pianists and their Technique, 470.

good technique and that the music student should begin by playing *by ear*. They must learn to read, quite obviously, but they should be an *aural learner* rather than a *visual learner,* Whiteside maintains. "Observe the ease and accuracy of pupils who have learned to play by ear. Their skill is never attained by those who learned the notes first and then built up a coordination that is dependent on the eye. Notes, after all, are merely symbols for sounds. The pupil who has learned music by the way it sounds hears the tone when he looks at the symbol. The movements that make this imagined tone audible are directed by his ear. They are as fluid as efficient, as coordinated as his movements when playing without notes."[284]

Whiteside looks to jazz musicians as an example of this fluid movement she advocates. She asserts that fine jazz pianists have naturally followed this plan and exhibit "a tune in their ears and a rhythm in their bodies and they let these two elements fuse by using nothing else as they learn their instrument." No serious student, she argues, can expect to achieve a beautiful performance and an adequate technique without following suit. He must feel the rhythm, and he must listen to the sound he is producing - and he must let this guide his every movement.[285]

There is much here with which I agree. Whiteside's advocacy for 'playing by ear' deserves serious consideration. Such an approach, by removing the complication of music reading, would certainly allow the beginning student in particular to give more of their attention to their technique. I do believe, however, that the jazz pianist comparison breaks down when one realizes that much of the work of a jazz pianist is largely harmonic and they generally will not improvise *beyond their technical ability*. Classical

[284] Gerig, Famous Pianists and their Technique, 472.
[285] Gerig, Famous Pianists and their Technique, 473.

pianists, on the other hand, are constantly challenging their technical boundaries in order to improve, not to mention that the music is too complex in many cases to learn by ear. I do agree with Whiteside, however, that it is important ultimately to feel the rhythm internally. Rhythm is certainly a most important musical ingredient.

Whiteside also believes that *physical activity* is crucial to piano-playing – defined in this situation as the act of moving the body at the instrument while playing. She believes that there is no true rhythm without physical activity- it can never be developed.[286] This concept of intentionally producing physical activity in piano-playing opposes the view of other pedagogues and teachers who view rhythm as a cerebral process. Her viewpoint has been corroborated by the teachings of influential figures in elementary music education, such as Emile Jacques-Dalcroze, Carl Orff, Maria Montessori and Zoltan Kodaly.[287] They all advocate complete bodily physical activity in the child's rhythmic development. Oftentimes, sadly, these rhythmic physical manifestations are repressed or inhibited in a student's later technical study at the piano.

Whiteside believes that pianists and all musicians are inherently dancers and should view themselves as such. This philosophy of musicians as dancers is expressed well by José Limón, a modern dance authority. He argues that all musicians are dancers, and that dancers can be good dancers only when they are good musicians.[288] He even invokes the name and works of Bach in support of this.

> "Let me only point to that supremely choreographic composer, that incomparable dancer of the spirit, J.S. Bach. There is a dance for every single human experience. What, may I ask, can we call the impassioned procreative act; what

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[286] Gerig, Famous Pianists and their Technique, 473.
[287] Gerig, Famous Pianists and their Technique, 473.
[288] Gerig, Famous Pianists and their Technique, 473

> else but dance is the convulsion of birth; and what of the frenetic rituals of adolescence; and the somber solemnities of maturity, the weddings, academic processions, inaugurations, coronations, funerals; what are these but the dances with which we are conceived, are born, grow, live and die? All this is dance, both profane and sacred. Bach contains it in all his music, whether secular or religious. He was irrepressibly a dancer. Embedded in the cantatas, the oratorios, among the chorales, the arias, and the recitatives, placed there with the most consummate mastery of drama and theater that compels you with the irresistible kinesthetic impetus which is dance."[289]

Whiteside takes these ideas and applies it to the piano. She maintains that left on their own, the pianist does not have the benefit of the singer's breathing, the violinist's bow arm, or even the skater's balanced activity to force him into a long-line phrase procedure and a compelling rhythm in his body. He must use full arm and bodily participation in order to achieve such a rhythm.[290] The functions of the various parts of the playing mechanism and their role in rhythm are also discussed in her pedagogical approach. "The torso itself frequently must bounce and dance to the music,"[291] she states. These claims hit home in a personal way. Throughout my piano studies, I have been told by many teachers that I needed to be more still while playing and that I needed to feel the rhythms more cerebrally. Such restraint was foreign to me and invited more inner tension which lead to physical manifestations of the same in my own playing. I wholeheartedly agree with Whiteside that the rhythm should manifest itself more

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289 Gerig, Famous Pianists and their Technique, 474.
290 Gerig, Famous Pianists and their Technique, 474.
291 Gerig, Famous Pianists and their Technique, 475.

outwardly. For is not rhythmic movement the outward expression of what an instrumentalist does with their playing arm anyway?

Whiteside advocates for the forearm as the most important part of the playing mechanism. It is the "natural implement for a fast-repeated action and its action is the central control for fast articulation. Its repeated action is always associated with traction of hands and fingers. That is, the hand and fingers operate inside its repeated action while it is going on."[292] She believed that incorrect use of fingers - reaching for any key with the fingers or using them primarily to supply hitting power, is at the heart of persistent technical difficulties. The fingers are merely the periphery of the playing mechanism. She stated, "The fingers transmit, not initiate, the power."[293]

Whiteside declares that *cooperation,* not *independence* of action by hand, fingers and forearm, must be what is practiced - rather than the individual control of each component. It is exactly this point which is basically unsound, in her opinion, in traditional training. She states, "Tradition believes in training levers for independent actions. The result is simply independent action - not cooperative actions. That is not nature's way of creating an expert coordination."[294] Whiteside's use of the word *cooperation* sets her apart even from Ortmann and Schultz, who, while believing in some concept of integration of the playing arm, never addressed the cooperation between the parts. It would even have been a stronger point, however, if anywhere in her account, she attempted to expound on how such cooperation of the components of the playing mechanism was to be achieved.

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[292] Gerig, Famous Pianists and their Technique, 476.
[293] Gerig, Famous Pianists and their Technique, 476.
[294] Gerig, Famous Pianists and their Technique, 477.

Whiteside also advocated that piano-playing should be studied, taught and analyzed more critically. She argued that, "Our Maker did not have piano playing exclusively in mind when he created us. Moreover, most of us have ordinary brains, ears, arms and fingers, and find that the processes of growth and maturity hinder rather than help the development of good piano-playing. In other words, we need to be unremittingly on our guard against excessive muscular contraction, as well as mental inflexibility. Like you, we cannot trust blind instinct in playing or teaching."[295] This puts her right in line with the viewpoints of previous pedagogues like Ortmann and Schultz in their indictment of ill-informed teaching. Whiteside even more than the other two could speak with some authority to pianists and piano teachers, having spent virtually her entire career in private piano teaching.

Section 9: Dorothy Taubman

Dorothy Taubman was an American music teacher, lecturer and founder of the Taubman Institute, who developed the *Taubman Approach* to piano-playing. The most recent development in piano pedagogy developed in the 1970's, Taubman identified some of the subtle differences between the way the freest pianist moved, and the way others moved. Rather than inventing a new way to play the piano, she observed what was already done by pianists who played with fluency and ease. But unlike many other piano pedagogues she did not base her approach on the authority of those players - but on the underlying anatomical facts. Such a basis for piano pedagogy is crucial in advancing the field in my opinion. In fact, I believe that all pedagogy involving complex movements of the human body need to have anatomy as a basis. Otherwise, it remains mostly

[295] Gerig, Famous Pianists and their Technique, 481.

conjecture, as I have shown in the previous sections of this chapter. For what is taught really, is not *how to play a given instrument*, but rather *how to play the body* so that an instrument can be the conduit for artistic expression.

The *Taubman Approach* has earned a reputation through its high rate of success in curing playing injuries. Taubman believed that physical problems with a somatic origin tend not to respond to ordinary treatments and therapies. Instead, they are improved or cured when the person learns a *better quality of movement*. Taubman's results with both injured and non-injured pianists are an example of what becomes possible when the physical task of piano-playing is analyzed from the perspective of biomechanically efficient movement.[296] Today, the Taubman Approach continues to be championed by the *Golandsky Institute* during the summers and masterclasses throughout the year as well as through the teachings of numerous well-known conservatory and university pedagogues who follow the approach.

The basis for the Taubman approach was on the concept of *coordinate motion*. The parameters of this are:

1. *Unification*. All the body parts performing work will function as a single unit. No single element involved will work independently of the unit.

2. *Mid-Range of Motion*. All body parts will move within the mid-range of motion of the joint articulation from which they depend. Conversely, movements to the extreme range of motion are avoided.

3. *Awkward Movements*. Movement roles are assigned to the body parts best able to perform them, thereby eliminating awkward movements entirely.

[296] Mark, What Every Pianists needs to know about the body, 4.

4. *Alignment*. Correct alignment of body parts is maintained under all conditions. Not only does this alignment allow body parts to move within their mid-range of motion with greater frequency, it also brings into play skeletal compression and support not available to misaligned body parts.

5. *Division of Labor*. No single body part will perform all labor. Instead, labor will be divided between all the body parts most able to perform it. Effort is thereby decreased in each muscle group, and this results in an increase of macro-amplitudes overall and a decrease of micro-amplitudes at each joint articulation.

6. *Efficient Use of Equipment*. The mechanism of the tool, in this case the piano action, will be used within its limits of design and to its utmost effect with a minimum of muscular effort.

7. *Minimal Muscular Effort*. Gravity becomes available to perform work under the foregoing conditions, thereby decreasing muscular effort overall to minimal levels.

8. *Synergistic Action*. The action of each coordinated movement is synergistic, magnifying and potentiating all the others. Consequently, the need for each discrete coordinate movement is reduced to minimal levels. When all elements are properly coordinated, the discrete elements become almost invisible to the untrained eye.[297]

Like Matthay and many other pedagogues since, Taubman believed that *forearm rotation* was an essential element to developing a virtuoso technique. This point is emphasized even in initial lessons with a Taubman teacher. To really understand the approach, I travelled to Philadelphia once a week to study with Robert Durso, a Taubman Master Teacher. He articulated verbally and visually not only the underlying concepts

[297] Wikipedia, Dorothy Taubman.

but also their practical application. Following are some of the highlights in developing a 'Taubman technique.'

Firstly, the wrist is always to remain high and never in a collapsed position. The elbow is fixed as a base from which rotation of the forearm can occur.   The rotary movement, however, should always feel easy and free of tension.   These movements are presented at first as a large, visible turning of the forearm. Over a series of steps over many weeks, various five-finger patterns and selected scales are utilized to become familiar with the movements and the sensations. The movements are progressively minimized to the point that it becomes invisible and the fingers actually appear to initiate the rotation of the forearm instead of the forearm generating the rotation and playing of the finger.   A *tapping sensation in each finger* when playing is the way that its described. Emphasis is placed on ensuring that the player still senses the movement internally though it may not be seen visually.[298] Once this technique is embedded into the player, these movements are then applied to piano repertoire.

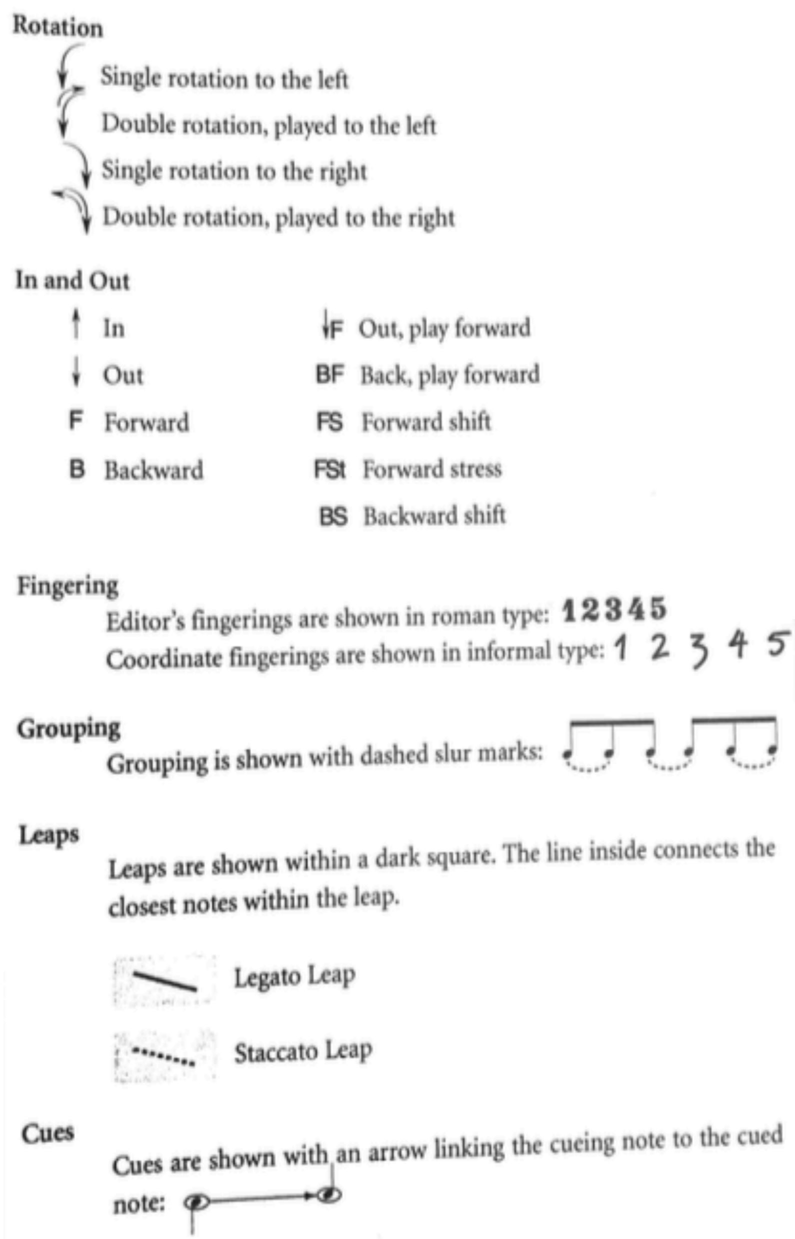
This experience impacted me in powerful way. It was not only a new way of playing but also a new way of *learning repertoire* – something that has not been dealt with by many pedagogical approaches and will be addressed later in this section. It also developed within me an improved attention to the movements that I make within a pianistic context. This is a feature of proprioception that I will touch on later as well. Taubmann's explanations are similar to Matthay's explanations of rotation, but she introduces her own terminology. A series of notes moving in the same direction are termed *double rotations* and notes moving in opposite directions are *single rotations*. A *double rotation* is so termed because of the preparatory motion in the opposite direction

[298]Durso, Recorded Interview.

that takes place before playing the key. A *single rotation* is the absence of this preparatory motion.

Within this basis of rotation, the *lateral movement of the wrist* is emphasized, going from note to note and in crossing over and under of the fingers as in scale playing. Rotation is further combined with the following concepts and symbols:

1. In and Out
2. Walking arm and Hand
3. Shaping
4. Grouping
5. Leaps
6. Interdependence
7. Fingering
8. Enslavement to Notation[299]


Rotation

Single rotation to the left
Double rotation, played to the left
Single rotation to the right
Double rotation, played to the right

In and Out

	In	F	Out, play forward
	Out	BF	Back, play forward
F	Forward	FS	Forward shift
B	Backward	FSt	Forward stress
		BS	Backward shift

Fingering

Editor's fingerings are shown in roman type: 1 2 3 4 5
Coordinate fingerings are shown in informal type: 1 2 3 4 5

Grouping

Grouping is shown with dashed slur marks:

Leaps

Leaps are shown within a dark square. The line inside connects the closest notes within the leap.

Legato Leap
Staccato Leap

Cues

Cues are shown with an arrow linking the cueing note to the cued note:

vii. Text describing pianistic movements

[299] The Golandsky Institute, Book of Musical Examples.

Coupled with these concepts, Taubman advocates for a *sense of stability or balance* after each note is played. Such balance over a note in her approach is crucial before proceeding to the next note. She also asserts that the fingers should be *released toward* the finger being played at a given moment and argues against the concept of placing the fingers in a '5-finger position' over the piano keys. Rather, the only muscular activity should be of the finger being used at that given moment. Ortmann also recognized this in his laboratory studies and describes this common problem. He states, "Wherever the third finger plays, as a result of the muscular contraction, the second finger is pulled toward it. It is a familiar pedagogic problem in violin and violoncello. In order to neutralize the deflection of the unused finger toward the used finger, the muscle on the other side of the index finger must be contracted." Taubman, however, does not see this physiological phenomena as a problem and certainly does not advocate for the contraction of the other fingers to 'neutralize this deflection.' I have found in my own playing that one I allowed the other fingers to be released and allowed the work of rotation to move me between keys, it eliminated the need for me to stretch the fingers and hence eliminated one of the sources of tension in my own playing.

One of the distinguishing characteristics of the Taubman approach is its use of repertoire to teach its underlying principles. In the Taubman approach to learning piano repertoire, it is learned *physically first and metrically second*. The underlying premise is that *the rhythm of physical movements does not always correspond with the rhythm of the music*. Therefore, these should be worked out independently and then combined. While other pedagogues of the past have discussed having a sense of rhythm aurally or even physically, this expands and differentiates that concept in a unique way. This is a radical departure from most piano pedagogy as it places the body at the center of the learning of repertoire before the musical aspects are addressed. In my view, this is probably why so many injured pianists under this approach have been able to recover.

Besides offering a rational, diagnostic system aimed at solving the musical and physiological problems of piano interpretation, the techniques Taubman pioneered have been used therapeutically to treat repetitive strain injuries related to piano-playing, and generally to rehabilitate injured pianists. Though no data exists in terms of numbers of pianists that have been rehabilitated, anecdotal accounts are plentiful. Of all pedagogical approaches that I have explored, Taubman's remains the only approach to have both a health and human performance impact for pianists. It would be interesting to observe aspects of the Taubman Approach in a laboratory setting.

One cannot deny that there is a wealth of worthy information contained within this cross-section of historical pedagogy. Indeed, many pianists and teachers continue to attest to aspects of their efficacy. However, these precious nuggets are embedded within and surrounded by many more concepts and practices that, while noble in effort, are simply inadequate at best and detrimental at worst. Unfortunately, the net combination of these two competing realities is one of pedagogical confusion. Through my critique, I have sought to demonstrate the need for a considerable review of much of the pedagogy that our field holds dear. A sifting of these approaches is desperately needed, and our field left on its own does not possess the requisite toolbox for this analysis to occur. However, in partnership with scientific disciplines like anatomy, physiology and kinesiology as well as working with engineers and others involved in developing technologically ergonomic devices, we can begin to build many of the tools to assist in the commencement of such analysis.

Part B: Scientific Analysis and Considerations of Piano Playing

Chapter 4: Historical and Practical Missteps in Developing Piano Technique

The importance of developing piano technique and the thorough development of the basic physical tools have been of most vital concern to keyboard performers and pedagogues across the centuries.[300] But the existing non-consensus on what makes for healthy and effective piano technique, coupled with the lack of a rigorous analysis of piano pedagogy, has resulted in much confusion as to which are the best approaches. Pianists and pedagogues truly have an impossible task sifting through the sand dunes of methods and treatises developed for the instrument. Furthermore, because of the lack of input from without, there continue to be missteps in modern times that have their basis in pedagogical history. Thus, the blunders that started with early methods continue to this day. However, unlike early pedagogues, the field can no longer claim ignorance based on the lack of scientific and technological understanding.

Firstly, there remains a prevailing fear among pianists and pedagogues that to study the purely physical aspects of performance will lead to a lack of musicality. Ernst Bacon, American pianist and composer of the early 20th century, believed that "piano playing will never be a science. If it were it would cease to be an art."[301] Schultz lamented such a viewpoint, stating, "There is a fear that a persistent use of the reasoning mind in reference to the objective phenomena of technique results in the deterioration and

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[300] Gerig, Famous Pianists and their Technique, 1.
[301] Gerig, Famous Pianists and their Technique, 5.

atrophy of the subjective emotions upon which the interpreter's art depends."[302] This has sadly resulted in many noble but incorrect biomechanical approaches. As Schultz writes, pianists and pedagogues "have groped uncertainly for truths which have been understood for centuries in the fields of physiology, anatomy, and mechanics." Some of their most serious mistakes, he argues might have been avoided had they simply consulted these sciences.[303] Ortmann also lamented this belief and suggested that it has kept many from pursing musical careers. He stated,

> "Very often, the necessary mechanical analysis is never made, and the pulls continue day after day in their attempts to do the mechanically impossible, until the hopelessness of the task and the ensuing loss of interest turn them from their task into non-musical activities. Whereupon the teacher attributes it to a lack of talent or poor studentship."

Further contributing to these misconceptions are those who justify the need for a plethora of approaches in the field of piano pedagogy. They believe that "surely more than one system has effectively presented technical truth and no one method holds a patent right to truth."[304] While such a viewpoint is an admirably romantic trait, such pedagogical confusion contributes to continued misunderstandings and misinformation that continue to be passed on by pianists and teachers. For example, there still exists the notion that difficulties in piano-playing can be overcome simply by more practice. Czerny even stated famously that "practice is the great Magician, who not only makes apparent impossibilities performable but even easy."[305] This veneration of 'practice' is still in vogue today, as many performers spend endless hours in the rehearsal halls of

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[302] Gerig, Famous Pianists and their Technique, 6.
[303] Schutlz, The Riddle of the Pianist's Finger, ix.
[304] Gerig, Famous Pianists and their Technique, 3.
[305] Gerig, Famous Pianists and their Technique, 108.

institutes and conservatories. And while many pianists do improve in their musical and technical pursuits, they also, as a consequence, can end up exhausted and injured.

Historically, pianists and pedagogues went all out in their efforts to develop the playing mechanism by developing non-musical exercises and devices designed to do so - albeit without the vetting process standard in sciences. One such device was the *chiroplast* that was advocated by many in the 19th century to improve positioning, and, in turn, accuracy. The pedagogue Kalkbrenner stated in support of this device,

> "By an early and frequent use of this apparatus, it is evident that the learner must become habituated to a proper position of the body, and a graceful movement of the arms; and the fingers must acquire an independent motion and equality of power rarely accomplished by other means."[306]

Exercises for the strengthening of the fingers without the aid of gadgetry were introduced as early as 1818 by A.E. Mueller and have continued to be used down to the present day – yet again without proper authentication from the fields of music or science. Thomas Prentice, in his book, ***Hand Gymnastics***, represents the most exhaustive commentary on the subject. His objective in the use of gymnastics was to strengthen and balance opposing sets of muscles.[307] Prentice stated, "The keyboard has no pretensions to be a gymnastic apparatus suitable for this scientific training; it was not invented for any such purpose. The player's hand and arm remain practically always in the same position, subject of course to innumerable slight changes, which do not, however, affect the argument. The set of muscles exercised is always the same. Here is at once a source of weakness."[308]

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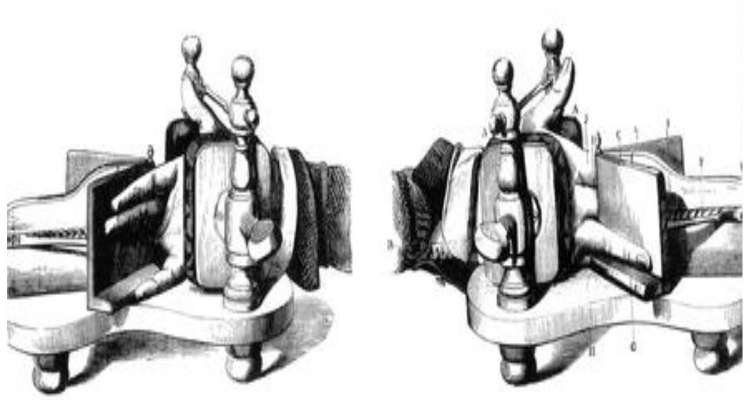
[306] Gerig, Famous Pianists and their Technique, 128.
[307] Gerig, Famous Pianists and their Technique, 233
[308] Gerig, Famous Pianists and their Technique, 234-235.

No matter how well intentioned these developments were, they both occurred outside the purview of science, engineering and technology. While the *chiroplast* may indeed have improved independence to a degree, it did so by fixation – the prevention of motion of the other parts of the playing mechanism.



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viii. Diagram of the Chiroplast

Such rigid fixation not only could lead to physical and health challenges but also limit the kind of repertoire that could be played. Certainly, the music of composers like Liszt and Rachmaninoff could not even be attempted with such fixation. Exercises for the strengthening of fingers unfortunately were developed much in the same way. Though it is interesting to observe how developing the opposing muscle groups in piano-playing would affect the overall physiology of the playing mechanism, the concept deserves further attention by pianists and scientists and awaits exploration.

Related to the concept of strengthening, many pianists still believe that the presence of tension and pain is an indicator of strengthening. They subscribe to the old adage "no pain, no gain." However, the existing literature maintains that, "Pain caused by

[309] Retrieved from https://www.sciencesource.com/archive/Chiroplast--Designed-to-Train-Pianists-SS2607562.html

our habits of movement is relieved by discovering and correcting those habits. If poor habits are not corrected, they can lead to injury, which in turn can cause permanent damage."[310] A significant part of the issue with piano-playing is that it inherently involves the *repetition of very similar motions*. In fact, playing any musical instrument requires repetitive motions, and piano playing, in particular is extremely repetitive. A motion that involves even a small amount of tension can lead to injury when repeated thousands of times a day over a period of years.[311] Such tension continues to develop because many teachers and pedagogues continue to advocate for methods that emphasize isolated movements – despite the most recent developments in pedagogy articulating the need for cooperative and coordinated movements. Such teaching methods based on finger movements isolated from supporting movements in the rest of the body are not only harmless, they are dangerous. Thomas Mark also supports this concept of cooperative movements and sums it up beautifully. "Saying that we play the piano with our fingers is like saying that we run with our feet. We play the piano just as we run: by complex coordinated movements of our whole bodies."[312]

There exists a misconception that anyone who plays beautifully must have an exemplary technique and can serve as a model for others. Not everyone realizes that Glenn Gould, Sergei Rachmaninoff, Artur Schnabel, and many other famous pianists were injured. Their injuries indicate that their techniques were flawed, at least in terms of a movement point of view. Obviously, we should acknowledge and emulate their artistic achievements, but it would be dangerous to model our techniques uncritically on theirs.[313]

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[310] Mark, What Every Pianists Needs to know about the body, 1.
[311] Mark, What Every Pianists Needs to know about the body, 1.
[312] Mark, What Every Pianists Needs to know about the body, 3.
[313] Mark, What Every Pianists Needs to know about the body, 5.

Also, there is a danger of attributing good technique to outward beauty. While quality of movement and quality of playing are connected, mere outward appearance does not always enable us to distinguish safe and dangerous movement. Two movements of the hand or fingers may look outwardly similar and yet one may be free and easy, the other stiff and tense.[314] Saying that someone plays with a poor quality of movement is not the same as saying that the playing is poor, and practitioners in our field need the skillset to be able to differentiate between the two.

In the past, there were those who espoused the benefits for pianists of taking care of one's overall health. Emil Von Sauer, German pedagogue and pianist stated, "Many young Americans who go abroad…break down upon the very vehicle upon which they must depend in their ride to success through the indiscretions of overwork or wrong living.[315] The performer who would be at his best must live a very careful, almost abstemious life. Any unnatural excess is sure to mar his playing and lead to his downfall with the public."[316] While his latter statements of how a musician should live may seem monastic at work, his initial claims are as true today as they were when he made them, regarding the lack of care and lifestyle choices of musicians. I believe this concept of self-care correlates with the quality and quantity of artistic output. It is applicable to musicians across the instruments and genres of music.

The quality of movement at the piano and the overall health of pianists is largely determined by the ergonomics of the instrument itself. Little research has been done on how the instrument itself contributes to the challenges of movement and health that pianists face. Many pianists, teachers and pedagogues seem to believe that our

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[314] Mark, What Every Pianists Needs to know about the body, 6.
[315] Cooke, Great Pianists on Piano Playing, 241.
[316] Cooke, Great Pianists on Piano Playing, 242.

instrument has reached a perfected state and always seem to place the sole responsibility of overcoming technical or health challenges at the feet of the musician. This belief is very much in error. Every other discipline is constantly in a state of progress and advancement, and the convergence of disciplines has resulted in amazing innovations. The very device on which I am writing my dissertation has become more ergonomically friendly to many, thus improving the efficiency of its use and limiting potential discomfort. The piano unfortunately has not had the same kind of advancement and certainly not at the same rate. Serious study of the technology and engineering of the instrument could lead to innovations that could reduce much of what pianists are dealing with technically and physically.

Connected to how piano technique *appears*, a great deal of piano technique is based on how it *feels*. It is believed by many that "*Naturalness* is, without a doubt, the final determinant of a valid piano technique. Such a technique operates in harmony with the laws of nature - with a special regard for those laws concerned with physiological movement and muscular coordination."[317] But how one determines '*naturalness*' in a practical sense, whether it be through observation of other pianists or one's own inner sense when playing, has yet to be adequately explained. This is not to mention that in many cases, one's sense of '*naturalness*' could be misguided - especially in fast-paced modern societies. We tend to move our bodies according to the way *we think of them*, not necessarily according to *the way they actually are*. This is even the case for those of us who have never *consciously formulated* beliefs about our anatomical and physiological being. As Mark reminds us, the human body "has a particular anatomical structure. In our brain is a representation of that structure. But *the representation, not the structure*

[317] Gerig, Famous Pianists and their Technique, 3.

determines how we try to move."[318] Such faulty representation certainly has profound implications for something as specific and complex as piano-playing and is the subject of the later chapter on proprioception.

These ideas, amongst others, will be discussed in the following chapters in this work. I will unpack much of the scientific, technological and proprioceptive aspects that are relevant to our field. I also hope to show how such knowledge could be of immediate benefit to pianists and to show a possible path in the development of modern piano pedagogy.

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[318] Mark, What Every Pianists Needs to know about the body, 11.

Chapter 5: Modern Scientific Literature and Piano Playing

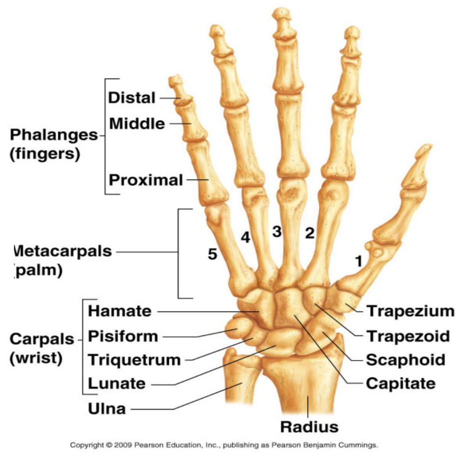
A number of scientific texts have attempted to study aspects of piano performance. Unfortunately, such texts are largely not discussed in conservatories or music schools, for the most part. Despite this lack of engagement from within the field, it is important to shed some light on the research that is being done that could be beneficial to a continued and improved conversation at the intersection of piano-playing and scientific research. Though a great deal of material could be covered here, I will focus on a few salient points of information. Such knowledge, I believe, could assist our field immensely. I will first examine aspects directly related to piano-playing as outlined in texts pertinent to the study of anatomy, physiology and kinesiology. Subsequently, I will canvas a variety of published scientific journal articles. In order to improve the field of piano-playing and pedagogy, it is imperative that we understand the tools with which we work.

From a skeletomuscular standpoint, there are important concepts that we must understand if our field is to improve. For starters, the wrist, hand and fingers have the most joints of any other area of the gross anatomy consisting of some 27 bones. Certain joints have differing movement capabilities. The DIP and PIP joints for instance are hinge joints, whereas the MCP and bones of the wrist are pivot and gliding joints. Because of the construction, movement in certain joints of the hand affects the freedom of movement in the other joints of the hand. Abduction of the MCP joint, for instance, does not allow the PIP and DIP joints to bend, only to extend.[319] It is also not possible to

[319] Oatis, Kinesiology, 286.

maintain an actively curved finger position without simultaneously having a relaxed wrist.

ix. Skeleton Diagram of hand and wrist bones



[320]

Which brings me to the wrist – the most mobile joint of the playing apparatus. It is the place through which the tendons pass to connect the extrinsic muscles of the forearm to the various joints of the hand. The wrist is not only a joint, but also a structure within the hand consisting of eight bones. What many pianists traditionally point to as the wrist is actually the articulation of the ulnar and radial joints. If we are going to improve piano pedagogy, we should be more conversant in the terms referring to parts of the body important to piano-playing.

The wrist as a whole is a biaxial joint allowing flexion, extension, radial deviation and ulnar deviation. The wrist combines these motions to perform circumduction and other global wrist motions.[321] However, within the scientific community there remains disagreement about the direction and magnitude of relative motion among the eight carpal bones during wrist movements. It becomes especially unclear when one understands that each of the carpal bones that form the wrist are capable of independent

[320] Retrieved from http://www.stepwards.com/?page_id=16959
[321] Oatis, Kinesiology, 273.

three-dimensional motion.[322] Furthermore, the wrist ligaments have demonstrated more sustained elongation before failure than elsewhere in the body. They behave viscoelastically, exhibiting higher loads to failure with increasing loading rate.[323] This explains why even very young children with little muscular strength can hold themselves up on the monkey bars on a playground just with their hands.

Since there are few activities that use the wrist in such a complex way as our field, studying the wrist movements that take place in piano-playing could be vastly beneficial for a number of interdisciplinary areas. Such studies could help the fields of physiology, kinesiology and neuromechanics by providing an opportunity for understanding how the carpal bones forming the wrist actually function. This benefit actually goes both ways, as the wrist is the most problematic and often injured area for pianists. Helping the sciences will in turn help us to understand the way the wrist works and thus hopefully prevent potentially injurious movements moving forward.

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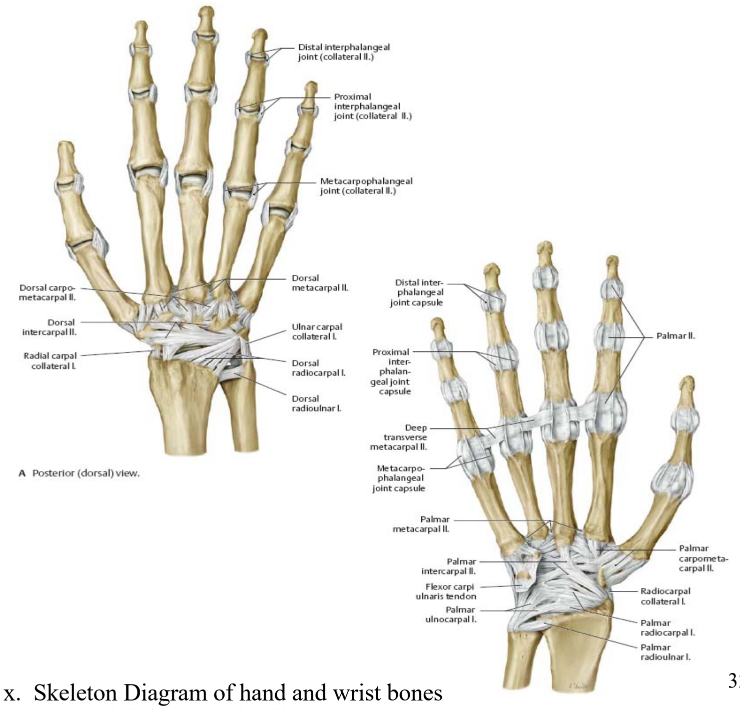
[322] Oatis, Kinesiology, 274.
[323] Oatis, Kinesiology, 272.



x. Skeleton Diagram of hand and wrist bones and their respective ligaments [324]

The ligaments of the fingers are another important aspect that impacts piano playing. This is particularly so for the MCP joints which are largely responsible for the distance or stretch a pianist can reach.[325] It is for this reason that two hands can appear to be the same size, but the reach can differ widely, based in part on the varying ability of these ligaments to stretch. It is also possible for someone with a smaller hand to have a similar reach to a person with a larger hand. Variations in the articular surfaces of the joints of the hands and fingers are another important consideration. This results in considerable variety in the available motion and stability of each joint. We as musicians are well aware of historical pedagogy designed to improve the stretch of pianists. These findings demonstrate why such practices were and continue to be harmful to so many. Tools that are able to look at both the ligaments and the joint shape variations are crucial

[324] http://digikalla.info/hand-ligaments/hand-ligaments-wrist-hand-atlas-of-anatomy-download/
[325] Oatis, Kinesiology, 286.

to understanding what kind of training and exercises are helpful or harmful to certain pianists.

Additionally, gender also appears to play an important role. Research revealed at passive range of motion in the MCP joint was significantly greater in women than in men for hyperextension.[326] While this peculiarity between the genders may matter little for the general population, the implications are immense for pianists, particularly female pianists, and suggest a potential evolutionary advantage for them. Such variation in the physiology is not limited to gender lines however. In sporting disciplines, physiological variation accounts for advantages in other disciplines. The length of Usain Bolt's legs, the percentage of fast-twitch muscles in Simone Biles and the shape and size of Michael Phelp's feet undoubtedly contribute to their 'talents' in their chosen sports. Along these same lines, I believe that much of what we consider 'musical talent' is, in actuality, *physical talent*. It is simply no more than having wider or easier range of motion within the joints of the hand or the ideal shape of the joint surfaces that hence produce potentially wider variations of speed, control and power. These variations, in turn, translates to listeners as 'musicality.'

Just as there are different size proportions from one human being to another, the same variations also exist within a human being. These differences occur on at least three anatomical levels, including, but not limited to, variations between the left and right arm, between the left and right hand, and between the fingers of each hand. The reasons for these differences are noteworthy. When examining myself for instance, my right shoulder is higher than my left one, and the articulation of my right arm in space also differs from that of my left arm. Additionally, the ring finger on my left hand is longer

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[326] Oatis, Kinesiology, 286.

than my index finger. Yet on my right hand, those fingers are equal in length. All of these physical anomalies I only discovered within the last five years, with more heightened awareness. And attention to such differences has made me a more mindful musician by improving the accuracy and efficiency of how I approach the technical aspects of piano-playing. Needless to say, awareness of these differences is crucial to informing not only one's own playing but the playing of others as well as the teaching.

Even though it seems simple to observe differences in the gross anatomy, these differences are merely a beginning to telling the complex story of *how* or *why* motion in piano-playing occurs. It is impossible to cover all of the considerations here, but I will share one example of the importance of this understanding. Though there is a lack of consensus on many issues in piano pedagogy, most pianists would agree that the ability to *pronate* is central to piano playing. Most pianists learn how to pronate within the first few lessons, for it is in this 'playing position' that we execute piano technique. In order for a pianist to pronate, the ulnar moves distally and laterally over the radius distally at the wrist joint. This movement of the ulnar allows the palmar side of the hand to point toward the ground.

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xi. Diagram of pronation of the forearm

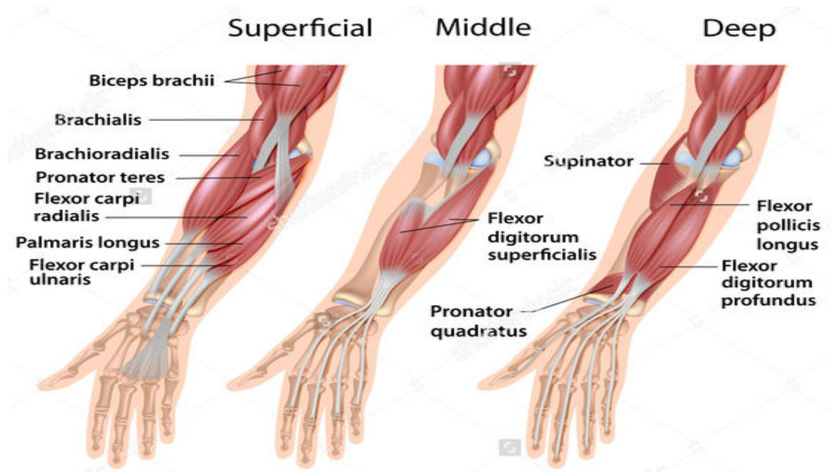
[327] Retrieved from https://corewalking.com/three-joints-elbow/

In piano playing, this position allows us to occupy the often-taught five-finger position at the piano. However, there are anatomical and physiological variations that impact a pianist's ability to pronate. The relative length of the ulnar to the radius is one such consideration. Research has shown that individuals with a longer ulnar relative to the radius – termed *negative ulnar variance*, will exhibit increased ability to pronate. In other words, these individuals pronate more easily than those having radius or ulnar of equal length. This variation has immense implications for pianists technically as the ability to pronate easily is central to pedagogy based in rotation as well as the execution of techniques like broken octaves and trills. This variation also has potential clinical relevance. Other aspects, including the tightness of the distal radioulnar joint capsule or tightness of the *pronator teres* muscle also promotes decreased pronation and supination. The greater the angle of elbow flexion, however, the easier pronation and supination also occurs because elbow flexion puts the *pronator teres* muscle into a slackened position.[328] This, in part, supports the argument for pianists to assume a more flexed elbow position.

This discussion of the musculature involved in pronation leads us into an understanding of the overall musculature of the playing apparatus. To this end, an understanding of the *Flexor Digitorium Superficialis (FDS)* is particularly crucial. This muscle is the extrinsic muscle of the forearm chiefly responsible for finger flexion, particularly the MCP and PIP joints and is of utmost importance in piano-playing.[329] What is important to understand is that outside of the middle finger, all the other fingers share proximal muscle attachments that become more independent distally. However, such independent activation occurs only in 'low-load' activities. More vigorous

[328] Oatis, Kinesiology, 297
[329] Oatis, Kinesiology, 300

contractions recruit shared units so that fingers contract together. In piano-playing, this implies differences in the physiological mechanics of playing fast single-note passages versus chords. One needs efficient independent finger activation, while the other requires concentric activation. And those differences are governed largely by the strength of finger contractions. It also demonstrates that piano-playing for the most part is a 'low-load' activity.[330] Training must therefore be geared towards developing the activation thresholds of the FDS to execute various piano techniques.



xii. Diagram of the muscles of the forearm

The *Flexor Digitorium Profundus* (FDP), also a finger flexor, on the other hand is 50% stronger than the FDS and is the only muscle that can flex the DIP of the fingers. However, it makes discrete finger activation of a single finger difficult. That is because the tendons of the fingers are mechanically linked to one another at the muscle belly and carpal tunnel.[331] This is of clinical and pedagogical significance and suggests a reason why many pianists could be suffering from tendon related injuries. A misunderstanding of the underlying musculature and its function has possibly led to incorrect use and

[330] Oatis, Kinesiology, 301.
[331] Oatis, Kinesiology, 313.

subsequent injury in pianists' efforts to produce finger flexion. It is akin to choosing to lift one's leg using the muscles at the hip joint without using those muscles responsible for also bending the knee in one's efforts to walk or run. Sadly, this kind of misunderstanding is common in piano-playing.

Individuals within the human population do exist who possess an absent or non-functional muscle, bone or neuron. In some populations, this absence could be considered a disability. However, in the arm and hands, studies have repeatedly shown that it is a common occurrence within certain populations. The *Palmaris Longus*, a wrist flexor muscle, for instance is missing in 14% of the world's population – particularly in Asian, Native American and African American populations.[332] Another example is the tendon of the *Flexor Digitorium Superficialis* to the little finger, which is commonly absent.[333] Though the absence of these structures has a negligible effect on the execution of most daily tasks, for an activity as physically complex as piano-playing, the effect may be more significant, and thus how it affects pianists deserves to be studied further. Because of the inherent redundancy in the intrinsic muscles of the hand and the extrinsic muscles of the forearm, one would think the absence of these structures would impact the degree of freedom available for more efficient movement and hence improve technical efficiency.

Neurologically, the hands are one of the richest areas of nerve endings in the body, which comes into play, quite literally, for pianists from both sensory and motor aspects. As it relates to the brain, the hands are assigned the largest area of brain mass of all the areas of the body at it is the most complex motor and sensory area. From a

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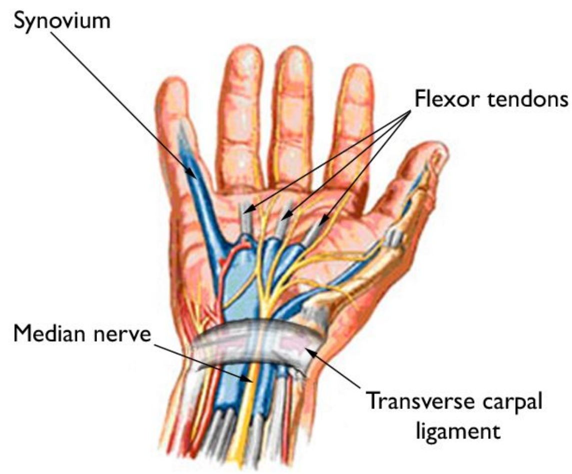
[332] Retrieved from https://en.wikipedia.org/wiki/Palmaris_longus_muscle
[333] Oatis, Kinesiology, 301.

movement standpoint, the hand has an infinite number of combinations of movement available to it, so the brain must be able to initiate these possibilities. The complexity of hand function is crucial, separating us from every other mammal. The fact that pianists get to develop this complexity more than any other group deserves special attention from both pedagogues and scientists – particularly from a neuromechanical and cerebral cortex development standpoint. One of the biggest gaps in our field is the absence of a working vocabulary to describe a majority of the movements and the internal skeletomuscular sensations we experience when executing piano-playing. Only the Taubmann pedagogy has attempted to develop such a standard of terms describing movement. Furthermore, no existing pedagogy to this day has attempted to describe the skeletomuscular sensations. Fields like science and engineering can certainly assist in codifying what we as pianists are already doing.

An understanding of the underlying function of other structures can also help in determining best therapeutic and surgical options. One such structure is the *transverse carpal ligament* (TCL) at the wrist which functions to stabilize the carpal arch and the tendons that cross the volar surface of the wrist within the carpal tunnel.[334]

[334] Oatis, Kinesiology, 343.



xiii. Diagram of the nerves, tendons and other structures of the wrist and hand

For many pianists, tendonitis and carpel tunnel syndrome affects their ability to play without pain and discomfort because of the pressure created by tendons constantly moving past each other, the resulting thickening of the tendon sheaths and the pressure that it puts on the medial nerve within the small space of the carpal arch. The usual medical recommendation is to transect or cut this ligament, thus creating more space for these tendons to move more freely and hopefully alleviate the pain and discomfort. However, cutting the TCL creates two additional problems. Firstly, it allows the tendon to bowstring further into the carpel tunnel thus making it more susceptible to injury because it is more prominent as well as interfering with stable contact between the hand and an object in a firm grasp. Secondly, and more crucially for pianists, this operation increases the range of motion required to pull the fingers through the same excursions pre-operatively.[335] In other words, more muscular effort is required to flex the fingers at the instrument. Such knowledge would assist pianists, teachers and medical professionals in really determining the best medical interventions when needed.

[335] Oatis, Kinesiology, 343.

Once we have this basic understanding of the structure and function of the physiological aspects, we can then see its applications to the field of kinesiology, of which the subdisciplines include biomechanics, exercise physiology, motor development, motor learning, pedagogy and psychosocial development.[336] For our purposes, biomechanics is the main contributor to qualitative analysis of human movement with which this work is concerned. Its applications are two-fold: the improvement of human performance and the reduction or treatment of injury.[337] And the factors that are to be considered in human movement include technique, psychological, anatomical and physiological structure, equipment design and exercise/conditioning programs. [338] On the merits of these aspects alone, there absolutely needs to be a marriage of these two fields. For as pianists and teachers, we are arguably already practitioners within this field. However, in my view, we have been practicing without much of the requisite knowledge crucial to effective practice. There are many principles for the application of biomechanics, but I will focus on the principles that are important to improving our understanding the kinesiology of piano and instrumental playing and performance.

The principle of ***force-motion*** is one such principle. This principle refers to the idea that unbalanced forces are acting on our bodies or objects when we create or modify movement.[339] Force-motion aptly describes piano-playing from the perspective of motion because the object (the piano) and our bodies are simultaneously generating reaction forces in many directions driven by the movements of the playing apparatus (our hands and arms). The force-motion principle in piano-playing has an added layer of complexity because of the reality that our motion is completely irregular as it is dictated in part by

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336 Knudson, Fundamentals of Biomechanics 2nd Ed, 4.
337 Knudson, Fundamentals of Biomechanics 2nd Ed, 5.
338 Knudson, Fundamentals of Biomechanics 2nd Ed, 6-8.
339 Knudson, Fundamentals of Biomechanics 2nd Ed, 30-32.

the musical score. As we continue to move the forces, magnitudes and directions continue to change. The ultimate goal is to achieve a balance of the best musical performance with the least physical cost to both the instrument and our bodies.

Secondly, there is the ***coordination continuum***. This is the concept that one must determine the optimal timing of muscle actions or segmental motions.[340] A musical performance is largely determined by a musician's coordination of time which generates amongst other things a sense of melodic and harmonic rhythm as well as phrasing and overall structure of a piece. In order to achieve a desired musical outcome, the timing of a musician's muscle actions and segmental motions must be extremely accurate. This principle is also concerned with sequential muscle and joint actions of which *low force-high speed* movements tend to largely consist of. Piano-playing inherently consists of the execution of *low force-high speed* movements within optimal timing constraints. Our understanding of this principle will certainly stand to benefit both fields.

Thirdly, ***segmental interaction*** – the concept that forces acting in a system of linked rigid bodies can be transferred through the links and joints.[341] Certainly, the piano can be considered a rigid body as the human body must work within its physical constraints. The placement of the keys and pedals as well as the overall wooden and metal structure are fixed points within the duration of a performance. The human body, particularly the arm from the scapula to the fingertips, could be considered a system of linked rigid bodies that we manipulate to various levels of fixation and relaxation in order to transfer force, generated by weight or muscular contraction, to the keys to produce sound. Understanding efficient force transfer through these linkages as well as the

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[340] Knudson, Fundamentals of Biomechanics 2nd Ed. 33-34.
[341] Knudson, Fundamentals of Biomechanics 2nd Ed, 34.

generator of these forces within a musical situation would be immensely beneficial to the well-being of musicians and curtail a lot of potential injuries from developing.

In addition to the observation of these principles amongst others, there are also other important subtopics that bear mentioning. **Anatomy** – the study of body structure**,** for example, is important kinesiologically with respect to anatomical planes and axes.[342] One of the movements pianists are constantly executing is changes of direction. Planes and axes will help us to describe pianistic movements more effectively, which is a start to developing a *movement vocabulary* for pianists. Muscle fiber arrangement also deserves study. The muscle fibers of the forearm for example are *pinnate* - meaning that their inherent design favors force production over range of motion. In piano-playing, an understanding of the variety of muscle fibers that make up the playing apparatus will allow us to intelligently improve aspects of dynamics and tempo. *Muscle synergy* is also important as we use various muscle combinations in the execution of piano technique. Anatomical variation in gross anatomy, muscular architecture and their biomechanical effects on muscle actions and injury risk must also be studied. Studying such variations amongst pianists is important to establishing biomarkers and hence prevent and manage injury.

Musculoskeletal mechanics is another such topic. It is the study of loads and variables in musculoskeletal tissue response to stress, strain and stiffness.[343] *Boneloading* for instance at the intersection of piano-playing could be of particular interest to pianists, scientists and medical professionals. Boneloading or *bone remodeling* refers to the exposure of bones to external forces, such as exercise, that results in greater osteoblast

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[342] Knudson, Fundamentals of Biomechanics 2nd Ed, 41.
[343] Knudson, Fundamentals of Biomechanics 2nd Ed, 70-71.

activity or the laying down of bone.[344] This is why for instance medical professionals encourage people as they move into mid and late life to increase weightbearing activities. In my piano studies, I have had the privilege of studying with two piano teachers who were well into their eighties. While the rest of their bodies appear to take on characteristics of those in their age group, their playing apparatus functions like that of persons decades younger. Many of the greats like Horowitz and Rubenstein also had great facility even in their later years. While the neuromuscular aspects like motor learning play a role, there seems to be a case for the 'exercise' of piano-playing and the forces that the bones experience bearing some responsibility for delaying the onset of arthritis and osteoporosis of the playing mechanism.

The *stretch shortening cycle (SSC)* is another example of the importance of musculoskeletal mechanics in piano playing. The SSC is defined as the countermovement away from the intended direction of motion that is slowed down or braked with eccentric muscle action and immediately followed by concentric action in the direction of interest. This results in potentiation or increase of force in the following concentric action if there is minimal delay between the two muscle actions.[345] Studying this concept within the context of piano-playing is of great utility to all in analysis of the pedagogy on *finger-lifting* for example. *Finger-lifting* inherently describes not only the process of the cycle, but also the reasons for its use. The balance of optimal potentiation and speed is something that deserves study within our context.

Linear and Angular Kinematics, the description of motion in terms of distance[346], velocity (speed and direction) and the description of angular motion[347], is

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[344] Knudson, Fundamentals of Biomechanics 2nd Ed, 76.
[345] Knudson, Fundamentals of Biomechanics 2nd Ed, 88-89.
[346] Knudson, Fundamentals of Biomechanics 2nd Ed, 107.
[347] Knudson, Fundamentals of Biomechanics 2nd Ed, 121.

absolutely crucial. If we as pianists and teachers are ever to understand segmental interaction between the various parts of the playing mechanism and that mechanism as it is in motion at the piano, we must engage this concept as important to expanding our toolkit. This is also where 3D analysis of piano-playing becomes really important. Firstly, many of the movments pianists execute within playing, while somewhat perceptive to the performer, are invisible to the naked eye from both perspectives of speed and direction to teachers and observers. Secondly, of those pianistic motions that are observable, they can only be observed incompletely. Most teachers, for instance, have never observed their students' playing or their own playing from below. 3D motion of a body segment has six degrees of freedom – three linear angles and three linear coordinates. All of these degrees of freedom are executed in performance in order to produce a musical performance. While it might be a stretch to expect that piano studios be outfitted with 3D cameras to capture this motion completely, I believe it is not a stretch for teachers and performers to have access to a space in schools of music or conservatories where this kind of in-depth analysis can occur. Only then, with complete observation of pianistic movements, can teachers begin to offer the kind of technical assistance needed to their students.

Kinematics however, only represent 50% of technical analysis. Teachers also not only need to observe the movements but also determine the cause or the source of the movements they are observing. This is what **Linear and Angular Kinetics** provides – the study of the *causes* of observable motion.[348] With the help of kinesiologists, we as pianists can use *inverse dynamics* – calculations working from kinematics to determine the resulting kinetics of linear and angular motion at the piano. *EMG sensors* attached to

[348] Knudson, Fundamentals of Biomechanics 2nd Ed, 133.

pianists could measure the electrical activity of specific muscles prior to and during specific movements. This is really important because of the muscular redundancy available in piano-playing and the varying efficiency of certain muscles in executing certain movements. It could also help to observe when a muscle could be overworking and a marker for stress and strain. In athletics, *force platforms* are used to measure ground reaction forces and torques of runners in 3D. If we can dare to dream, one day a smart piano with a built-in force platform at the key or keybed level could assist pianists and teachers in much the same way.

In addition to textbooks articulating the physiological and kinesiological aspects relevant to piano-playing, there have also been a number of science articles that have attempted to study aspects of piano performance. Unfortunately, just as in the above aspects already mentioned, such articles are largely not discussed in conservatories or schools of music. Despite this, it is important to shed some light on the research that is being done that could be beneficial to a continued and improved conversation at the intersection of piano-playing and scientific research.

The journal article, ***Hand Biomechanics in Skilled Pianists Playing a scale in thirds,*** is one such important article. In it, researchers found that "Pianists, who attend to the *integral relationship of their particular musculoskeletal characteristics* to the piano technique at hand, discover an efficient path to technical advancement and, consequently, to injury prevention. Thus, a study of pianists' hand biomechanics in relation to different piano techniques is highly relevant, as hand features may influence various techniques in different ways."[349] In other words, the approaches to piano pedagogy should be as varied as the physiological variations from one pianist to another.

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[349] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 1.

In their study, the authors demonstrated how ulnar deviation at the wrist joint positively impacted tempo when playing double thirds. *Pearson Correlation Analysis* showed a positive association between ulnar deviation and tempo; the other biomechanical features showed no relationships with any of the performance criteria. All biomechanical features were closely related to each other with one exception: wrist ulnar deviation was not associated with any other biomechanical features; rather, data suggests possible negative associations. This study underscores the importance of wrist mobility in piano skill development. Further research using a complete set of prototype piano techniques and multiple-level pianist-subjects could provide substantive biomechanical information that may be used to develop efficient pedagogy and prevention strategies for playing-related injuries as well as rehabilitation.[350]

This study also discussed the need for pianists to have biomechanical knowledge in order to achieve their technical and musical ends. It states:

> "Many pianists today are hurried to achieve the end-results, the highest possible level of piano proficiency, often without taking into account their biomechanical characteristics. As a result, they may struggle blindly on acquiring techniques to the point of injury. It is not merely the drive to a high level of achievement coupled with the lack of a thorough basic technical preparation that trigger injuries, but a lack of biomechanical knowledge may cause one to deny the opportunity to develop the utmost efficiency in using their given biomechanical characteristics."[351]

[350] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 1.
[351] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 1.

Pedagogues of the early 20th century had advocated as such and it is of great value to have scientists authenticate what many had previously requested.

Additionally, this study emphasized the non-positive correlations of other factors often emphasized in piano playing. It points to other empirical studies that revealed positive relationships among joint mobility, finger span, and skilled piano playing. However, the role of wrist deviation in the ulnar direction in skilled piano playing had not been considered. Further, the lack of correlations between all hand biomechanics and wrist ulnar deviation and the non-relationship of all hand biomechanics, with the exception of wrist ulnar deviation in playing the scale in thirds, were not anticipated[352]

This study also explored how one develops finger independence biomechanically. It maintained that individuation is developed by whole-arm coordination, conditioning the timing of finger flexion, building the strength of intrinsic muscles between fingers, enabling steady musculoskeletal fixation at the finger joints as well as strengthening the muscles of the forearm, shoulder and upper arm.[353] Previous pedagogues had indicated the importance of coordination or cooperation between the components of the playing mechanism. It is interesting also to learn practically what goes into whole arm coordination.

The need for individual approaches based on the specific biomechanics of an individual is also discussed. Skilled pianists create solutions to different piano technical problems by applying their unique set of biomechanics to achieve proficient performance. To this end, knowing one's hand biomechanics would be very useful in developing efficient skills for various techniques.[354]

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[352] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 6.
[353] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 6.
[354] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 7.

This study questions the '*mind-centered*' approaches in piano pedagogy. Much of piano pedagogy maintains that the essential requirement of skilled piano-playing lies ultimately in the mind. A study of the *mind-body connection* can be further explored as we gain more facts about the biomechanics of pianists and their relationship to skills development. Meanwhile, pedagogues could benefit by considering individual pianist's hand features as they assign appropriate technique and repertoire at various developmental stages in order to ensure efficient skill development as well as injury prevention. Such biomechanical strategies could also be helpful in the rehabilitation of injured pianists.[355]

Finally, the study expressed the desire to put all existing pedagogy through the rigor of scientific analysis. Lee states, "As a postscript, I must profess that science in piano techniques study does not precede the age-old practice of the few well-regarded pedagogues; science helps to affirm the good pedagogy and gives tools to separate the misguided pedagogy."[356]

Though not specifically related to the piano, the study ***Finger Independence: Linking the kinetic and kinematic variables*** explored how forces in the one intended finger also generated forces in other fingers - the concept termed in the field of kinesiology as *enslaving*. Researchers here studied the dependence between voluntary motion of a finger and pressing forces produced by the tips of other fingers of the hand.[357]

Researchers revealed that the force produced by a given finger is also produced by neighboring fingers in the same direction.

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[355] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 7.
[356] Lee, Hand Biomechanics in Skilled Pianists playing a scale in thirds, 7.
[357] Kim, Finger inter-dependence: Linking the kinetic and kinematic variables, 1.

> "Index finger motion caused the smallest force production by the slave fingers. Larger forces were produced by the neighbors of the task finger; these forces showed strong modulation over the range of motion of the task finger. The enslaved forces were higher during the flexion phase of the movement cycle as compared to the extension phase. The index of enslaving expressed in N/rad was higher when the task finger moved through the more flexed postures."[358]

This has implications for all piano-playing and deserves recognition in our pedagogical approach as pianists are constantly generating forces and using a continuum of "flexed postures" in performance. Additionally, it begs the question of the existence of a tipping point beyond which the force generated by a given finger acts to inhibit quality of movement in other fingers and subsequently produce muscular tension.

In another study, ***Strength Training increases training specific multi-finger coordination in humans****,* the importance of potential finger exercises for tasks involving multi-finger coordination, is explored. The researchers found that for all the groups measured, finger strength, measured by the maximal voluntary finger force of pressing four fingers, increased significantly in all training groups.[359] In contrast, however, finger independence also decreased significantly for all the training groups. They concluded that the neuromuscular system adaptations to multi-finger ST (strength training) are specific to the training protocol being employed, yielding improvements in different types of multi-finger coordination (i.e., coordination-specific ST), finger force control, finger strength and a decrease in finger independence. Finger independence, depending on the nature of the task, may or may not be favorable to certain task performances. It is

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[358] Kim, Finger inter-dependence: Linking the kinetic and kinematic variables, 1.
[359] Shim, Strength Training increases training specific multi-finger coordination in humans, 2.

suggested that ST protocol should be carefully designed for the improvement of specific coordination of multi-effector motor systems.[360]

This inverse relationship between strength training and finger independence is a very important finding. Over the centuries, exercises have been developed for pianists in order to improve finger strength and independence. This study sheds light on the fact that while exercises are beneficial to improvements in finger strength, they need to be carefully constructed in order not to hamper the independence factor. Shim supports this and showed that both strength training regimens of four-fingers as a group and single-fingers individually are associated with decreases in finger independence. The greater decrease of finger independence found with four-finger training as compared to single-finger training is an expected outcome considering that simultaneous finger actions during four-finger training encourages positive covariation of finger forces. This decrease in independence with a given exercise protocol is an important factor because finger independence is a critical aspect of the manual dexterity involved in everyday tasks. Typing on a keyboard, for example, requires individual movements of fingers. Considering the negative effects of ST to finger independence, Shim argues that ST may not be beneficial to pianists, guitarists, or professional typists[361]

There are also considerations related to the neural pathways involved. Shim states, "Due to the central and peripheral constraints for independent finger actions, the CNS is required to produce actions of non-task fingers opposing the actions of task fingers to avoid involuntary actions of non-task fingers conflicting with the task finger actions. For example, if a task finger is flexed, the CNS might prevent the flexion of

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[360] Shim, Strength Training increases training specific multi-finger coordination in humans, 3.
[361] Shim, Strength Training increases training specific multi-finger coordination in humans, 16.

non-task fingers by extending them."[362] There exists conflicting pedagogy related to this point. Some advocate for an approach where the fingers are positioned over the keys – whether in a five-finger position or in a chord. Others like Taubman advocate the total relaxation of non-task fingers. Continued research in this direction would bring clarity to which approach is best.

Future studies point to the role of developing the *intrinsic muscles* of the hand to improve independence. The decrease in finger independence appears to be caused by the *extrinsic muscles* with multi-finger insertions because activations of the *flexor digitorum profundus* and *flexor digitorum superficialis* induce simultaneous kinetic and kinematic actions of all fingers. Shim suggests that intrinsic muscle training may be more beneficial for people who play keyboard and string instruments as well as professional typists.[363] Schultz actually advocated that the intrinsic muscles of the hand (termed *small muscles of the hand* in his approach) were best. Shim's continued research in this direction would bring clarity to this crucial question also.

The study, ***The prevalence of playing-related musculoskeletal disorders in relation to piano players' playing techniques and practicing strategies***, is also significant as the researchers in this instance were concerned with the motor skills and practice strategies employed by piano players in relation to playing-related musculoskeletal disorders (PRMDs).[364] Alsop revealed that a disproportionate number of pianists who consider themselves professionals suffer from injuries. A higher proportion of professional musicians (71.9%) reported PRMDs in comparison with 38.1% of

[362] Shim, Strength Training increases training specific multi-finger coordination in humans, 17.
[363]Shim, Strength Training increases training specific multi-finger coordination in humans, 19-20.
[364] Alsop, The Prevalence of piano related musculoskeletal disorders, 1.

respondents who were not professional musicians. Respondents who played with elevated shoulders and maintained a neutral wrist posture were also likely to report PRMDs. Professional pianists were more likely than non-professional players to report PRMDs, while among those who experienced PRMDs, respondents who defined themselves as teachers reported more severe symptoms than did players. Respondents who had played the piano for longest, who practiced for the most hours and most regularly were most likely to report PRMDs.[365] While many of the findings appear intuitive to pianists on the surface there are two areas here that were very striking.

Firstly, the fact that the percentage of professional musicians who suffered from injuries was significantly more than half. This suggests a serious flaw in some aspects of our craft. Secondly, the fact that teachers reported more severe symptoms than players suggests that there are serious flaws in the way piano teaching is approached. These two findings indicate the kind of vicious cycle that continues to occur in the field.
Some of the factors involved in injuries are also discussed in this article. Factors that may contribute to the incidence of PRMDs appear to include biomechanical inefficiency of wrist, finger, elbow and shoulder postures and movements, extremely long hours of practice, and insufficient regard for the characteristics of and structural differences between individual pianos.[366]

Also commented on in this study, is the neglect of *motor skills assessment* in piano examinations. Motor skills are the foundation of piano-playing as the demands of arm, hand and finger movements are enormous. Alsop laments that despite the prevalence of injuries in pianists and teachers, the piano syllabus of the Australian Music

[365] Alsop, The Prevalence of piano related musculoskeletal disorders, 1.
[366] Alsop, The Prevalence of piano related musculoskeletal disorders, 2.

Examinations Board does not assess the motor skills involved in performance. Rather, it emphasizes the musical skills including the speed of playing, evenness of sound, and quality of touch that should be demonstrated during the examination. Alsop admits that such an assessment is difficult as there exists no consensus as to what kind of motor skill or movement technique represent best practices: "Yet an individual's performance cannot be evaluated on the basis of the motor skills that were used at a particular moment to achieve a goal, but only on the musical results of the action." I suggest, however, that the lack of such assessment is a major hindrance and necessary given the data presented here on the prevalence of injuries. Such observation of motor skills development is not just the concern of pianists and their teachers in the early stages but should be a continuous component throughout the lives of pianists and teachers. We should not conduct ourselves any differently from elite athletes who regularly subject themselves to health and human performance analysis.

This study also revealed that there has been no comparative study to show the frequency of injuries associated with a particular playing technique. There is a dearth of scientific information concerning the frequency of PRMDs associated with the use of the traditional and weight playing techniques. Consequently, educators cannot offer evidence-based recommendations regarding piano-playing techniques for the prevention of PRMDs at the present time.[367] Furthermore, little evidence exists to suggest healthy practice strategies that allow optimum training without giving rise to PRMDs.[368] Pedagogues of the past have already commented on the need for this type of study and here it is being reiterated by researchers. Additionally, concern was expressed regarding

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367 Alsop, The Prevalence of piano related musculoskeletal disorders, 3.
368 Alsop, The Prevalence of piano related musculoskeletal disorders, 2.

the lack of technical information available on approaches to repertoire that was written for another keyboard instrument that are now performed on the modern piano. There is no published advice to pianists on how to use different or more economical movements in order to adapt their playing, so that music composed for an instrument with one kind of action can be performed on an instrument with a different kind of action, and/or a heavier piano-key.[369] The concept of *touch-weight* is a critical subject that will be explored in the chapter to follow.

The important of a multidisciplinary approach to dealing with PRMDs was also discussed. Because PRMDs are complex and have multi-factorial etiologies, they cannot be resolved by musicians or physicians alone. It is essential to develop multidisciplinary approaches in order to provide pianists with programs that will help them avoid PRMDs. Such programs involve encouragement to develop healthy practice habits, the promotion of energy-efficient biomechanical motor skills and the early use of effective treatment when necessary. In this way, the incidence of PRMDs in pianists may ultimately be reduced.[370] Such approaches in my view are long overdue. Piano-playing is inherently a multidisciplinary skill. Therefore, it only makes sense that the approach to PRMDs must also be of a similar vein.

Researchers in this study conducted a survey of 503 pianists where data was collected on the various areas of the arm in which injuries were reported. Of all the areas, the wrist was found to be most susceptible. Below is a summary of their findings: *Wrist postures:* There was a significant relationship between playing techniques and

[369]Alsop, The Prevalence of piano related musculoskeletal disorders, 3-4.
[370]Alsop, The Prevalence of piano related musculoskeletal disorders, 4.

reported PRMDs. A total of 349 respondents reported using neutral wrist postures, of whom 47.0% experienced PRMDs. One hundred and eight used traditional, neutral to flexed wrist postures, of whom 30.6% experienced PRMDs. Forty-one reported using the weight-playing technique involving neutral to extended wrist postures, of whom 26.8% experienced PRMDs."[371] This is interesting that the neutral wrist group has more injuries than those employing a flexed or extended wrist posture. This finding supports the notion that wrist mobility is important in piano playing.

Shoulder postures: A significantly higher proportion (52.5%) of the 99 respondents who reported using an elevated shoulder posture also reported PRMDs, compared with the 40.1% of the 394 players who reported using a non-elevated shoulder posture and experienced PRMDs.

Elbow postures: The majority of respondents (a total of 397) reported using a bent rather than straight elbow posture. There was no significant association between elbow posture and experience of PRMDs.

Finger postures : Similarly, the majority of respondents (a total of 437) reported using curved rather than flat finger postures. There was no significant association between finger postures and experience of PRMDs.[372]

Reasons were also postulated as to why an extended wrist posture is less likely to produce injuries. Researchers found that wrist position had a significant effect on the force produced by individual fingers and overall, with the greatest force produced by the fingers when the wrist was extended (lowered) by 20° with an ulnar deviation of 5°. In short, if the wrist is in a position such that the pianist does not have to work so hard, he or

[371] Alsop, The Prevalence of piano related musculoskeletal disorders, 7.
[372] Alsop, The Prevalence of piano related musculoskeletal disorders, 7-8.

she may be less likely to experience PRMDs.[373] This kind of information is of great value to pianists as it has direct implications in their ability to produce varied dynamics more efficiently.

The importance of abduction and adduction of the wrist is also discussed. The wrists not only allow flexion-extension motion, but also abduction-adduction motion. As the pianist's hands move up and down the keyboard, he or she has constantly to adjust the angle of wrist to keys. According to the literature on ergonomics, it is much less risky to maintain the wrist in a neutral position, activating the muscles as little as possible, than to use flexed, extended, adducted or abducted positions. However, this demands constant co-contraction of the forearm musculature to stabilize the wrist joint, which may greatly reduce the speed of piano-playing when movements are required in more than one direction. Moreover, the pianist needs to activate the forearm muscles and tendons when accelerating and decelerating, which uses more energy and can therefore cause fatigue. This may also increase the risk of PRMDs. Circular movements of the wrist and elbow require less energy and enable more efficient use of the hands and fingers when playing the piano.[374] Again, this is very valuable information that needs to be more widely disseminated in the field.

The study emphasized that when pianists suffer injuries, many seek help from their teachers rather than health professionals. Alsop states, "Respondents who reported PRMDs typically experienced pain and aching in the wrist, hands and fingers. Fewer than half sought help – the majority from their teachers, although teachers were the most

[373] Alsop, The Prevalence of piano related musculoskeletal disorders, 12.
[374] Alsop, The Prevalence of piano related musculoskeletal disorders, 12-13.

likely, of the three groups surveyed, to experience PRMDs themselves. It may well be the case that pianists lack confidence in medical practitioners and are therefore reluctant, when injured, to seek medical help in the early stages of PRMDs, which can cause difficulties in evaluating and eradicating the problem."[375]

Experienced piano teachers may know that certain playing postures should be used to prevent possible strain arising from the use of particular piano techniques. They may not be sufficiently familiar with anatomy to understand how they work mechanically, or why they are more efficient in terms of saving energy. Piano teachers may recommend methods for preventing and managing PRMDs based on their own experience, rather than research-based evidence. After all, music education curricula do not require piano teachers to understand or even recognize PRMDs. For these reasons, most teachers have only a limited ability to advise injured players effectively. Medical practitioners and physiotherapists may be able to treat symptoms but, unless they know how players can employ motor skills to perform specific piano techniques with maximum economy, they are ill-equipped to offer practical advice for preventing further injuries.[376] Alsop's statements clearly articulate the knowledge gap that exists between musicians and medical professionals. I believe it is an intersection that they, along with piano technicians and human performance scientists, can contribute to that would be a groundbreaking new field of study – the Science of Artistic Expression.

Finally, and related to the input of piano technicians, the study postulates exploring *types and models of pianos* as a marker for potential injuries. Alsop states, "It

[375] Alsop, The Prevalence of piano related musculoskeletal disorders, 15.
[376]Alsop, The Prevalence of piano related musculoskeletal disorders, 15.

was not possible to investigate a further potential factor underlying PRMDs: the differences between various models of piano used in daily practice."[377] This is especially important in modern times as certain models of piano are preferred. And each, while similar in the overall mechanics have peculiarities that impact the biomechanics of piano-playing.

Though not technically a research study, the article ***Establishing a biomechanical basis for injury preventive piano pedagogy*** is important because it emphasizes the importance of a multidisciplinary approach to piano injuries and brings much of the existing literature into context. Russell, in this article, emphasizes the need for a broad multi-disciplinary approach and the roles that musicians, medical professionals, experts in biomechanics and piano technicians have in establishing a basis for injury preventative piano instruction are presented. Both the piano and human hand are very complex systems. Several areas of current investigation in biomechanics that are relevant to establishing a basis for piano pedagogy that results in injury-free playing are summarized. These areas include clarifying the impact of geometric and muscular redundancy, limb biomechanics, keyboard mechanics and neuromuscular control on playing the piano.[378]

While emphasizing the importance of how our bodies are affected in piano playing, it also emphasizes understanding the interaction with and the action of the instrument as well. Russell states, "The biomechanical circumstances that give rise to these injuries are complex and the differences between playing techniques that allow these injuries to occur and those that prevent injuries may be subtle. The action of playing

[377]Alsop, The Prevalence of piano related musculoskeletal disorders, 15.
[378] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 1.

a piano involves the interaction of a mechanical device (the piano action) and a biomechanical system (the human arm)."[379] The considerations regarding the 'mechanical device' are not even addressed by most. It certainly was not addressed in my educational experience at any of the musical institutions I attended. However, I do not believe I am unique in that position as I believe my experience echoes that of many pianists studying at the highest levels.

The fact that pianists do not often speak about their pain or injuries is also problematic. Researchers found that injured musicians are not always willing to admit their injuries for many reasons. These include the fear that widespread knowledge of an injury may impact their careers as well as concern for the reaction of their teachers. Researchers found it difficult to identify the numbers of these injuries that simply go unidentified and untreated. They suggested that some are hesitant to report pain or injury due to a fear of physicians and hospitals.[380] I recall the experience of a pianist I met who was also studying the Taubman approach as a result of injuries he had suffered while studying at a renowned conservatory in Ohio and had to take the semester off. He indicated that his lessons were a last-ditch effort to revive his performing aspirations before he was dismissed from the conservatory. Thankfully, he was able to heal and resume his studies. His experience, though, represents the battle pianists have, often with little support physically or morally. In further support of this issue, researchers examined university-level music students and found that only 13.1% of pianists suffering from injuries asked for medical care. It is a sad state of affairs that pianists are not seeking assistance from the sources best able and equipped to provide it.

[379] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 2.
[380] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 2.

Though the source of pain in piano-playing is varied, the most common source of pain was tendon inflammation. Researchers examined the different types of hand pain experienced by a group of 200 pianists and found that pain due to tendon inflammation was found in 28% of the cases, enthesopathy was found in 24.5% of cases, and muscle pain in 19% of the cases. Neurological problems (including dystonia) were found in 14% of the patients, finger joint pain in 11% of the cases and neck pain or pain in the torso in 2.5% of the cases. It is also suggested here that the pain is often the result of hyper-abduction of the thumb and little finger as would be required in playing large chords. Similarly, the impacts of injury in piano-playing are varied and can affect many aspects of the pianists' life as well in society as a whole. Russell stated, "The injured pianist may suffer from loss of control (34%), a diminished facility in playing (18%), reduced endurance (18%), or reductions in the maximum speed (18%) when executing fast, forte passages."[381]

Surgery has become an important consideration in addressing injuries. "Of serious injuries requiring the consultation of a hand surgeon, surgery was proposed for about 19% of the patients in an attempt to address the problem." [382] Differentiating between injuries happening to individuals early or later in their studies is also to be considered. "Remember that these injuries are happening both to individuals early in their piano studies as well as to those who have trained for many years under the private tutoring of accomplished musicians."[383]

Russell outlines the role that four fields can play in addressing the challenges in piano-playing:

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[381] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 4.
[382] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 4.
[383] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 5.

Musicians. Any study of the injuries that result from playing the piano must be done with a full appreciation of the art and those who teach it. The words we use to describe piano technique and approaches to specific technical challenges often imply body movements in an imprecise way (from the point of view of an engineer). A thorough understanding of pedagogical approaches and the various schools of piano technique is required in order to make progress in understanding the biomechanical implications of the movements. The nature of the relationship between student and teacher is an important link in the chain that may lead to injury.

Medical professionals. Various groups of individuals within the medical profession serve as the primary sources of care for injured pianists. These people that see and treat large numbers of these playing-related injuries have a unique perspective on possible relationships between causes and injuries. Their expertise goes beyond the statistics describing the rates of occurrence of these injuries. The collected anecdotal evidence that they possess can play an important role in gaining the required understanding. It is important to note that in most cases medical professionals are called upon only after an injury has occurred.

Biomechanical engineers and neuroscientists. Any study of human movement requires developing and understanding of the body as a complicated biomechanical system. The relationships between the motion of a limb, the muscles which cause the motion and the complex system of nerves that control the motion are mathematically involved and many counter-intuitive results arise from the analytical and experimental study of these relationships. These issues are all the more difficult in the case where the limb comes into contact with an object which, in this case, is the piano key. Muscle and tendon properties are far more difficult to understand than typical engineering materials.

These areas of study are progressing rapidly and are of critical importance in order to provide a solid biomechanical foundation for the development and presentation of sound approaches to piano pedagogy. Errors, misconceptions and a lack of awareness of these issues are common in the pedagogical literature4.

Piano technicians. We must not forget the important role of the piano itself. Changes in regulation of the piano may make a significant impact on the approach an individual may have to playing that piano. Piano technicians (and piano manufacturers) deal not only with the technical requirements of keeping instruments in good working order but in adjusting them to suit the demands of students and performers. They too have an extensive base of empirical, if sometimes anecdotal, knowledge which should play a role in the research.[384]

Defining the motion of the fingers and by extension the whole playing apparatus is important to our understanding of piano-playing. While the key motion is mechanically well-defined, the motion of the finger that causes it is not. Not only can the finger take on a variety of shapes during the motion but the different joints in the finger can be moved differently to create the depression of the key. Beyond the finger, the wrist, elbow, shoulder and the rest of the body can all contribute to the motion that results in the depression of the key. These motions are not random but are the result of the pianist's choice of technique and posture. Each configuration will place different loads on the joints and ligaments, will require different sets of muscles to create the motion and will place different requirements on the concentration and skill required to produce the movement. The different movements may all create an identical tone. The differences

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[384] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 5-6.

between the movements are thus critical in examining the demands on the performer and possible injuries that may result.[385]

Understanding the musculature and joints of the arm are important. Unlike typical robotic systems, the human arm has many more muscles than degrees of freedom in movement. In addition to the complexities inherent in muscle as an actuator, muscles also have complex geometric relationships to the motions of the joints that they move. Another challenge results from the fact that most muscles generate more than one movement. This is especially true of many of the muscles that move the fingers. As they also pass the wrist, their contraction will also tend to cause the wrist to bend. This must then be counteracted by other muscles. Not only do single muscles cross multiple joints but in some cases, they move multiple fingers. While these anatomical features are well documented, the mechanical implications of these facts are complicated and in many cases counter-intuitive. Careful examination of various playing techniques is required to assess the impact of muscular redundancy on their likelihood of resulting in injury.[386]

We also see the need to consider the concept of relaxation in piano pedagogy. In order for any joint to move in both directions at least two muscles are required — one to extend the joint and the other to flex the joint. In biomechanics, this is referred to as an *agonist-antagonist pair of muscles*. The ability to move in both directions is one of the reasons for the muscular redundancy outlined above but a second, perhaps more fundamental mechanical attribute can be affected by this muscular redundancy - the stiffness of the joint (or joints). In many schools of piano technique, the stiffness of the limb is to be minimized — a relaxed and flexible wrist is generally considered ideal.

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[385] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 8.
[386] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 8-9.

This goal of relaxed movement has complex biomechanical implications. Muscle properties are such that, even when no neural input is activating a muscle, a force is required to change its length as a result of its passive stiffness. "The mechanical and geometric configurations of the muscles and joints of the arm and hand mean that in considering the muscular requirements for a given movement, the entire arm and the inter-relationships between all muscles must be considered. The implications of these facts can, again, be quite surprising and counter-intuitive."[387]

The neurological aspects of piano-playing add yet another layer to this complex activity. Once a desired movement is recognized, the brain, based on past patterns of behavior, complex inter-relationships between past and future movements, and many other issues, selects the muscles that will create the movement. The manner in which this is done is another current and challenging area of research that must be considered when evaluating various technical approaches to piano performance. Transmission of the neural signals from the brain to the muscles in the arm takes time as does the transmission of neural signals from sense organs in the hand or from the ears back to the brain. These delays depend on the muscles and senses involved but the total delay between the brain sending a command to a muscle and sense organs making the brain aware of the result of that command is at least 1/20 of a second and can be as high as 1/5 of a second. Whatever the precise delay time after the brain issues a command for a particular note, many other notes can be played before the brain is aware of the results of playing the first note. From a control engineering point of view, this dramatically

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[387] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 9.

increases the complexity of understanding how the brain might be controlling these rapid movements.[388]

Russell also outlines five areas where our understanding must advance. He states, “The mechanics of the piano and the biomechanics of the human limb can each form the basis of a complex field of study. In particular, in order to understand the links between technique, pedagogy, performance and injury in pianists it is important to:

1. Advance our understanding of the mechanics of the piano action;
2. Study the wide variety of limb configurations and their impact on the biomechanics of depressing a key or sequence of keys;
3. Study the impact of muscular redundancy on overuse injuries, and in particular, to examine various schools of piano technique in terms of their ability to take advantage of muscular redundancy;
4. Study the impact of muscular redundancy on limb stiffness in the context of technical requirements, and;
5. Consider the implications of neuromuscular control issues on the resulting motions and muscular contractions.”

Each one of these areas is challenging. Much is already known about these areas individually, but considerable research is required to integrate and understand all of these aspects of the biomechanical performance of the arm and hand in order to more completely assess the relative merits of various approaches to playing and teaching the

[388] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 10.

piano.[389] It is indeed a challenging endeavor but one that is necessary to bring piano-playing and pedagogy into the modern era and out of the same age of antiquity as much of the repertoire we perform.

The study, ***Avoiding Piano-related Injury***, is interesting as it looks into this whole area from the standpoint of techniques actually used by pianists. Drawing upon established quantitative data, this study took a qualitative approach in describing and analyzing the execution of selected piano technical tasks.[390] In this article, Wristen emphasizes the importance of analyzing movement patterns as crucial in determining appropriateness of movement. Undertaking systematic qualitative analysis of movement patterns performed at the piano can offer valuable information in developing or modifying piano technique. In developing technique, students and teachers have typically relied primarily on recommendations of skilled performers. However, advice offered by individual players is most often based on individual subjective experiences. Though such recommendations may prove helpful, in many instances they may actually be counterproductive to the development of biomechanically appropriate piano technique.[391]

Collaboration with the disciplines of ergonomics and biomechanics can prove invaluable. With input from these recently developed sciences, it is now possible to examine piano technique in order to determine how the human body may be used maximally and most efficiently. Since medical, biomechanical, and ergonomic studies have theorized that some physical motions, most notably extreme wrist motions, can

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[389] Russell, Establishing a biomechanical basis for injury preventive piano pedagogy, 11.
[390] Wristen, Avoiding Piano Related Injury, 2.
[391] Wristen, Avoiding Piano Related Injury, 2.

contribute to the development of an injury, it is worthwhile to examine piano technique with the possible aim of minimizing these motions.[392]

This study argues that the utility of templates from athletic performance can prove useful to piano-playing. Wristen states that "A procedure for using these norms in conducting a qualitative biomechanical analysis of an individual pianist was adapted from a procedure established by J. R. Higgins' for the observance and description of an athletic performance. While Higgins's method is somewhat dated, it has long been widely accepted as a basis for visual biomechanical analysis and is readily adaptable to the task of playing the piano."[393]

As demonstrated in previous studies explored here, injuries can have their basis in a wide variety of factors and Wristen argues that some of those factors could be inherent. "An injury is not necessarily the result of inappropriate technique. Individual genetic predisposition toward injury plays a central role in injury development; some individuals simply seem to be injured more easily than others."[394] This is an interesting point to be considered when exploring injuries in piano-playing. One possible interpretation could be that the ratio of people genetically predisposed to injury who are also pianists is statistically significant when compared to the general population. That would in turn lead to a host of other possible areas of exploration beyond the realms of piano-playing.

As already emphasized in previous studies, the relationship between experience and injury is to be considered as well. Wristen states,

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[392] Wristen, Avoiding Piano Related Injury, 2.
[393] Wristen, Avoiding Piano Related Injury, 3.
[394] Wristen, Avoiding Piano Related Injury, 3.

"Hillberry and others have demonstrated that *keystrike force* is lower for more experienced pianists than for less experienced ones. As the player progresses on the learning curve, he or she may be less vulnerable to injury, as motion patterns become less erratic. This observation might be true not only in terms of years of piano-playing experience, but in terms of the player's learning curve for a particular piece of music regardless of playing level."[395]

Developing a checklist for the visible and the invisible sensations is crucial for effective piano pedagogy. It is important to note that these checklists describe *observable motion only*. They cannot provide, in and of themselves, information about how *production of a certain motion feels* to the player. Visible motion is one outward sign of a healthy piano technique, often being produced by much finer, more minute muscular reactions. Thus, these checklists cannot be used prescriptively in the teaching of a skill. In fact, instructing a player to consciously produce these visible motions can actually produce inappropriate physical tension. Piano pedagogy must concern itself with discovering methods to transmit this deeper, internal mastery of physical motion.[396]

Related to the importance of developing checklists, Wristen emphasizes the importance of using *qualitative studies* in analysis of piano-playing. Instead of directly measuring and quantifying data, qualitative studies seek instead to describe and analyze the quality of movement. Such qualitative analysis can be used very effectively in examining piano technique. In order to conduct a qualitative analysis, basic knowledge of involved human anatomy and mechanical principles is necessary, as is a thorough understanding of the motor skill or movement pattern to be analyzed. Unfortunately,

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[395] Wristen, Avoiding Piano Related Injury, 4.
[396] Wristen, Avoiding Piano Related Injury, 4.

pianists are not generally experts on biomechanics, and biomechanicists/medical practitioners are often not experts with regard to the subtleties of piano technique. These checklists were designed to be used as general guidelines for visually examining a player's technique, representing a practical "middle ground" between the worlds of music and medicine.[397]

Observing movement in *various planes of motion* is important. Since movement patterns involved in executing skilled movement at the piano often occur on multiple planes, it is necessary to observe movement in all the involved planes. In the case of piano performance, motions are made in the *frontal, sagittal, and transverse planes*. Most of these motions may be observed from the side of the player at the level of the keyboard, or from above looking down on the hands on the keyboard.[398] Wristen states,

> "The observer may need to focus attention on a specific small part of the anatomy or concentrate on larger areas. Attention to eye movements of the performer may also yield helpful information; a movement may be uncoordinated simply because the performer is not looking at the right part of the keyboard. Another factor to consider is the number of trials or executions of the movement, which should be observed before an analysis is undertaken. Highly-skilled performers may vary little from performance to performance, but less-skilled performers typically have high variability. The greater the inconsistency in the performer's technique, the larger the number of observations that should be made."[399]

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[397] Wristen, Avoiding Piano Related Injury, 4.
[398] Wristen, Avoiding Piano Related Injury, 5.
[399] Wristen, Avoiding Piano Related Injury, 7.

As the pedagogues discussed have previously pointed out, Wristen contends that to correlate *level of skill in performance* of a pianist with the *level of analysis of their skill* is problematic. Though skilled performers are usually better equipped to analyze the quality of a performance, this is not always the case. The best pianists do not always make the best teachers. Instead of relying solely on personal experience, the piano teacher should consider relevant biomechanical and ergonomic considerations in teaching piano technique.[400] Many schools of music and conservatories would do well to remember this in their selection of both students and teachers.

Also, Wristen discusses the challenge of the inability of a skilled pianist with their ability to give verbal feedback to their teachers. Perhaps the most important source of information is the performer himself or herself. Since only the performer knows how a movement feels, his or her feedback is invaluable. However, it is important to note that not all performers are sufficiently kinesthetically attuned to their bodies to provide meaningful feedback. Moreover, learning a new skill often involves a certain degree of incoordination due to unfamiliarity, but this incoordination or discomfort should not be confused with actual physical pain.[401] Part of the challenge with pianists and teachers is the lack of a working vocabulary of both injuries and biomechanics in order to describe what is occurring physiologically - especially the tensions and discomforts that are invisible to the eye.

Wristen gives some proposed parameters for checklists with considerations for hand size, tempo and physical comfort. The first is that the checklists may be used to analyze the movement pattern either as it occurs in an isolated technical exercise, or

[400] Wristen, Avoiding Piano Related Injury, 9.
[401] Wristen, Avoiding Piano Related Injury, 9-10.

within repertoire as long as the passage has the same skill parameters as that described in the checklist. The second consideration is that hand size will affect motion at the piano, most notably, lateral adjusting motions effected by the wrist. In general, the smaller the hand, the greater the required degree of radial and ulnar deviation. A third factor to consider is that variations in tempo will affect observable motion. In general, the slower the tempo, the more pronounced and visible the motion. When executing the movement pattern at a faster tempo, the same motions are usually still present; however, the motions become smaller and sometimes even invisible. Fourth, sometimes attempting to think about and to consciously integrate a motion can actually increase tension. In working toward a desired sound or movement, it is essential for the student to always remain conscious of physical comfort.[402] While there are challenges within these proposed parameters and this articulation of them is nowhere near exhaustive, developing such a checklist is a sound beginning to providing piano teachers and pedagogues with the tools useful within lesson or masterclass settings. Wristen's work is a good beginning to giving teachers the kinds of tools we need in the field.

All these articles have helped to demonstrate what a wealth of knowledge is available in the scientific community that is of direct relevance to our field, while in turn, studying the physiological aspects of piano-playing can greatly benefit the sciences in their efforts to improve their understanding of human neuromechanical function. It is my hope that we can begin to understand the ways in which both fields can benefit and, as a result, develop significant linkages between what has traditionally been separated.

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402 Wristen, Avoiding Piano Related Injury, 10.

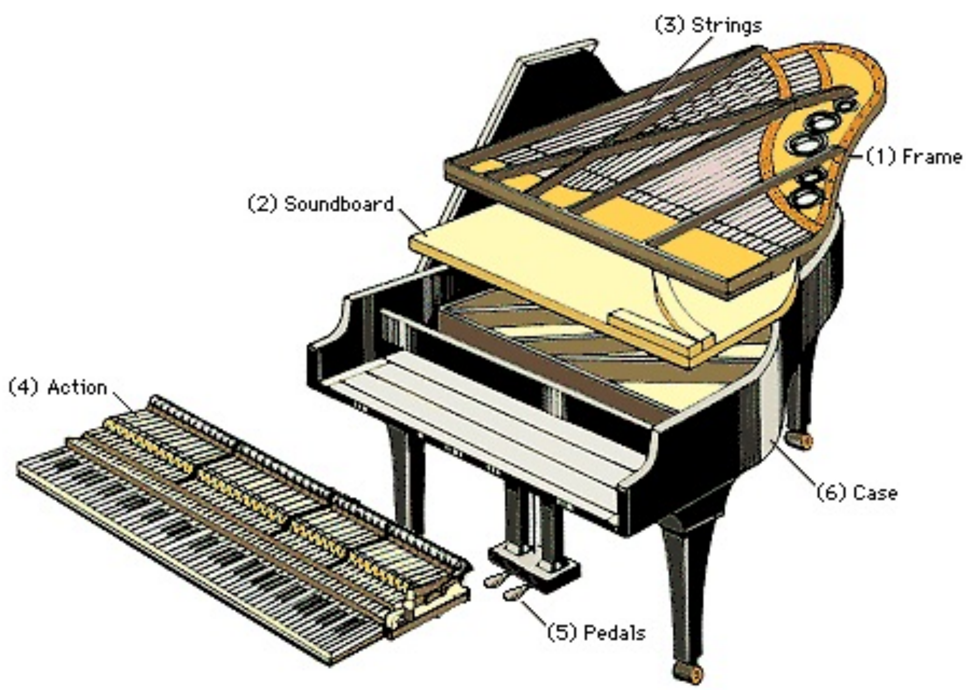
Chapter 6: Piano Technology and Piano Playing

One of the areas almost completely overlooked in piano pedagogy is the size, structure and mechanical function of the piano and its impact on piano-playing. More than any other instrument, pianists sadly seem to be the least attuned to their instrument. String players are involved in the tuning, bow maintenance and string care. Woodwind and brass players are knowledgeable in the oiling, tightening of screws, making of reeds and care of mouthpieces. In both cases, their connectedness to their instrument goes far beyond their technical and musical goals.

On the other hand, the vast majority of pianists do not have a complete understanding of the device upon which their artistic expression depends, its possibilities and its limitations. I also believe that the fossilization of traditions in piano performance and pedagogy have played a major role in retarding any potential progress in the expansion of not only the pedagogy, but also of the instrument itself. Additionally, and perhaps more controversially, I think the modern piano itself – its structure and function, has played a role in both the challenges of technique and the prevalence of injuries.

Before going into what has been done in the past and identifying what should likely be corrected, it is important to take a look at the structure and function of the modern instrument itself. I am grateful that my experiences at the Peabody Institute of Johns Hopkins University and the University of Maryland in their respective Piano Maintenance departments have given me a rare view into the inner workings of the instrument. I believe that every pianist should have an understanding of the instrument, both in performance and technologically.

There remains much debate as to whether the piano is a string instrument, because it possesses over 200 strings, or, in actuality, a percussion instrument because of the hammer mechanism used to produce sound from those strings. Regardless, because of the combination of both strings and hammers, the piano is arguably the most complicated of musical instruments, consisting of over 2500 parts. I will not endeavor to comment on all of the parts. Rather, I will focus on the major parts that I believe pianists should be aware of.



[403]

xiv. Diagram of the piano's gross anatomy

[403] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/

The **Frame**, also called the plate or harp, is made of cast iron and supports the tension of the strings.[404] The amount of pull or stress exerted by the strings is enormous, ranging from 18 tons on an average upright to almost 30 tons on a nine-foot concert grand. Positioned right below the frame is the **Soundboard**. Without this structure, the sound of a string vibrating would be pretty feeble. This large, thin wooden diaphragm is glued around its perimeter, functioning similarly to the *soundpost* in a string instrument. The soundboard is usually made from Sitka spruce, planed or smoothed to about 3/8" thick.[405] This wood has just the right balance of stiffness and flexibility to effectively transmit sound. The soundboard is also crowned or bowed slightly upward towards the strings which helps it to maintain compression. This makes it more vibrant and keeps it from caving in under the pressure from the strings. **Strings** are the most numerous component in the piano, possessing over 200 in a piano. Each treble note usually has 3 strings, the upper bass notes have 2, and the lower bass notes have only 1. This is because the higher notes are made of thinner and shorter strings. Treble strings are made of steel. Bass notes have a steel core, with a copper winding that allows the string to vibrate freely while having enough thickness to produce the low note. To conserve space and fit the longest possible bass strings into a cabinet, modern pianos have the bass strings crossing diagonally over the treble strings.

[404] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/

[405] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/

xv.. Photo showing the range of string lengths and quantity for each note

The sensitive inner mechanism of the piano which translates all the nuances of piano playing to the hammers that hit the strings is called the **Action**. This is the critical part that pianists interact with directly to produce sound. Each piano key is connected through a series of levers and other moving parts on which there are 25 points that can be adjusted individually. The speed of touch that a pianist uses alters the functions of each point of adjustment on the action. Understanding the cycle of the action mechanisms is essential for evenness, speed, power and control. These work together to produce the quality of sound a pianist desires when playing one note.

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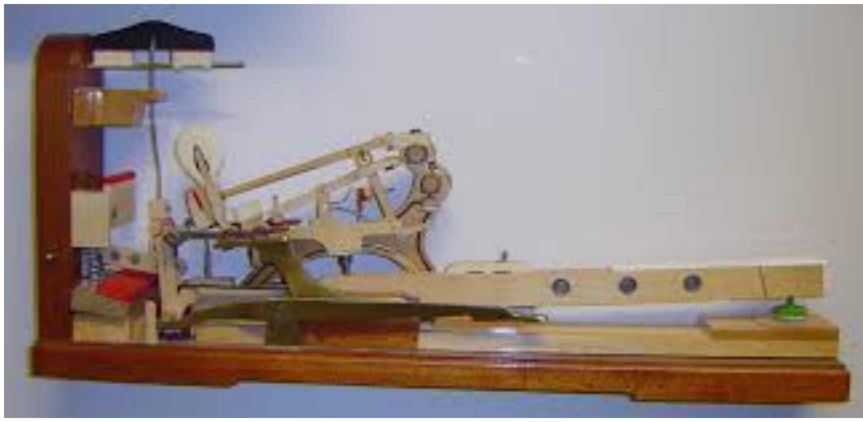
[406] Retrieved from http://www.pianoren.com/piano-glossary/


[407]

xvi.. Photo of the action of a single key

On the action as a whole, there are many thousands of parts consisting of materials like wood, paper, cloth, felt buckskin, brass, plastic and steel that must work together in a precise chain reaction, with accuracy as high as a thousandth of an inch.[408] For this reason, physical adjustments are necessary to allow the moving parts of the piano mechanism to cycle properly and thus optimize touch response and tone. These physical adjustments, termed *regulation*, are essential to facilitate the evenness, speed, power and control of pianists. These adjustments must be made to compensate for wear, compacting of cloth and felt, and changes in wooden parts due to atmospheric conditions that come most noticeably with the change in seasons.

Connected to the action are the **Pedals.** Pianos usually have 2 or 3 pedals that perform special operations like sustaining or softening the sound of the piano. They are connected to the action by a series of levers, dowels and springs called the *trapwork*.[409] Considered to be part of the piano action, they too need to be regulated in order to

[407] Retrieved from http://www.kungfubrothers.com/pianoactionmodels.html
[408] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/
[409] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/

function properly. The **Case**, the rim of a grand piano, is the wooden framework to which the plate is bolted, and the soundboard is glued.[410] The rim is in 2 parts: the inner rim and the outer rim. The plate and soundboard are attached to the inner rim. On some of the best pianos, the inner and outer rim are made as one piece to provide a stronger foundation for both structure and sound. Other pianos add the outer rim later. Different manufacturers use different woods such as laminated maple, spruce and beech.

The **Pinblock** is a laminated plank made of a hardwood such as maple or beech that runs the width of the piano and is attached to the plate and inner rim. Embedded in holes in the pinblock are steel tuning pins, around each of which is coiled one end of a piano string.[411] The pinblock has to hold the tuning pins tightly enough by friction alone, so that the strings maintain their proper tension without slipping and hence losing the correct pitch of the string. Overtime, adjustments are made to the pins to 'tune' the piano. The strings pass over **Bridges**. There is a long curved one for the treble and a shorter one for the bass strings which transmit vibrations of the strings to the soundboard. Steel bridge pins are driven into the bridges to keep the strings in place, to aid in sound transmission and to cleanly terminate the vibrating portion of the string - much like a guitar player's finger would press down on the fretboard.[412] The other end of the string terminates at the plate near the tuning pins. Most bridges are made of maple or beech, either solid or laminated, sometimes with a top layer, or cap.

Despite this seemingly optimal construction, there are many challenges with its current construction that have a direct impact on the performance and health of

[410] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/
[411] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/
[412] Grand Piano Construction, Retrieved from http://www.concertpitchpiano.com/

musicians. The first aspect is the intersection of keyboard shape with human joint movements. Both the keys and the keyboard of any piano are rectangular in structure. This means that in order to play the keys on the piano, pianistic movements are largely limited to linear movements. However, the joints of the body are constructed such that the movements are curved or changing. Rectangular movement requires the coordination of and tension at various joints in order to main these lines. Such movement uses the ligaments and muscles in a way that is not directly related to sound production and overtime could lead to pain and injury.

Let's look at the example of reaching the outer ranges of the keyboard. In order to play the extreme reaches of the piano, the wrist joint undergoes extreme adduction and the elbow extreme extension. The shoulder, as a result, holds the weight of the entire arm and strongly contracts in order to support the arm between notes. It also serves as the pivot from which playing can occur which is another mechanism entirely. From my experience, it is not a position that can be sustained without significant metabolic and physical costs which could ultimately lead to pain and injury, particularly over a period of decades. If, however, the keyboard was curved in shape, it would allow the playing apparatus to move outwardly at the shoulder joint. Little wrist movement would be required to maintain the position, and the elbow would become the pivot from which the hand and forearm can move into the keys. Since the piano's creation by Christofori in the early 1700s until the early 20th century, the technology of the piano was consistently advancing. Then it just seems to stop, as there appears to have been no notable advances during the last 100 years. Indeed, as recently as 1965, Marguerite Long was championing Monique de la Bruchollerie's 'curved keyboard' with the extreme reaches brought within easier reach of the hands.[413] And though this innovation was and still is not accepted in mainstream circles, the 'curved keyboard' concept is certainly based in sound ergonomics and many pianists would benefit from this– particularly from an injury-prevention perspective.

Secondly, the size of the individual piano key is also problematic. One of the biggest reasons that, in my view, advancement in piano technology should be further along is the knowledge of how joint mobility and ability to stretch plays into success in playing an instrument of a standard size. The three physiological determinants, therefore, of adaptability of the hand to the keyboard stretches are: length of finger, width of hand, and the angles of abduction among all fingers. *Finger abduction* in this case refers to the spreading or stretching of the fingers.[414] The dimensions of the keyboard and the manner in which composers have written for the piano are such as to make the stretching of the necessary distances a challenge for even normally full-grown hands. The narrow hand necessarily uses greater spread of the fingers, and thus increases the difficulty of flexing the fingers, since flexion and abduction are in at least moderate physiological opposition.[415] Also, as indicated earlier, difficulties of technique may also frequently be traced directly to a narrow range of movement in some joints due to the articulation of the joint or the flexibility of the tendons. Many hands with sufficient stretch to command an octave easily, cannot stretch because the angle of abduction between 4 and 5 is too small.[416]

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[413] Gerig, Famous Pianists and their Technique, 496.
[414] Ortmann, Physiological Mechanics of Piano Technique, 311.
[415] Ortmann, Physiological Mechanics of Piano Technique, 312.
[416] Ortmann, Physiological Mechanics of Piano Technique, 319.

For roughly 100 years, there has been a ‘one size fits all’ approach to the piano keyboard, despite the wide variation in hand sizes within the human population. Much of the literature relating hand size to piano-playing is in the performing arts medicine field, identifying small hand size as one of the possible causes of pain and injury among pianists. I believe the lack of consideration of hand size has affected piano construction. Pianists with larger hands never really know what the difficulties of their small-handed counterparts are, and the smaller-handed pianists never really find out how much easier all the difficulties are with larger hands. This is because small-handed people never wake up the next morning with larger hands and the larger handed people have never experienced the difficulties of smaller-handed people. Their hands were already big enough long before they were attempting repertoire that was challenging enough to reveal the advantage of larger hand size.

Some manufacturers have experimented with 7/8 size keyboards and the reports are seemingly positive. Adopters of these *reduced-size keyboards* report relief from pain and tension, and other benefits, such as improvements in specific technical and musical skills, faster learning times, and greater comfort and security.[417] This would bring the piano in line with many other instruments who recognized early on in their development the need for different sizes in achieving pedagogical and musical success. Yet again, this technological development has not been widely accepted by mainstream pianists, teachers and music institutions even in the face of evidence of the benefits of a modified approach to instrument construction. Many in the field, whether actively or passively,

[417] Boyle, Hand Size and the Piano Keyboard, 1.

continue to hold fast to the technological traditions of the past - no matter how counterintuitive they are to the performance and health of pianists.

My third challenge with the instrument has to do with the action – particularly with its regulation. Over the past 100 years, pianists and teachers have grown to accept the peculiarities of the instrument's setup as standard and interconnected. Three of these peculiarities I will highlight here. One such reality is the fact that the keys get heavier as the size of the instrument increases. Termed as *touchweight*, every key on the piano has lead weights in them – embedded in the side of the wood underneath the keytops to counterbalance the weight of the hammers they lift.[418]

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xvii. Photo of the weights embedded within a piano key

Because pianists vary in both physiology, speed and strength, what is comfortable for one pianist is akin to running underwater for another. Yet many pianists are being forced by virtue of playing on an instrument of 'standard weight' to endure playing under less than optimal conditions for their physiology and kinesthetics. An athlete lifting weights would never lift a weight beyond what they are capable of and expect to come out of that experience unscathed. A runner would never put the treadmill speed beyond

418 Bean, Touchweight, Retrieved from http:// www.pianofinders.com/educationa/
419 Retrieved from http://forum.pianoworld.com/ubbthreads.php/topics/1264192/heavy-touch-weight.html

what they are capable of running. Yet consistently in our aims to achieve desired artistry, we endure incredible muscular tension in the hands and arms. Pianists should have instruments regulated to their individual comfort levels. Music institutions and concert halls should have instruments of varying *touchweights* so that pianists can perform at the highest artistic levels without sacrificing their bodies. Like Horowitz did in his day, we as pianists need to begin demanding this from manufacturers and institutions alike.

Not only are the weights of keys different between instruments, but also within the same instrument. As the keys sound lower in pitch, they progressively get heavier. This is a serious problem when one considers not only our physiological development, but also the repertoire of our instrument. [420]

xviii. Photo of the piano action

By virtue of the asymmetry of the weight required throughout the range of the instrument, pianists are inherently creating a physiological imbalance between the right and left side of their bodies that could be a precursor to injury. Additionally, because of

[420] Retrieved from https://www.libertyparkmusic.com/choosing-between-grand-and-upright-piano/

the weight difference throughout the range of the instrument, it potentially changes the biomechanical and technical approach to playing within certain registers. To drive the analogy home, consider a weightlifter at a bench-press machine. If they are only lifting the 45lb bar, the visible effort would usually be confined to the chest and arm regions. However, if one were to add two 45lbs plates to each side, the legs and back suddenly become more involved in addition to the chest and arms. The result is that the overall biomechanics of the movement due to the increased muscular force required to handle the weight. A similar phenomenon happens with pianists, albeit on a lesser and less visible scale.

There are however, important differences between the musician and the pure athlete. Many of us even under much tension and duress continually submit ourselves to this strain for the sake of the music. The moment an athlete overexerts themselves however, they are trained to and usually cease the workout or the sport. Also, though there are sports where these imbalances are created such as tennis, baseball and golf amongst others, athletes recognize the importance of physiological balance and are usually offsetting this imbalance in their training with complementary exercises. I am unaware of any existing pedagogy that accounts for such developmental differences or the peculiarities of the instruments, which is unfortunate, since these peculiarities and differences could be creating or contributing to conditions for the development of injury.

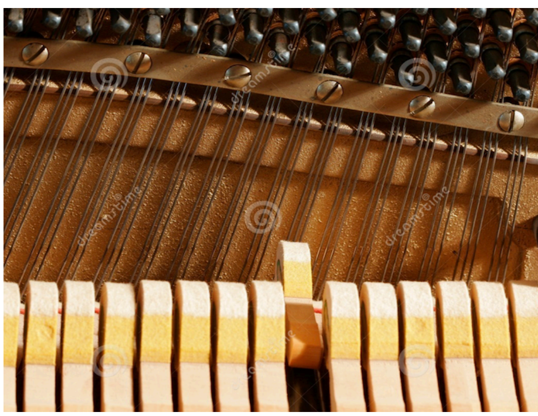
There is also the problem of the physiological and mechanical peculiarity of repertoire assigned to our instrument. The peculiarity of the piano repertoire's construction when executed on the modern instrument also plays an important role in the creation of physiological imbalance. With a few notable exceptions such as Bach, Brahms and Scriabin, the repertoire of most composers heavily favors the use of the right hand. This is by virtue of the fact that the notes of higher pitch lie toward the right side of the piano keyboard and is usually the range where both the melodic material is generated, and virtuosity is displayed. What this means for aspiring pianists though from a physiological standpoint is that the right side of their bodies is being pushed far more biomechanically than the left side. This overemphasis on the right side of the body would also seem to suggest that the susceptibility of pianists to injury on the right side in particular is very high. Some may argue that the progressively lighter action toward the right side of the piano keyboard helps to mitigate these effects. I would refute this opinion by stating that because the repertoire melodically and technically is right hand-centric, it exponentially increases the time that pianists spend in learning the biomechanics of the repertoire. To date, I have not seen a study that looked at the bilateral nature of pianists' injuries and such a study would be interesting to see. In my view, there is a case to be made that the right side for most pianists could be more susceptible based on the realities of the repertoire.

The final aspect I will touch on related to the physical challenges of piano-playing based on the piano's design has to do with the inherent imbalance of sound production. This has to do with inequalities of string amounts, lengths and thicknesses in the registration of the instrument. Most pianos have between 220 and 240 strings.[421] A majority of the treble register, roughly the top 65 keys, allocates three strings per key. The tenor and bass register, on the other hand, allocate two strings and one string per key respectively. Because every note gets its own dedicated strings, there is an excellent

[421] Piano, Retrieved from http://www.madehow.com/Volume-3/Piano.html

opportunity for balancing the thickness, tension, and length of strings to optimize pitch and sound quality. As the notes get higher in pitch, both string length and thickness decrease. Modern pianos are built to try to have the optimum length, tension, and thickness for each note, but there are many challenges and compromises made.

The major compromise that I wish to highlight is related to the fact that the higher sounding notes have both *thinner* and *shorter* strings. Thinner strings have a shorter sounding length which causes them to be quieter and have a faster decay. This effect is amplified the larger the instrument and the larger the acoustical space that the instrument resides. There is very little difference in length of the strings between the highest notes of an upright piano and the length of those same notes in a nine-foot concert grand.


[422]

[423]

xix. Photos showing the similarity of the string lengths at the highest octave between pianos models

On the other hand, there is a huge difference in the length of the lowest notes on the same instruments which creates a greater inequality of balance though the sound quality is much louder and richer with the longer string lengths of the bass notes. Though

[422] Retrieved from https://www.dreamstime.com/royalty-free-stock-photography-inside-piano-strings-image2356167
[423] Retrieved from http://www.pianoren.com/piano-glossary

piano makers traditionally gradually reduce and eventually remove the damper mechanism for the highest notes to create the illusion of more volume, the inequality largely still exists.

What does this mean for the aspiring pianist and teacher? It means that in order to achieve a balance of sound in practice and performance, pianists have to exert more force on the keys on the right side of the piano keyboard and correspondingly less force on the left side of the keyboard to achieve a balanced sound. This increased force could be produced two ways. Firstly, increased force can be generated by a release of right arm weight directed to the right side of the keyboard and a corresponding 'holding' of left arm weight toward the left side. The second way increased force can be generated is by increased muscular contraction in the right arm directed to the right side of the keyboard and vice versa. Such a practice over a period of years, without corresponding techniques to encourage rebalancing are bound to have physiological health impacts and is certainly a marker for injury.

When I look at my own physiological makeup and biomechanical function, I notice three things that drive this point home. Firstly, my right shoulder is noticeably higher than my left shoulder indicating potentially more muscular tension on my right side. This also results in my right arm being a bit shorter in length than my left arm. Secondly, the way my bones articulate at rest is also markedly different. When laying down and comparing my right and left sides, my right scapula does not lie flat, my right shoulder is raised, and my right wrist does not relax when both of my hands are resting on my torso. Thirdly, my right forearm has a smaller range of motion in its ability to pronate and supinate when compared to my left side. While I do not have the requisite skills to make any actual medical diagnosis, I believe that the instrument has played a role in the differing ways my arms have developed. A study that examines the intersection of piano-playing, and bilateral arm function differences could reveal similar trends in larger groups of pianists.

While we, as a field, have done well in managing the peculiarities of our instrument, I do not think that pianists should continue to make physiological sacrifices in their pursuit of artistry. We live in an age where technology has advanced sufficiently to easily solve many of the challenges inherent to our instrument. An interdisciplinary team of musicians, scientists and engineers are fully capable of creating an instrument that allows balance as a base line both in terms of volume and physiology while not sacrificing richness of sound quality. The physical and mental requirements of performing concert piano works are already enormous. It is my hope that soon, we will have an instrument that allows translation and not hindrance of our innate artistic abilities.

Indeed, there have been attempts to push the technological advancement of the piano in the past – many of whom even had the endorsement of some of the great composers. One such advancement was the development of manual layers for the piano, much in the same way the harpsichord and organ has developed. One of the most promising innovations was the ***double keyboard piano***, invented by the Swiss musician Emanuel Moor in 1921 – a student of Liszt. Godowsky, who performed on it, was greatly impressed with its potential. The double keyboard piano allowed one to reach very easily from one to the other, often playing on both at the same time with the same hand. This double keyboard obviates large stretches and makes it possible to play tenths and large intervals with perfect ease and smoothness. It entirely does away with big jumps.[424] In her discussion, Winifred Christie, a concert pianist of the early 20th century and wife of its inventor Emmanuel Moor, demonstrates the double keyboard's great utility in performing the music of the past.

> "The greatest triumph really is that it is now possible to play Bach Fugues with the same clearness as on the *clavicembalo* or *organ*, emphasizing certain tones, building contrasts and dynamics similar to those on an organ, and at the same time preserving the typical peculiarities of the piano. This invention makes the piano a polyphonic instrument and brings back to it the wealth of color which its predecessors possessed, and which has been abandoned with the construction of the modern piano. This is an invention by a musician: for M. Moor is an organist and a pianist."[425]

Liszt even stated, "It would seem that the addition of a keyboard one octave higher allowed more possibilities." Again, despite this advancement and advocacy, this proposed advancement fell on deaf ears once again and no further steps were taken in this development of the instrument.

Even years before the double keyboard was around, there were pianos on which sound qualities could be manipulated, much in the same way as their keyboard predecessors. Franz Liszt stated, "The most recent advance in piano construction will no doubt make possible all tone contrasts which heretofore have been unattainable. The loud pedal on most pianos revealed the need of the extension of further possibilities. The

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[424] Gerig, Famous Pianists and their Technique, 501.
[425] Gerig, Famous Pianists and their Technique, 502.

expressive manuals of the organ will naturally lead to the creation of a piano with two or three keyboards, which will certainly conquer the musical world."[426] Sadly, no further advancement has occurred. Christie even lamented about the piano, "It seems hardly comprehensible why the *piano*, when it replaced the *clavecin,* gave up the rich effects of two keyboards and coupling. In this respect, the hammer piano brought no improvement. In fact, it was rather a step backward for the technic of the virtuoso."[427]

Every aspect of technology in these modern times is constantly and consistently advancing. The notion of *perfection* of any material, device or infrastructure is merely temporary and simply does not exist. Humanity seemingly has an innate desire to push itself to be better in every respect of life. The creation of the airplane, breaking the 10-second barrier in the 100m or the creation of the internet serves as evidence of this. I hope that one day, the piano and the instrumental music world by extension, will have the same curiosity and join the rest of the world in enjoying the thrill of technological advancement – especially when it stands to benefit both from the performance and health of those in the field.

[426] Gerig, Famous Pianists and their Technique, 500.
[427] Gerig, Famous Pianists and their Technique, 500.

Chapter 7: The Proprioceptive Sense and Piano Playing

Pianists are consistently engaged in the use and interaction of many senses. They use the *visual sense* in reading the musical score as well as in their *spatial awareness* of keys and distances. They use *touch* in not only depressing and releasing the key, but more specifically, *how* the key descends and releases. Most importantly, pianists use their *auditory senses* as the musical experience is predominantly one of listening for both ourselves and our audiences. It is this sense that musicians use to discern *dynamics, tempo, rhythm, texture, structure and mood*. More importantly, it is this sense that governs the use of our other senses.

While the above senses are absolutely crucial to successful piano-playing, I believe that more attention needs to be given to another sense - the *proprioceptive sense*. Proprioception is defined as where and how our limbs exist in space. The success of any musical performance at the piano is directly correlated with the use of one's body – and the 'playing apparatus' in particular. It is the use of 'playing apparatus' in a coordinated fashion that actually produces the desired artistic outcome. It is my belief that pianist and piano pedagogues need to be more acutely aware of this sense. We must also recognize however that in some cases, this sense is not accurate. In other words, what one *believes* they are doing or *intend* to do from a movement standpoint is not actually what is being manifested kinesthetically. And though teachers can assist in *where* our limbs exist in performance through observation, they are ill-equipped to aid in the *how* as much of the motions we execute are invisible to the naked eye.

Some pedagogues of the past believed in the importance of this sense. Matthay for instance stated, "Only by the sensations thus experienced can we realize what are the limb conditions that are obtained both in good and in bad playing and by calling upon or recalling such sensations we can then reproduce the effects and can acquire right habits and can teach others to acquire them."[428] Matthay in his commentary here was referring to the *internal conditions* of the limbs. I argue, however, that this should be expanded to include the *external reality* particularly where the limbs are situated relative to each other and where they are situated relative to the instrument itself. This is an area is where teachers could potentially be of immense help to pianists - if they are so equipped.

One of the foremost thinkers in history in the area of proprioception is ***Frederick Matthias Alexander***. An actor and orator of the 19th and 20th century, he was able, through awareness of how he used his body and the resulting tensions caused, to cure himself of chronic laryngitis for which the doctors of the time had found no solution. Today, this practice is referred to as the *Alexander Technique*. Though not developed exclusively for musicians, Alexander's work deals almost exclusively with *developing attention to proprioception* and uses it as a basis from which to use our bodies more efficiently. From this perspective, I think it has direct applications to pianists and anecdotally has demonstrated tremendous benefits. I count myself as one who has benefited from this practice for the past five years both in and outside of piano-playing. In his book, ***The Use of the Self***, Alexander starts from the premise that disease is related to the wrong use of the body. In his pursuit of becoming a professional speaker and actor, Alexander became hoarse and experienced periodic laryngitis. All treatment from doctors and voice trainers provided at most only temporary relief. This led him to

[428] Matthay, The Visible and Invisible in Pianoforte Technique, 16.

embark on years of self-study through observation. What he discovered was that "if pulling back my head, depressing my larynx and sucking in breath did indeed bring about a strain on my voice, it must constitute a misuse of the parts concerned."[429]

Furthermore, in his attempt to correct this, he discovered that when he "succeeded in preventing the pulling back of the head, this tended indirectly to check the sucking in of breath and the depressing of the larynx. I was led on to the further discovery of the primary control of the working of all the mechanisms of the human organism."[430] One of the mechanisms Alexander paid great attention to was the *head-neck-back relationship* – which has direct implications for what we observe in pianists in how it impacts *physical* and ultimately *musical performance*. In piano-playing and pedagogy, many speak only of a vague sense of 'posture' without thinking of the impact that is has on the playing apparatus or the actual musical outcomes.

Furthermore, there is little pedagogy on the relationship of these parts in space as pianists move to the extremes of the instrument. For example, there seems to be no existing scholarship on the critical role of the *pelvic bone* - the point of balance for pianists from which the components of the playing mechanism are supported and emerge. Alexander's work deals with the nature of this relationship, which is especially important for pianists as we will sit for tens of thousands of hours over the course of our lives.

Of importance to Alexander's work was the concept that an incorrect use of one area of the body impacted the other parts of the body. Alexander argued that the functioning of the organs of speech was inseparably bound up with a misuse of other mechanisms which involved the act of shortening the stature.[431] Conversely, the best

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429 Alexander, The Use of the Self, 27.
430 Alexander, The Use of the Self, 27-28.
431 Alexander, The Use of the Self, 29.

conditions were associated with a lengthening of the stature. To lengthen one must put my head forward and up.[432] If one observes many pianists today, many are not allowing their torsos to lengthen. In fact, in many cases there is an active 'shortening' as many 'crouch' in their efforts to bring their heads and eyes closer to the keys. Such activity is actively compressing the spine which in turn has neuromechanical implications for the optimal functioning of the playing apparatus. Surely, this also has an adverse impact on both the musical outcomes as well as health.

xx. Inefficient standing postures

One of Alexander's discoveries as he pursued the cause of vocal strain was the realization that in his attempt to lengthen his torso by allow his head to move forward and up, he was actually doing the opposite. In other words, the belief that he was doing something right had no bearing on the reality due to his *thwarted kinesthetic sense.* Alexander articulates this condition stating, "The sensory feedback system that informs us where we are in space in relation to the earth may sometimes be untrustworthy. This also applies to the relationship of one part of our body to another. I was indeed suffering from a delusion that is practically universal - the delusion that because we are able to do what we 'will to do' in acts that are habitual and involve familiar sensory experiences, we shall be equally successful in doing what we 'will to do' in acts which are contrary to our habit and therefore involve

[432]Alexander, The Use of the Self, 30.

sensory experiences that are unfamiliar."[433] If such was the case for the larger skeletomuscular groups in the head, neck and back areas, consider the implications for the smaller, finer movements of piano-playing. The development of this awareness is crucial for pianists both in their initial development and especially when pain and injury are involved.

Related to this faulty kinesthetic sense, Alexander argues that being under a teacher's directives is not enough to overcome this if not under careful, continuous observation. He states, "The belief is very generally held that if only we are told what to do in order to correct a wrong way of doing something, we can do it, and that if we feel we are doing it, all is well. All my experience, however, goes to show that this belief is a delusion."[434] I believe pianists to be the worst offenders of this even as they dedicate countless hours in the practice room with the most noble artistic intentions. Many only realize in those periodic lessons under their teacher's observation that their time was not well spent due to misunderstood or misapplied technical and musical concepts.

In order to overcome certain habits, Alexander advocates for the *embracing of the kinesthetically unfamiliar*. He argues that the use of a specific part of the body in any activity is closely associated with the use of other parts of the organism, and that the influence exerted by the various parts one upon another is continuously changing in accordance with the manner of use of these parts. If a part directly employed in the activity is being used in a comparatively new way which is still unfamiliar, the stimulus to use this part in the new way is weak in comparison with the stimulus to use the other parts of the organism which are being indirectly employed in the activity, in the old

[433] Alexander, The Use of the Self, 32.
[434] Alexander, The Use of the Self, 33.

habitual way.[435] In other words, the improvement of the use of themselves requires the carrying out of necessary procedures that are new and, when first experienced, 'feel wrong.' These concepts have implications in piano-playing as so many of us often believe that we can change one part of the apparatus without impacting another part. This work by Alexander refutes that viewpoint and is important to consider in injury treatment and retraining. Much of piano-playing is based on what 'feels' natural which, according to Alexander, should never be a basis for which to correct physical habits to improve technique, prevent injury or reduce tension, pain and injury.

Direction, the act of thinking an action, is another foundational principle presented by Alexander. He believed that *movement has to be under conscious control* in order to be successful. Alexander states, "I had never thought out how I directed the use of myself, but that I used myself habitually in the way that felt natural to me.[436] This method of direction has led me into error proving that the 'feeling' associated with this direction of my use was untrustworthy. I found that the feeling by which they directed the *use* of themselves was also untrustworthy, indeed, that the only difference in this regard between them and myself was one of degree."[437] Pianists are often encouraged to allow things to happen naturally and little attention is given to developing conscious control of the movements in piano-playing.

Alexander argues that one of the reasons for the *misguided kinesthetic sense* has to do with the modern world in which human beings exist. This observation is especially interesting, considering Alexander lived over 100 years ago and his viewpoint is even more relevant today. He comments that "in our present state of civilization which calls

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435 Alexander, The Use of the Self, 34-35.
436 Alexander, The Use of the Self, 35.
437 Alexander, The Use of the Self, 35-36.

for continuous and rapid adaptations to a quickly changing environment, the unreasoned, instinctive direction of use such as meets the needs of the cat or dog was no longer sufficient to meet human needs.[438] If then this untrustworthiness of feeling was a product of civilized life, it would tend, as time went on, to become more and more a universal menace, in which case a knowledge of the *means whereby* trustworthiness could be restored to feeling would be invaluable.[439] I must cease to rely upon the feeling associated with my instinctive direction, and in its place employ my reasoning processes."[440]

I believe that much of this *instinctive direction* we call upon to execute piano-playing could very well be misguided and a source of the physical pain and injury that many pianists experience today. And unfortunately, instead of recognizing the role that 'civilized society' plays in disrupting this *instinctive direction*, many teachers simply label such pianists as 'untalented.' While Ortmann maintains that "piano-playing is concerned entirely with voluntary movements before repetition relegated them to the reflex field," I wonder that if the learning of these 'voluntary movements' were being interfered with, could pianists really rely on this 'reflex field' to produce an artistic experience with any degree of confidence?

Alexander also discovered in his self-study that by *thinking* of a given action he could begin to bring about the control of movement he wanted - the idea of taking control of the use of the mechanisms of the human creature from the instinctive on to the conscious plane.[441] John Dewey, American psychologist and educational philosopher, has called this *thinking in activity*, and anyone who carries it out faithfully while trying to

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[438] Alexander, The Use of the Self, 37.
[439] Alexander, The Use of the Self, 38.
[440] Alexander, The Use of the Self, 39.
[441] Alexander, The Use of the Self, 39.

gain an end will find that he is acquiring a new experience in what he calls 'thinking.[442] Solomon, the writer of the Proverbs, also supports this view. "For as he thinks in his heart, so *is* he."[443] In this context, 'so is he,' is expressed in a directly physical sense. Alexander takes this 'thinking' concept further.

He believed that it was not enough just to simply have an intention at the beginning of an act. Continuing to think in a truly conscious way is necessary as we carry out the steps in order to achieve our ends. He states, "In working for a given end, we can all project one direction, but to continue to give this direction as we project the second, and to continue to give these two while we add a third and to continue to keep the three directions as we proceed to gain the end, has proved to be the *pons asinorum* of every pupil I have so far known.[444] I must be prepared to carry on with any procedure I had reasoned out as best for my purpose, even though that procedure might feel wrong. My trust in my reasoning processes to bring me safely to my end must be a genuine trust, not a half-trust needing the assurance of feeling right as well."[445] This approach really supports the pedagogy of Whiteside and others who advocate for the learning of the physical aspects of playing the piano separately from the learning of the score. It would be difficult to give one's attention to these physical processes and sensations while also remaining faithful to the musical score.

Alexander also discovered the concept of *expanding the ends* while carrying out the physical processes to achieving a given result was critical to changing habits. The stimulus of a decision to gain a certain end would result in an activity differing from the old habitual activity. This new activity could then be controlled for the gaining of any

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[442] Alexander, The Use of the Self, 42.
[443] Prov 23:7, King James Version
[444] Alexander, The Use of the Self, 42.
[445] Alexander, The Use of the Self, 45.

end that was consciously desired.[446] In piano-playing, the variety of musical choices are endless from a physical standpoint which makes this concept really applicable. Pianists need the choices of 'musical ends' readily available both physically and mentally. I also believe that this variety in 'musical ends' provides a neuromuscular plasticity and mental flexibility especially valuable not only to pianists but all musicians as they engage in the artistic performance process.

Additionally, Alexander's work gives us insight into how use of the *primary control* – the head-neck-back relationship, affects other aspects beyond neuromuscular control. Of his teaching practice, Alexander stated, "I could not enable my pupils to control the functioning of their organs, systems or reflexes directly but by teaching them to employ consciously the primary control of their use I could put them in command of the means whereby their functioning could by indirectly controlled."[447] Heart rate, eye movements and visceral manifestation of 'nerves' are important considerations that affect the performance success of pianists. To understand how the primary control plays a role in the function of these areas is again of great value to pianists.

Alexander also maintained that human activity in modern times is primarily a process of *reacting unceasingly to stimuli* - either from within or without oneself.[448] This, constant reaction, he argues, is the root cause of ingrained kinesthetic habits of movement or *use of self*, as he terms it. And because of such ingrained habits, such people are incapable of correcting specific defects without addressing the habits of the whole body. Alexander stated, "Where the concerted use of the mechanisms of the organism is faulty, any attempt to eradicate a defect otherwise than by changing and improving this faulty

[446] Alexander, The Use of the Self, 47.
[447] Alexander, The Use of the Self, 51.
[448] Alexander, The Use of the Self, 52.

concerted use is bound to throw out the balance somewhere else."[449] To combat this 'cause and effect', Alexander also emphasizes the importance of *inhibition* as central to this work. He expresses that those who wish to change something in themselves must learn to make it a principle of life to *inhibit* their immediate reaction to any stimulus and they must continue this inhibition whilst they cultivate new kinesthetic habits.[450] Alexander warns that it is courting failure to continue to depend upon the feeling of old habits which 'felt right' but which were obviously wrong since they led to faulty kinesthetic habits.

Additionally, Alexander brings to light the limitations of medicine in addressing the biomechanical issues that people often experience. In reference to medical professionals, he argues that the medical curriculum does not include training in how to direct patients to use their physical selves in ways that promote overall good health. This understanding is largely not considered in medical diagnosis as the field does not recognize the relationship between faulty kinesthetic habits and unsatisfactory standards of functioning which, according to Alexander, is always found in association with diseases. Therefore, Alexander states, "Any deductions he may make therefore will be based on incomplete premises, and the value of his work limited both in the field of prevention and of cure."[451]

In my view, this has implications for not only the underlying philosophies of piano pedagogy but also of medicine. Modern medicine in particular tends to take a very specific as opposed to a holistic approach to treatment. One only need watch pharmaceutical commercials to recognize this pitfall – treatment for one ailment produces

[449] Alexander, The Use of the Self, 54.
[450] Alexander, The Use of the Self, 105.
[451] Alexander, The Use of the Self, 88.

multiple side effects. Yet we continue to rely on medicine in spite of an underlying philosophy that appears questionable. Alexander is correct in that the human body must be approached as a whole - especially crucial for those operating at the highest levels of kinesthetic complexity as pianists do.

Alexander advocates that this concept of wholeness extends to the *mind* also and should not be conceptualized as separate from the *body*. Alexander remarked that "It is impossible to separate mental and physical processes in any form of human activity."[452] Certainly instrumental performance typifies Alexander's statement as it lives at this 'body-mind' intersection. I believe scientific study at this intersection could be beneficial not only to musicians but could improve the lives of all humans as we strive to live as 'whole people.'

Other literature exists that puts the work of Alexander to more practical use. Richard Brennan, founder of the first Alexander Teacher Training College in his book, *The Alexander Technique* sought to achieve that. He stated, "The ease and grace with which we move slowly becomes lost as we take on more burdens and responsibilities. The Alexander Technique can help us to regain poise and ease during even the simplest tasks."[453] I think this could be one explanation as to why those who started piano at an early age seem to move with more fluency than those who begin later since piano technique would have been incorporated into a body that still had the 'ease and grace' of youth.

The relationship of the head, neck and back that Alexander spoke about is further explored here. As stated previously, *Primary Control* is the dynamic relationship

452 Alexander, The Essential Writings of F.M. Alexander, 161.
453 Brennan, The Alexander Technique, ix.

between our head and the rest of the body which is referred to as 'the head-neck-back relationship." [454] This relationship is crucial in piano-playing as the torso is simultaneously our point of balance on the piano bench as well as the place from which the active playing apparatus emerges.

xxi. Photo of Arthur Rubenstein sitting at the piano

When the *Primary Control* is interfered with, it can interfere with other reflexes throughout the body and cause a lack of coordination and balance.[455] Toddlers and lower animals represent the perfect example of *uninterfered* primary control as the head is perfectly balanced and the place from which movement of the rest of the body is initiated. Unfortunately, many pianists demonstrate some of the worst outcomes of *interfered* primary control with overly forward-curved and compressed spinal columns and heads that jut forward, putting strain on the muscles of the neck. Such contortions of the *primary control* observed from pianists must certainly play a factor both in piano-playing efficiency and tension in the playing apparatus.

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[454] Brennan, The Alexander Technique, 7.
[455] Brennan, The Alexander Technique, 7.

xxii. Photo of Glenn Gould sitting at the piano

Faulty sensory perception is also explained by Brennen. He stated, "The sensory feedback system that informs us where we are in space in relation to the earth may sometimes be untrustworthy. This problem also applies to the relationship of one part of our body to another." In other words, what we feel we are doing may in fact be the opposite of what we are actually doing.[456] Brennan explains the importance of *inhibition* by describing Alexander's concept of *thinking in activity*. He stated, regarding Alexander, "Simply by thinking of his head going forward and upwards he prevented the pulling back of the head, which in turn lengthened his stature and produced a beneficial effect."[457]

Brennan believes the practice of the Alexander Technique is a simple, yet profound way of becoming more aware of the balance, posture and coordination of our bodies as we perform our numerous everyday activities. This, he argues, subsequently allows us to be more aware of the excessive muscular tension that most of us

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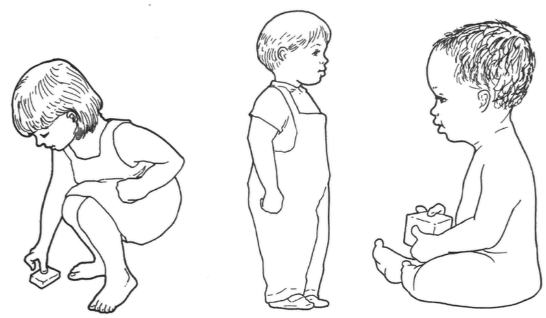
[456] Brennan, The Alexander Technique, 9.
[457] Brennan, The Alexander Technique, 11.

unknowingly hold within our bodies.[458] The way in which we *hold our bodies* is the result of an accumulation of life's past experiences - physical, emotional and mental.[459] Therefore, the four-year-old will be more upright in a natural and effortless way, whereas the sixteen-year-old will be much more slumped, and in order to keep erect while standing or sitting will invariably pull in the lower back. This will cause a shortening of the whole stature.[460]



xxiii. Diagram of postures of young children

xxiv. Diagram of sitting posture of a school-aged student

Brennan also asserts that *sitting* is responsible for much of humanity's postural troubles and the other health challenges that follow. He argues that the spine is under greater pressure when sitting than in almost any other position and the troubles are compounded as people get older.[461] An average child who starts school at the age of five and leaves at the age of eighteen will probably have sat for more than forty thousand hours during that time, over half their waking life.[462] Coupling this reality with those children, youth and adults who also play the piano, the hours of pressure on the pianists'

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458 Brennan, The Alexander Technique, 12.
459 Brennan, The Alexander Technique, 13.
460 Brennan, The Alexander Technique, 14.
461 Brennan, The Alexander Technique, 15
462 Brennan, The Alexander Technique, 15.

spinal columns I believe are of epidemic proportions. Pianists sit for hours on a bench without any support and pivot from this position in order to reach the extremities of the instrument as well as to alter the amount of weight that goes into the keybed. Certainly, the additional pressure pianists place on the spinal column is a contributing factor to the health challenges they face.

Brennan also explains the perils of the modern age being a result of people often having to accomplish many more activities in a set time, far more than previous generations did. This, he argues, undoubtedly contributes to anxiety and tension[463] as many live *goal-oriented lives* as opposed to *process-oriented ones*. Termed by Alexander as *end-gainers,* many are more interested in achieving an end than experiencing the *means whereby* that end is reached.[464] In our current postmodern age, the ability to multitask is considered desirable because it arguably helps the multitasker achieve more. A consequence of multitasking, however, is that one's attention to *process* suffers. Such a lapse in attention to process has serious implications for pianists. So many pianists rush feverishly to learn new repertoire in preparation to survive rehearsals, lessons and performances, without giving any thoughts as to the *means whereby* they are learning or performing. While a more deliberate and thoughtful approach to the process of piano-playing could mean that less is 'accomplished,' over the long-term, it could solve a great deal of pianists' challenges and hence lead to better musical outcomes and less physical expense.

Additionally, Brennan states that the practice of Alexander Technique helps to improve *awareness*. He observes that "as you gradually become aware of yourself, you

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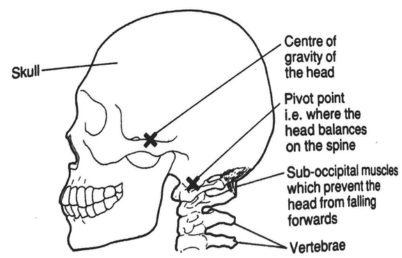
[463] Brennan, The Alexander Technique, 17.
[464] Brennan, The Alexander Technique, 17.

will begin to notice the muscular tensions I have mentioned. Certain muscles become more and more tense while others become over relaxed. This process takes place over many years and will eventually affect the physiological structure of the muscles." I think most pianists are completely ignorant of the effects piano-playing has on their bodies, until they experience debilitating pain. If pianists can become more aware of the tensions involved in playing it would go a long way in helping us to prevent injury instead of waiting for pain as a warning signal.

Brennan also articulates that the principle of *pause* - the conscious inhibition of one's desire to take a reflexive action, provides the possibility for choosing an action with more efficiency. Brennen believes that observing pauses "can help to you stop and think before proceeding with your actions. This will allow you to do any activity with much greater efficiency of movement; in other words, to perform tasks with much less effort."[465] The success of piano-playing I believe is largely dependent on developing the ability to *pause* – especially critical in practice and rehearsal settings. I believe that pianists who practice this will have more success physically and musically as piano performance is largely dependent on the reflexes they have built up during the practice and rehearsal process. Brennen also states, "We often perform our actions in a stereotyped way and these habits *feel right to us*, regardless of the strain they put on our structure."[466] I observe that so many pianists perform in a 'stereotyped way,' whether it be based on observing other 'great' pianists and mimicking or through direct teacher encouragement to do the same.

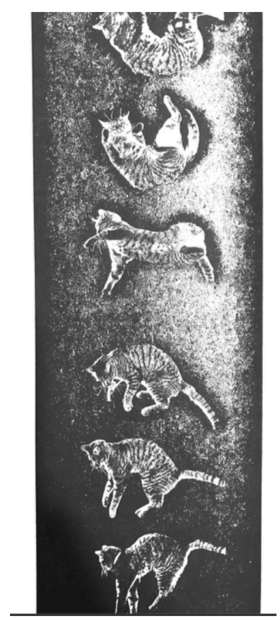
[465] Brennan, The Alexander Technique, 22.
[466] Brennan, The Alexander Technique, 23.

Brennan articulates that the Alexander Technique is not as much a process of *learning* but rather *remembering* what many have long forgotten. He states, "It could be defined as a process of unlearning or re-education of the entire psycho-physical functioning of the human being."[467] Brennan also emphasizes the cooperation of the *whole self* stating "The body, the mind, the emotions and the spirit are inseparable, and that if any one of these is misused the other three will be affected.[468] Because our physical habits invariably stem from the rigid way in which we think, when we become aware and consequently change the patterns of the way in which we move, we are also altering the way in which we think."[469]



xxv.. Diagram of the human skull

Brennan moves into an explanation of how the head is the initiator of movement. The reason that the pivot of the head is behind its center of gravity is that, in order to move, all a person has to do is relax the sub-occipital muscles. The head will then go forward slightly and because of its weight will take the whole body into movement. A human being has only to let go of the tension in certain muscles and a complex reflex system will do the rest.[470] Brennan states, "We are designed to 'fall' into movement and when infants first begin to learn to walk, they do just that. They constantly look as though they are about to fall flat on their faces, yet they save


xxvi. Diagram of a cat in freefall

[467] Brennan, The Alexander Technique, 24.
[468] Brennan, The Alexander Technique, 25.
[469] Brennan, The Alexander Technique, 88.
[470] Brennan, The Alexander Technique, 49.

themselves just in time by the reflex action of their legs."[471] Such 'falling into movement' is part of the movement vocabulary of piano-playing, and so this knowledge has many useful applications as pianists attempt to negotiate the physical extremes of the instrument in a healthy way.

Brennen also expounds on the principle of *thinking in activity*. He defined it as, "Projecting messages from the brain to the body's mechanisms and conducting the energy necessary for the use of these mechanisms."[472] In my opinion, thinking of the physical mechanics involved in playing is actually useful to pianists. Studies have shown that the firing of the neurons that control movement still fire whether there is actual movement or the idea of movement and could be a useful component of the learning process of not only pianists but other musicians. Most critically, it could have the benefit of reducing the amount of physical practicing traditionally thought to be needed.

Michael Gelb's is the founder of the High-Performance Learning Center. His book, *Body Learning,* combines Alexander's own writings with that of psychologists, educators and scientists to bring new light to the importance of *reimagining ourselves and our physical movements*. The educational philosopher John Dewey stated, "The hardest thing to attend to is that which is closest to ourselves, that which is most constant and familiar. And this closest something is, precisely ourselves, our own habits and ways of doing things."[473] This is especially so for injured pianists whom after years of study finding themselves having to retrain to move in a completely different way in order to remedy their injuries and by extension, their playing. Most unfortunately never make the decision to engage in that work.

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[471] Brennan, The Alexander Technique, 51.
[472] Brennan, The Alexander Technique, 73.
[473] Gelb, Body Learning, 3.

To the relationship of *use* and *function*, Walter Carrington, founder of the Constructive Teaching Center, stated, "The nature of the relationship between mind and body is still undetermined." Instrumental performance is one of the few disciplines that lies at this crossroads. To explore the nature of this relationship would benefit all areas of human scientific endeavor. Whatever the treatment, the common denominator of successful efforts to overcome destructive habits is the fundamental decision to change. The power to choose, predicated on individual responsibility and integrity, is the core concept of *Use*.[474] Alexander realized this the moment he had issues with his voice. This principle is the hallmark of helping to stem the tide of injuries experienced by musicians and particularly pianists. Those most frequently seeking Alexander lessons have always been musicians, actors and dancers, whose quality of *use* directly affects their ability to make a living.[475] Musicians certainly are already benefiting from this work as many conservatories and music schools have Alexander teachers on staff. How much more important is it to study Alexander's work from the standpoint of instrumental pedagogy and neuromechanics.

John Dewey stated, "The world seems mad in preoccupation with what is specific, particular and disconnected in medicine, politics, science, industry and education." Alexander's work on the contrary seeks to bring to light the importance of *uniting the human mind and mechanism*. Similarly, this work on piano-playing and pedagogy hopes to integrate seemingly disconnected disciplines into an integrated whole thus producing a truly interdisciplinary field of study.

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[474] Gelb, Body Learning, 26.
[475] Gelb, Body Learning, 27.

Gelb argues that *inhibition* is crucial to better function not only at the mechanical level but also at the level of the tissues and organs within the body. Sherington wrote, "There is no evidence that inhibition of a tissue is ever accompanied by the slightest damage to the tissue; on the contrary, it seems to predispose the tissue to greater functional activity thereafter. In today's world, we stiffen our necks and literally throw ourselves off balance in unconscious response to many aspects of our environment. Our nerves become jangled and our capacity for inner quiet is diminished by the pounding to which we subject our senses."[476] This certainly is true of many pianists and by extension other musicians and seen at its worst in the context of performance anxiety amongst other things.

Gelb expresses that *giving direction to one's mechanism* is more challenging today more than at any other time in history. He stated, "Most people were unable to direct their attention and as a result suffered from 'mind-wandering' or over-fixated concentration.[477] Since every visualization or thought has immediate physiological effects, choosing what one thinks becomes increasingly important."[478]

Alexander always emphasized *the process* of attaining a goal, rather than a narrow focus on the goal itself, an approach which differs from that ordinarily taken in dealing with the material world.[479] But he recognizes that overcoming habits and the will to do right are mutually exclusive stating, "The *means* or *effective conditions* for the realization of a purpose exist independently of established habit and even that they may be set in motion in opposition to habit." Dewey agreed with this idea, concluding that "a man who does not stand properly forms a habit of standing improperly, a positive,

[476] Gelb, Body Learning, 61.
[477] Gelb, Body Learning, 77.
[478] Gelb, Body Learning, 77.
[479] Gelb, Body Learning, 80.

forceful habit. The common implication that his mistake is merely negative; that he is simply failing to do the right thing, and that failure can be made good by an order of *the will* is absurd. Conditions have been formed for producing a bad result, and the bad result will occur as long as the bad conditions exist."[480] Rather *treating the steps within a process as ends in itself* is a better way to achieve the ultimate ends. "Until one takes intermediate acts seriously enough to treat them as ends, one wastes one's time in any effort to change habits. Of the intermediate acts, the most important is the next one. The first or earliest means is the most important end to discover."[481] In other words, the vicious circle of misuse and failure can be stopped through attention to process.[482]

The failure of many people in this postmodern age to maintain good physical and mental health has to do with being solely performance-driven. Whether it be in the context of family life, career pursuits, social responsibilities or personal growth, the neglect of good physical use has led to a decreased quality of life even as we appear to live longer. The work of Alexander and others invites us to self-reflection, particularly in how we use our bodies as directed by our minds. For those whose quality of movement forms the bedrock of their livelihood, it should be both mandatory and self-explanatory that we should chart a different course. I am certainly encouraging pianists, teachers and pedagogues to do so and therefore bring about a much-needed resurgence of research and practice in our field.

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[480] Gelb, Body Learning, 82.
[481] Gelb, Body Learning, 83.
[482] Gelb, Body Learning, 118.

Chapter 8: Survey Study: Pianists, Piano Teachers and Medical Professionals

Section 1: Description and Rationale for Study

One of the interesting aspects of the field piano-playing and pedagogy is the overall lack of consensus. This lack of consensus in turn leaves an undefined knowledge gap despite the presence of over 300 years of pedagogy. It is important to determine the principles and practices that modern aspiring pianists and their teachers are currently espousing, particularly for purposes of this dissertation. Conversely, we need to differentiate what is considered to be unimportant to piano-playing and teaching by the lack of its inclusion in independent, private and institutional music study. Additionally, we need to discover the areas in which participants in the field of piano-playing and pedagogy recognize their own lack of understanding. Lastly, we need to determine the level of desire for the input of other fields that could improve playing and teaching from a health and human performance standpoint.

To uncover the knowledge gap that exists within this field as it relates to the health and neuromechanical aspects of piano-playing, I developed a series of 3 surveys. These were geared toward three groups - pianists, piano teachers and medical professionals. They were distributed and collected electronically using the online *Qualtrics* software platform. The resulting data was analyzed to determine trends in each population. We hypothesized that the findings would reveal the following:

1: There is a lack of information within music institutions focused on the musculoskeletal, neurological, psychological and kinesiological tools, processes and concepts required by and used by pianists to execute fine piano-playing.

2: There is little variety and availability of resources within other academic and research institutions of similar information that could be relevant and helpful to aspiring pianists.

3: There is no emphasis on the development of body awareness and a finely tuned proprioceptive sense amongst aspiring pianists.

4: There is a lack of guidance and resources within and outside the field when aspiring pianists suffer physical challenges, pain or injury.

5: There exists no consensus of the orientation, condition and use of the wrist and fingers in piano-playing. The fingers and wrists represent the critical key to pianistic success as well as the source and cause of much physical discomfort, pain and injury in pianists.

A goal was set of having 100 participants and recruitment was done using flyers, internet postings, recruitment letters to university and conservatory faculty and student bodies as well as direct recruitment of potential study participants. Because of the selective nature of the target groups, the study was open to anyone across the globe. Of the 3 target groups, the goal of at least 100 participants was achieved only in the pianists' category with 145 total participants. In the piano teachers' category, there were only 34 participants. Many teachers simply did not respond to direct communication through email. In direct emailing of 49 piano teachers, many of whom I had worked with in the past, only 2 replied and both stated that they were too busy and that the summer would be a better time for them to allocate the 15 minutes needed to complete the survey. This lack of response from so many suggests that piano teachers, in general, are incredibly busy. Perhaps it was a bit idealistic to believe that that they would have the time to participate in this study.

One of the more surprising outcomes that was not anticipated was the overt negativity that many piano teachers expressed in response to the survey. In an online piano teacher group particularly, the study link was posted to the media platform and teachers were encouraged to participate. The outcome was that the public were reticent to answer many of the initial questions, and as a result, some teachers openly discouraged participation in the survey – even after these concerns were engaged with and reasons were given for the given lines of inquiry. Others claimed to already have the answers to areas of piano technique and injury and saw little need for such in-depth scientific analysis or for its incorporation in their own training, nor its necessity in the training of their students.

One teacher argued with me at length regarding the role of body weight in piano technique, claiming that very young children were able to play with enormous power. Whether or not the findings of the study are substantiated or refuted, it was surprising that many piano teachers simply were not open to authentic engagement in a study directly related to the field in which they work nor curious about the outcomes. Paradoxically, equally as many pianists who participated in the survey study spoke to the importance of this work and wanted to know the ultimate outcomes. Despite this state of affairs, we can make inferences regarding piano teaching from the data pianists provided that are statistically significant.

In the medical professionals' category, there were only a few surveys completed with little feedback to direct communication. Moving forward in subsequent studies, it would be important to build in incentives for participation. This was beyond the reach of this study at this time due to the lack of both personal and research funding. Despite the lack of participation in the last 2 categories mentioned, the findings in the pianists' category are significant enough to address some of the above claims.

Section 2: Results

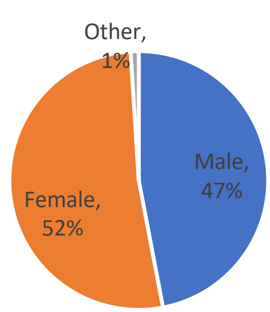
Subsequent to data collection, both quantitative and qualitative analyses were conducted using a variety software tools designed for those purposes and standard to the neuromechanics field. Graphs were then generated. The complete graphs related to the survey questions can be found in Appendix V. Four our purposes here, only the graphs directly related to the five hypotheses will be presented in the discussion section.

Section 3: Discussion

Though the survey sought to focus on the five research questions postulated, secondarily, it was also the hope to receive other information that could be the basis for continued research in the field of piano-playing and neuromechanics. In this regard, this study generated a lot of interesting findings that could be the basis for new lines of inquiry.

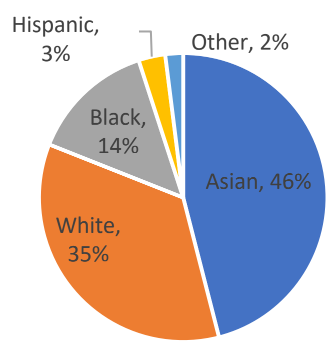
The sampling across the genders was surprisingly very balanced with virtually even representation of females and males **(Fig.1).**

Fig. 1. Participants By Gender



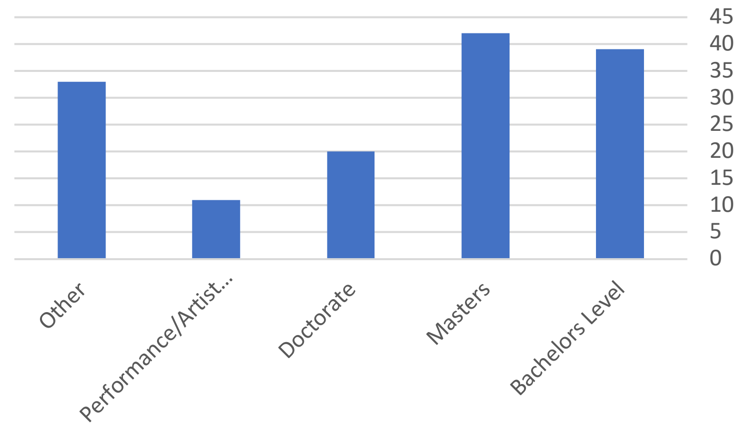
Though the ages were wide ranging, the average age was about 30 which suggest the majority of participants are quite young with the median age actually between 24-29 of those polled **(Fig.77 –** See appendix V**)**. However, when we superimpose this seemingly youthful group with an average of over 20 years of training it suggests years of habits developed and an accumulation of micro-trauma and injury over that period **(Fig.77).** The sampling across races **(Fig. 2)**, while not balanced, actually in my view closely represents the racial demographics of the field of piano performance with Asians and Caucasians far ahead of populations of color. A more in-depth data analysis could potentially reveal how the story of the data changes when a given gender or race is selected.

Fig. 2. Participants by Race



The sampling with regards to level of training really hit the targets with 77% of participants having achieved at least a bachelor's degree or higher **(Fig. 7)**. Therefore, it can be said that the data is pretty reliable having come from a population that consistently practices and performs classical repertoire thus could be considered *aspiring pianists*. It would also be interesting to see the story the data tells if the sampling only included those achieving a master's degree and higher. For at that level of education, it is currently believed that pianists play at the highest levels and have given many concerts by this stage in their training. More data would be needed to substantiate that.

Fig. 7. Participants Level of Training



The question of handedness is also a great line of inquiry with a majority claiming to be right-handed **(Fig.3)**. Much of the piano repertoire, outside of composers like J.S. Bach (due to his use of counterpoint) and Alexander Scriabin (due to his favoring of the left hand), is right-hand heavy. Piano-playing prides itself on the achievement of balance between the hands and much of our technique is geared towards the development of this trait. In light of this, it is interesting that 50% of pianists still feel that the hands are unbalanced **(Fig. 37)**. It begs the question as to whether one group is more susceptible to injury or has an easier time with some types of repertoire. More interestingly, is the unbalanced group's development a result of the nature of the piano itself? Piano technology for instance would indicate that it is easier to produce sound in the lower registers thus it stands to reason that pianists will overcompensate with their RH in order to achieve a balanced sound. How does handedness then impact piano neuromechanics and the changing physiology of pianists?

Fig. 3. Participants by Handedness

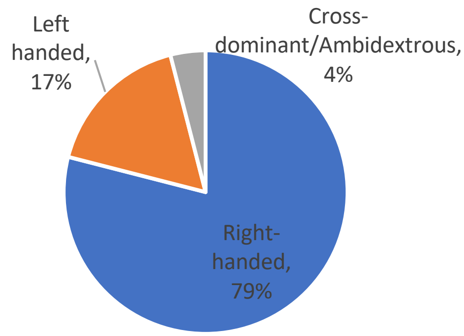
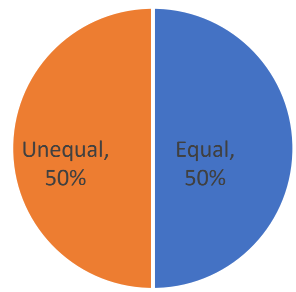


Fig. 37. Relative Strength of Hands



Hand size has long been an area of interest for pianists and has in many cases been an indicator of talent, the technical approach chosen in how to play the instrument, the repertoire one can be more successful with and the susceptibility to injury of one group versus the other. The approach of using two credit/id cards, while somewhat crude, gives us information on the range of hand sizes present in the world of elite piano performance. Additionally, the length of two cards actually corresponds to a one octave reach on the piano, an important benchmark in a pianist's ability to play a majority of the traditional repertoire. And while only 27% of pianists surveyed had a resting hand length that was longer than a credit card **(Fig. 4)**, 81% of pianists still had a reach that was longer than one octave or 2 credit/id card lengths **(Fig. 6)**. This suggests that the biomechanics is different for someone with smaller hands which in turn changes the outlook of one group's injury susceptibility. This is determined by muscle and tendon flexibility in the playing apparatus in addition to the shape of the skeletal joint insertions which also play a role. More in-depth research is needed to explore this important area, though it would be interesting to explore the data if one group was selected out, even in this limited context.

Fig. 4. Participants by Hand Length compared to length of 2 adjacent credit/ID cards

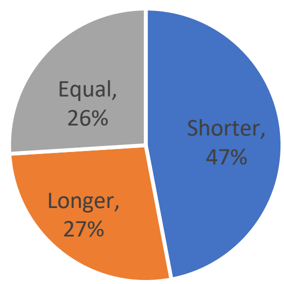
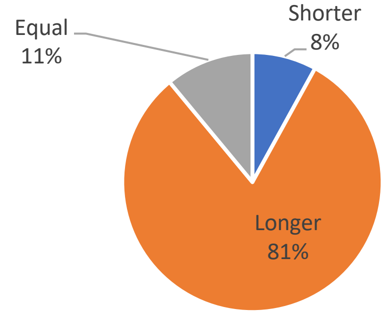


Fig. 6. Participants by 'Thumb to Little Finger' Stretch compared to length of 2 credit/ID cards

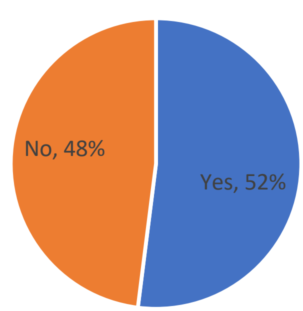


What information and training exists within music institutions focused on the musculoskeletal, neurological, psychological and kinesiological tools, processes and concepts required by and used by pianists to execute fine piano playing?

Pianists have stated that they have had an average of five teachers over the course of their lives and yet they also claim that only two on average have been technicians or technique-focused **(Fig.77 –** See Appendix V**)**. This is not unique within our field or perhaps in the wider field of instrumental performance. Many teachers articulate that, at a "certain point" in the life of a pianist, one's technique should be already established. Others claim, like Liszt, that their focus is more on the artistic or musical side of performance and that students should have that worked out before they "arrive" in their studios. However, piano-playing is, at its most basic level, a specific form of movement that in turns produces specific movement within a device (the piano) which in turn produces sounds, the collection of which hopefully leads to artistic expression. Inductively, this means that piano-playing and piano teaching is primarily about producing and teaching a *form of movement*, which is in itself a *physical act*. Coaches and trainers of any sport even at the professional level are always involved in the mechanics of their sport, even such "artistic sports" as figure skating and gymnastics. Otherwise, they could not authentically call themselves a coach. Therefore, believing that one can call oneself a piano teacher while remaining ignorant of the physiological mechanics of piano-playing is a major gap in the field.

The data reflects this gap, where 48% of pianists have never studied any scientific fields that are involved related to piano-playing **(Fig.12)**. Of the 52% that have studied, 56% of those have gleaned such knowledge from their piano teachers and 58% of that have studied within the context of the academic institutions of which they have been a part.

Fig. 12. Participants who studied piano-related sciences/technology



The larger majority however (72%) have studied independently **(Fig.13)**. Of those that have studied, only 44% have studied the biomechanics of piano-playing and

54% have studied the mechanism of the instrument itself **(Fig. 14)**. Meanwhile 100% have studied memory, as expected due to the nature of current piano performance standards. Biomechanics and instrument structure and function are the crucial areas necessary to both artistic success and injury prevention and unfortunately, the data shows an overall neglect in the study of these areas.

Fig. 13. Forum for study of piano-related science/technology areas

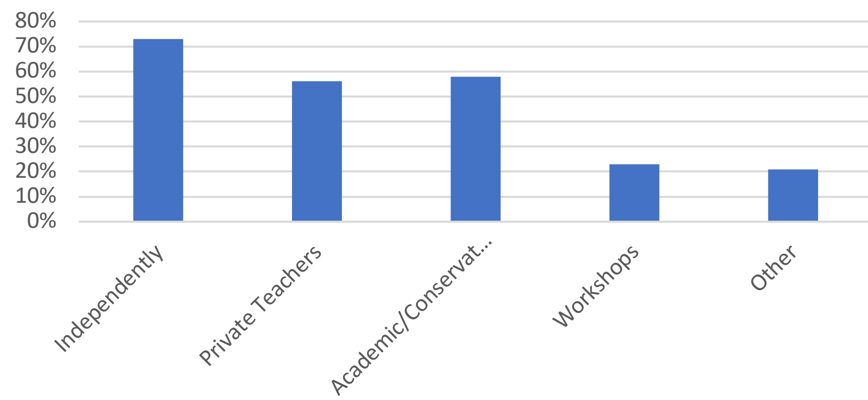
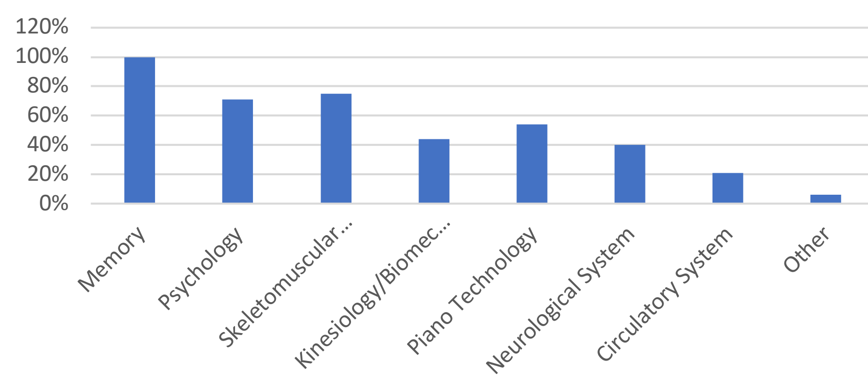
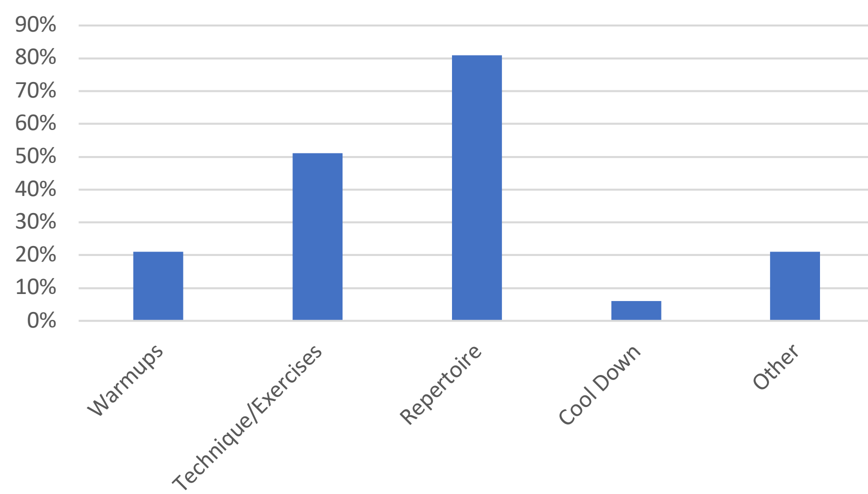


Fig. 14. Piano-related areas of science/technology studied



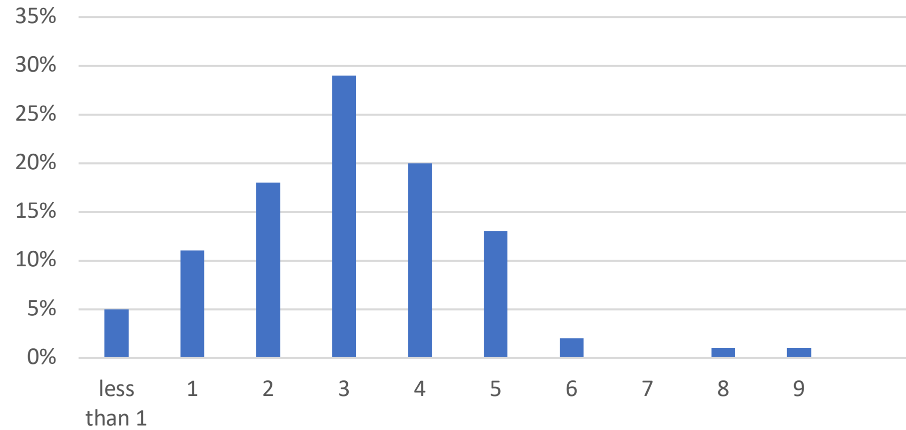
The composition of lessons also needs to be addressed. Visiting the world of sports again, one would not consider engaging in a practice or a meet/game day without aspects like warming-up and drills and cooling down once the activity has ended. While the terminology is not transferable in a traditional sense, pianists are the "athletes of the small muscles." The data maintains the need of similar treatment as those engaged in more traditional athletic pursuits. It is striking that only 21% of teachers engage in any kind of directed warmup routine with their students and only 6% engage in a cool-down **(Fig.8).** These percentages mirror themselves largely in the practice room routines of pianists. If pianists indeed are the "athletes of the small muscles," the data maintains the need of similar treatment as those engaged in more traditional athletic pursuits.

Fig. 8. Components of Piano Lesson Structure



Another area that needs exploration is the idea of the amount of practicing that pianists should engage in daily. On average, participants revealed that they engage in over 3 hours of practicing on a daily basis with the median range being between 3- 5 hours of practice **(Fig. 10)**.

Fig.10. Typical Number of Hours Per Day of Practice



While again this seems usual in the field of elite piano playing, one would be hard-pressed to find a professional sport where this is the case. Pianists, on top of these 3 hours, may have many more hours of rehearsals, lessons and performances which were not included in these 3+ hours. While more data is needed to explore the physiological costs of such a rigorous physical routine, when one considers that 39% have been seriously injured **(Fig.26)**, and 80% have suffered with pain and discomfort in their playing **(Fig.22)**, our field is begging for radical changes in this area. This is especially worrying when only 10% of allocated practice time on average accounts for breaks **(Fig.77**- See Appendix V**).**

Fig. 22. Participants having experienced pain

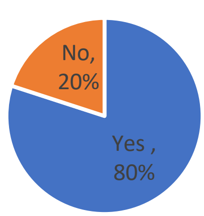
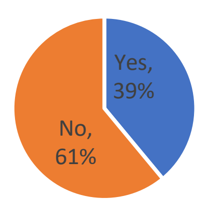
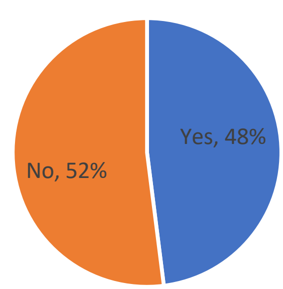


Fig. 26. Participants that have been Injured



It may seem harsh to direct much of the blame of the state of affairs in piano-playing on the teachers. This data coupled with the push-back from many teachers received, leads me to suspect that many of them may simply not possess the knowledge in these areas and thus are ill-equipped to help students. Indeed, coaches in professional sports are not the absolute authority in the lives of their athletes. There are teams of trainers, doctors, physical therapists and sports scientists that are ensuring that the athletes receive everything they need to be at their very best – not to mention the psychologists, motivational consultants and spiritual leaders that are also on staff. No such 'team' exists currently in the field of piano performance. The piano teacher, whether they want to or not, remains the absolute authority. And 52% of pianists do not engage in any other supportive practices that could be of benefit in the same way that athletes do **(Fig.11)**. Those that do spoke of exercising, stretch and massages in a general sense while others spoke of grip masters and finger stretching to which they subscribed. This speaks to the gap in knowledge between all the associated fields and practices that I believe is long overdue to be addressed.

Fig. 11. Participants who do non-piano exercises/practices to aid piano-playing



Are there a variety and availability of resources within other academic fields and medical and research institutions that could be relevant and helpful to aspiring pianists?

While it is incumbent upon pianists and piano teachers to be educated in the physiological and biomechanical aspects of their craft, it is impossible for teachers in particular to be the absolute authority in piano-playing and in related areas. Input is needed from a variety of fields of study including medical professionals, scientists and piano technologists, in particular. The knowledge gaps in the field have to be met by a multidisciplinary effort. Though I have discussed the presence of literature that could be helpful to the study of piano-playing, there is very little pure research studying piano-playing. In my own collection of science journal articles geared toward this research, there have been only about 30 journal articles written in the last 12 years related to piano-playing. And only a fraction of that specifically studies the critical neuromechanics and physiological aspects involved. And not since Otto Ortmann *Physiological Mechanics*, written almost 100 years ago, has a serious scientifically-based text on piano-playing been attempted.

The data reveals that 48% of pianists are not studying scientific areas related to piano-playing at all **(Fig.12)**. Of the 52% that are, a larger percentage are studying the scientific aspects independently (73%) than in academic institutions (58%) or with teachers (56%) **(Fig.13)**. This suggests that pianists are searching for this information. Unfortunately, such courses are rare within universities, not to mention music schools and conservatories.

Fig. 12. Participants who studied piano-related sciences/technology

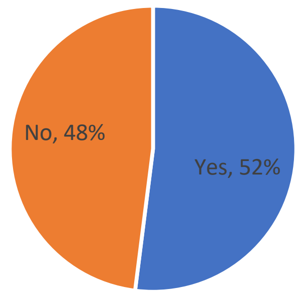
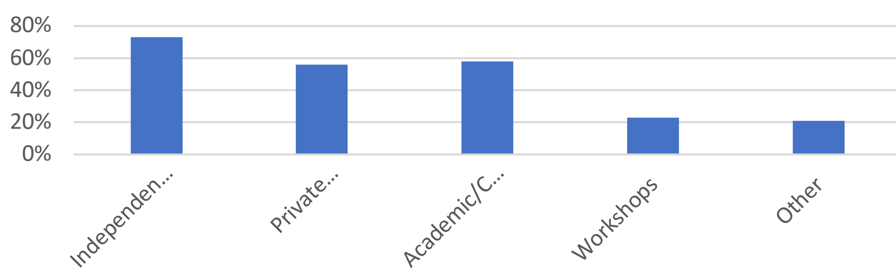


Fig. 13. Forum for study of piano-related science/technology areas



Of the areas pianists study, the study of memory is the area of most focus for pianists at a whopping 100% which makes perfect sense since much of our time is spent ensuring memory's reliability. Meanwhile piano technology and biomechanics lag far behind at 54% and 44% respectively **(Fig.14).** Considering that 80% of pianists have suffered pain throughout their careers, the data suggests a correlation between these areas least studied and the physical challenges that abound **(Fig.22).**

Fig. 14. Piano-related areas of science/technology studied

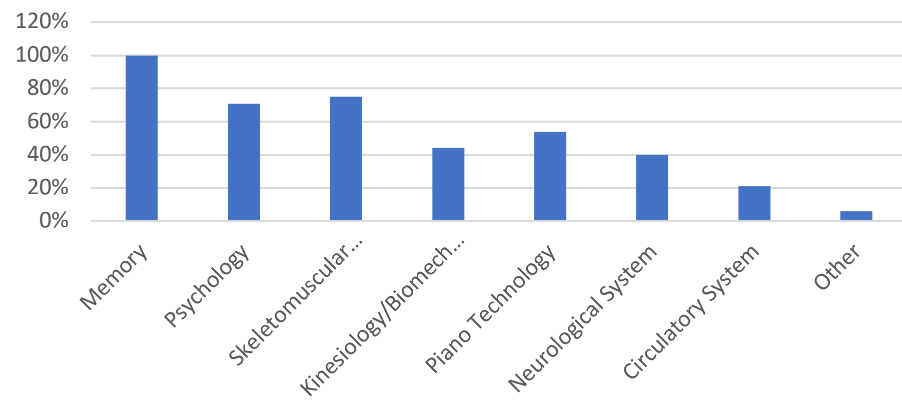
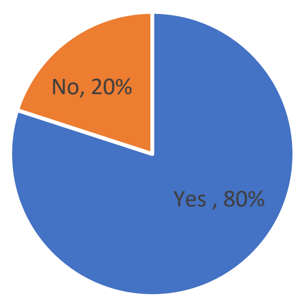


Fig. 22. Participants having experienced pain from Piano Playing



Not only do scientists have a role, but also piano builders and technologists As a pianist who also studied the instrument from a technician's standpoint for 5 years, I have an understanding of how the instrument works. It also has many inherent flaws that have played a role in the prevalence of pain and injury amongst pianists. Sadly, that knowledge is missing from the educational experience of most pianists. Should we not have an understanding of the instrument on which we make our careers? And should not the instrument be developed much in the same way that computers and other devices are consistently being improved, not simply maintained so that it works? The sciences and piano technologists have a role to play in the filling of this knowledge gap. Currently this is not happening.

The data also reveals that the medical profession is not playing a role. While in athletic sports where medical professionals are amongst the first to be sought after when physical problems arise, pianists are not being educated about the medical implications of their field nor seeking those that are knowledgeable. The data confirms this as 57% of pianists have not studied injury prevention **(Fig.15)** and 83% have not studied injury management **(Fig.16)**. When considering the previous data about the frequency of pain and injury in pianists, the need for medical knowledge and intervention is clear.

Fig.15. Participants that Studied Injury Prevention

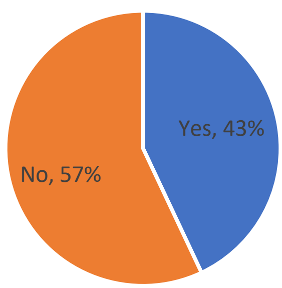
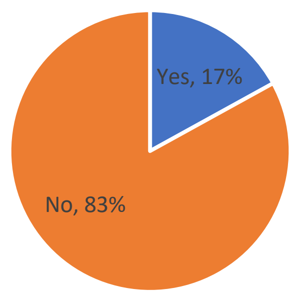
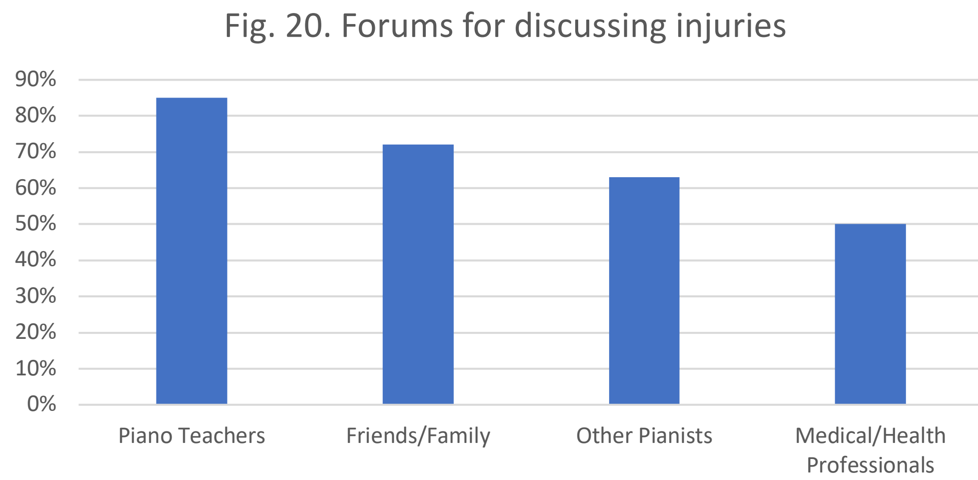


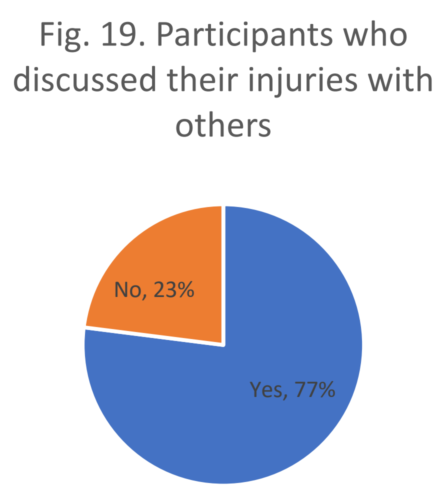
Fig.16.Participants who studied Injury Management



Admittedly however, it seems as if there is either a lack of trust of medical professionals or an "over-trusting" of teachers. The data demonstrates that when pain or injury occurred, the piano teacher was the popular point of contact at 85% **(Fig.20).** Meanwhile medical professionals were the least trusted at 51%**.** More research is needed as to why this is the case. I suspect that perhaps medical professionals do not understand piano-playing well enough to be a resource for injuries, therefore pianists are afraid of them. Hopefully, this question could be answered in the future by improved participation in our physicians/medical professionals survey.



One of the unanticipated outcomes of the data was the fact that 23% of pianists did not consult anyone about their injuries – teachers, family, friends or medical professionals **(Fig.19).**



More research is needed as to why such a large percentage simply do not seek help. Perhaps in such a competitive field as piano performance, any display of vulnerability could negatively impact one's career with arts administrators. Maybe it has to do with a belief in the old adage "no pain, no gain" and that pain is a symptom of improving strength and endurance. Maybe it's a fear of their teachers. In the medical field, where an epidemic is classified at about 8%, it appears in the field of piano-playing we are dealing with something far more serious, both physically and perhaps psychologically.

What attention is there to the development of body awareness or to the proprioceptive sense amongst aspiring pianists?

Awareness is a key component in improving human performance in any capacity. The variety of movements that a pianist needs to have at his disposal is as infinite as the number of compositions being produced. Such is not necessarily the case for many athletic pursuits as their movements operate within the confines of that particular sport. This is compounded when considering the coordination of many joints of the playing apparatus and the muscular redundancy that is unique to the hands and fingers. Not only do pianists need to consider the movement itself but also the speed and power of that movement as they correlate to tempo and dynamics. Additionally, pianists have to be able to sense the weight of the keys as it impacts subsequent movements. This is precisely why the brain allocates more motor and sensory cortex space to the hands than other larger parts of the body. The complexity of what goes on in piano-playing physically and neurologically far exceeds that of most athletic endeavors.

The data demonstrates that while pianists generally appear to understand the parts of the body that are involved in piano-playing, they do not always seem to be aware of them while in the act of playing. The percentages for each part of the body highlighted in every case decreased when the word *important* in the first question changed to *aware* in the second **(Fig.30-31)**.

Fig. 30 .Areas of the body believed to be important in piano-playing

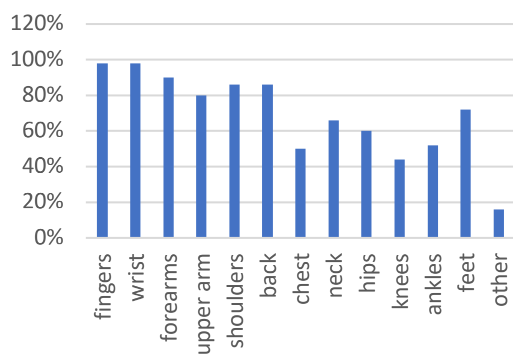
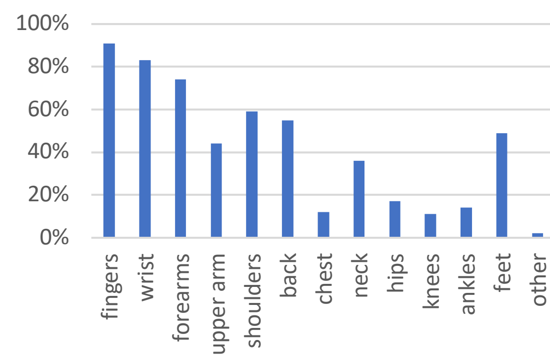
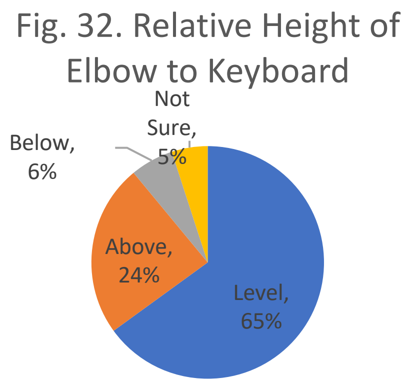
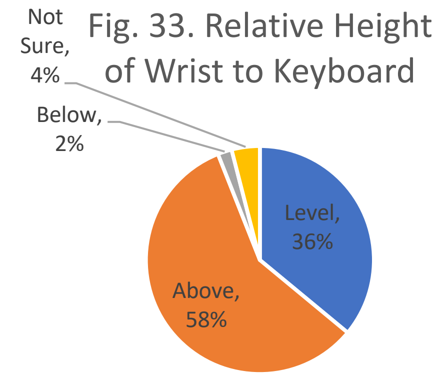


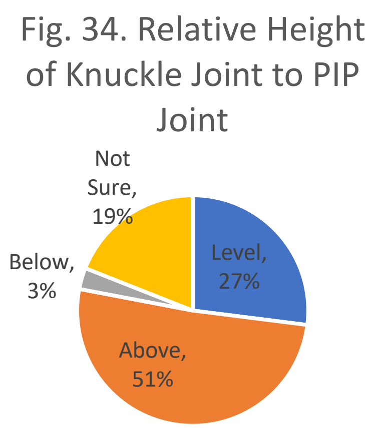
Fig. 31. Areas of the body pianists are aware of during piano-playing

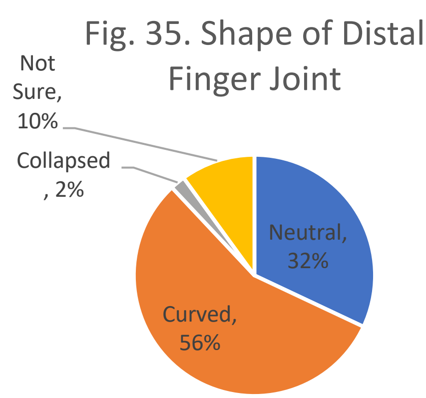


Secondly, the data showed that pianists generally seemed to know where active parts of the playing apparatus existed proprioceptively. There seemed to be general consensus on where the elbow joint, wrist joint, MCP (knuckle) and PIP joints should be oriented in relation to each other. However, in each case, there was a significant enough percentage of at least one of the other options to necessitate the need for further research into this area **(Fig.32-35)**. I suspect that maybe ratios of the various dimensions of each body part play a role in the preferred orientation as well as more general physical attributes such as height. It could be as well that most pianists did not understand the parts of the body that were being referenced which begs the question as to the lack of basic physiology training that pianists appear to have. It is very difficult in my view for instance to play in a position that the knuckle is at the same level as the PIP joint and yet 27% of participants claimed this to be the case while 19% were not sure **(Fig.34)**.









The data demonstrates that perceived sensations of speed, strength and control of the individual fingers by pianists is equally as diverse **(Fig.39-56 –** See Appendix V**)**. While I think part of the data suggests physiological differences in pianists, I also think the data points to lack of awareness. While the data show general overall trends, like the inherent belief in the overall inadequacy of the ring and little finger in piano-playing, statistically significant percentages in various choices for each category I think demonstrates also a lack of awareness of the very tools with which we work.

Of the most difficult aspects of the data to decipher were questions of sensations and movements of the various joints of the playing apparatus before and during piano-playing **(Fig. 57-71 –** See Appendix V**).** Even qualitative analysis proved somewhat inconclusive here. Anecdotally, many of the pianists confessed after completing the survey that they had the most difficulty answering this question. It suggests that possibly they have never given any thought to this question. But it is a crucial one, as force is transferred across many joints in piano-playing before it even reaches the key. Additionally, one of the knowledge gaps in piano-playing and teaching has to do with developing a vocabulary that describe the *outward movements* and the *inner sensations* felt in successful piano-playing. It is also in these joints that much of the physical discomfort and many of the injuries arise.

Qualitative analysis of the data revealed again a non-consensus across the categories. Words like "*Firm, Hard, Strong, and Tight*" and "*Relaxed, Soft, Loose and Free*" were virtually equally as popular in describing the sensations along all the joints of the playing apparatus before and during playing. This suggests that even at the elite level, opinions vary widely in what is happening internally from a physiological standpoint and externally from a movement standpoint. More in-depth analysis of the data could reveal trends. However, 3D analysis of piano-playing and inverse dynamics on joint forces already in use to study athletic movements could easily bring clarity and consensus to these questions. But a piano teacher and pianists with no access to these tools needs a standard vocabulary with which to operate and to bring awareness to these facets of piano-playing.

Is there guidance and resources within and outside the field when aspiring pianists suffer physical challenges, pain or injury?

At this point, an argument has already been made as to the prevalence of physical pain and injury amongst pianists. There is even research available that suggests that piano teachers are even more prone to injury. Therefore, teachers are seemingly always equipped to assist aspiring pianists. But medical professionals and therapists, in my view, should be equipped to fill this knowledge gap. To this end, a survey was created specifically to target medical professionals. Unfortunately, the level of participation was even poorer than that of piano teachers with only 4 participants. Insight is needed into the training of medical professionals in order to determine the kind of interactions they have had with musicians, the kind of training and experience they have in this area of medical treatment, the perceived gaps in their own training that leave them ill-equipped to assist musicians meaningfully and their own views on best practices in the prevention and treatment of pianists' injuries. Despite the lack of this information, we can deduce some things from the data collected from pianists.

Firstly, there is very little communication between pianists and medical professionals. The evidence of this is that though 39% of participants have been injured **(Fig. 22)** and 80% have experienced pain directly stemming from piano-playing **(Fig.26)**, 95% of that group have simply taken a break from the piano as their remedy of choice **(Fig.77 –** See Appendix V**)**.

Fig. 22. Participants having experienced pain from Piano Playing

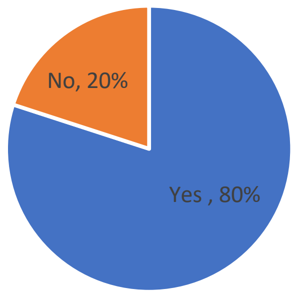
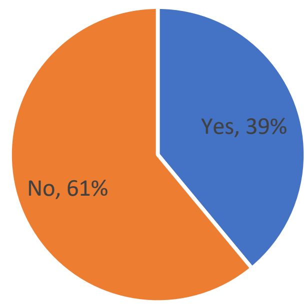


Fig. 26. Participants that have been Injured



Medical assistance ranked last on their resources of choice. When juxtaposed with the fact that 43% of those injured **(Fig. 27)** have had those injuries reoccur, this suggests that there is a great need for medical intervention and more data is needed as to why this is the case.

Fig. 27. Participants whose injury/pain reoccured

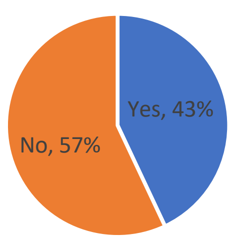
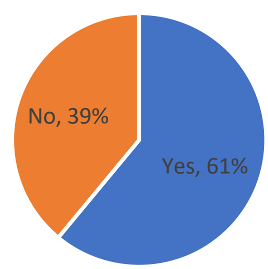
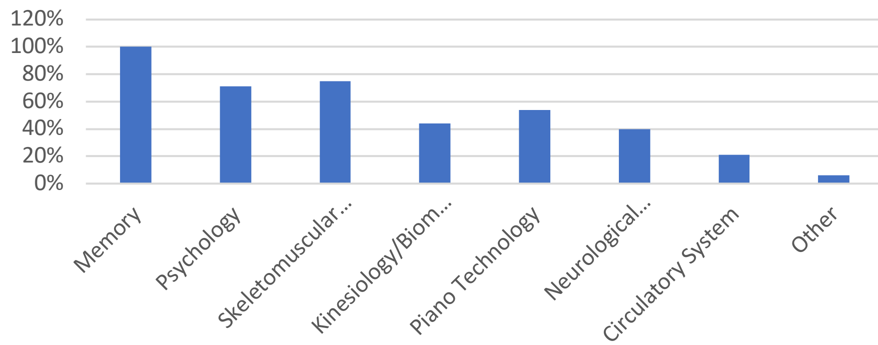


Fig. 28. Changed Technique because of pain/injury



Secondly, the data interestingly shows us that 61% of those participants tried to change something in their technical approach to piano-playing **(Fig.28)**. While inefficient technique could be a source of the injury and some retraining may indeed be necessary, it is noteworthy that this is occurring outside the purview of those that understand the human body the most. From the data, pianists do not appear to even know the parts that they are working with; only 44% of the 52% who have studied scientific areas related to piano-playing have studied biomechanics **(Fig.14)**. Admittedly, this would presuppose physicians have this training in these areas. Particularly in the case of biomechanics, it would be interesting to see if that is part of standard medical training.

Fig. 14. Piano-related areas of science/technology studied



Just a final note. In this survey study, participants were allowed to skip questions that they did not wish to answer, in addition to choosing options such as "other" and "not sure." It was interesting to note that the question skipped over the most had to do with pianists labeling their injury where we provided a list of injuries that were common. While "tendonitis" was the most popular choice, the second most popular choice was "other." In this other category, a significant percentage of pianists admitted that they did not know what the injury was called. They could only define their injury by the areas of their gross anatomy. This further suggests a lack of and a need for medical intervention. It is alarming that pianists for all of the science and technology at our disposal in this modern era are still in large part taking on the role of doctor, pharmacists and physical therapists, roles for which they are ill-equipped for and thereby seemingly doing themselves more harm than good.

Is there general agreement regarding the orientation, condition and use of the wrist and fingers in piano playing?

From both our survey data discussed so far, coupled with the historical treatises, it can generally be agreed upon that the wrist joint and fingers are the most important parts of the gross anatomy to pianists, pedagogues and teachers. However, historically there has been a lack of consensus on how they should be used. Coupled with the fact that the wrist and forearms are the ones most complained about by many of the pianists who are experiencing pain **(Fig.23-24)** and that tendonitis is the most common injury according to our data **(Fig.77-** See Appendix V**)**, it is necessary to shed light on this area.

Fig. 23. Body Areas currently in pain

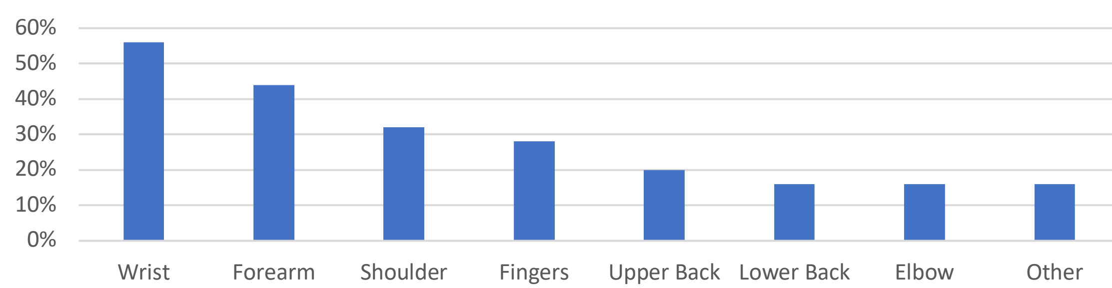
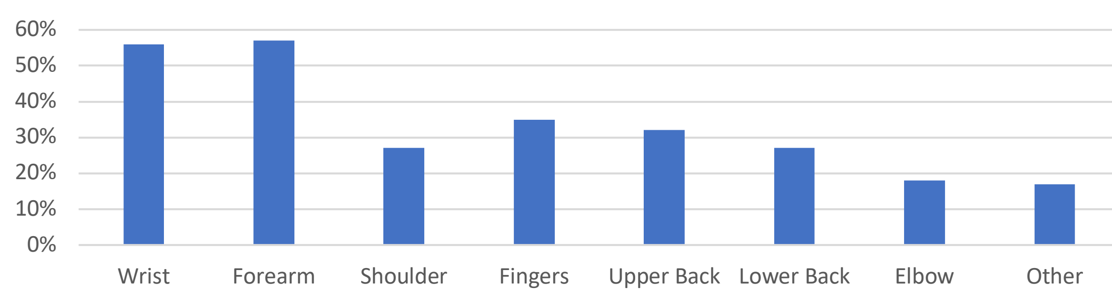
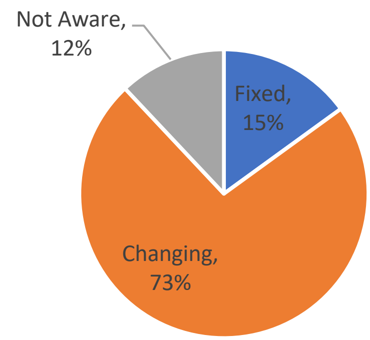


Fig. 24. Body Areas that were in pain



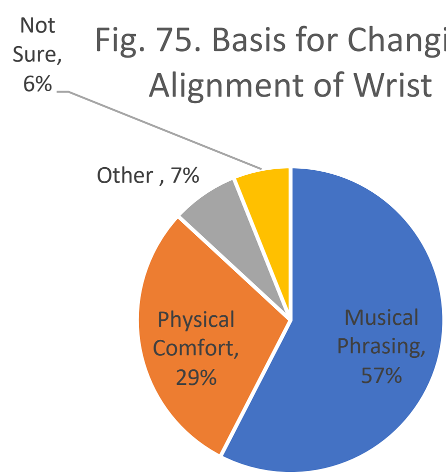
Our data reveals that 73% of pianists are consistently changing the alignment of their wrist **(Fig.73)**, finger, forearm when they are playing piano.

Fig. 73. Alignment of Wrist



This seems reasonable as the variety of movements needed to execute the vast repertoire are immense. What is very interesting however is how this alignment is selected by pianists. Though 57% of participants selected their alignment based on the musical phrasing, a significant portion of 29% selected their alignment based on physical comfort **(Fig.75)**.

Fig. 75. Basis for Changing Alignment of Wrist



It would be very interesting to separate the data to see the prevalence of injuries between these two criteria. Furthermore, we can gain further insight using tools already available in science to measure physical stresses on the various joints and muscles of the body. Our pilot study on lateral wrist orientation hopefully is the beginning of bringing such clarity to this universally important and problematic area of the playing apparatus.

Section 4: Challenges with the Survey Study

Outside of the challenges already articulated above regarding the lack of participation from various important groups, there were a number of other challenges that were not anticipated. Moving forward with such research, adjustments could be made to ensure that the data is more reliable, and participation is improved.

The length of the survey was one such challenge. Elite level pianists appear to be some of the most regimented people in the world and many simply would not participate because of the length of the survey. Additionally, many participants left the survey incomplete though the survey did allow participants to skip questions. I suspect that many questions were skipped for faster completion of the survey.

The specificity and broadness of some of the questions was another consideration. I noticed that many responses – in particular those open-ended questions varied widely in quality and in some cases demonstrated a misunderstanding of the question. On the opposite end of the spectrum, many questions were so specific that in many cases, pianists admitted that they had never thought about the questions. The body awareness and movement questions of the playing apparatus come to mind. Related to that, the use of scientific and medical vocabulary revealed a knowledge gap in pianists' understanding of the human body as well as the injuries from which they personally suffer. The question where pianists were asked to name their injuries, for instance, was answered the least in the entire survey.

Asking pianists to provide quantitative data was another challenge. Many of the questions in the survey asked pianists to provide percentages to get a sense of proportions related to areas like practicing and lesson structure. In the future, it might be more useful to get actual time averages to which quantitative analysis techniques could then be applied.

In asking participants to measure their own hand sizes, there is no way to properly know if they used the recommended tools correctly. Admittedly, the only way to really get a sense of hand size is to perform direct human subject testing which was an initial goal of this work.

The questions related to repertoire, while not specifically correlated to injury were designed to show similarities of technical challenges amongst pianists. However, these correlations cannot be properly made without analyzing the underlying biomechanics of both the pianists and the technical demands of the score itself. Again, direct human subject testing will bring more clarity to this question though the survey did demonstrate trends.

Though I was happy with the quantity of responses, there were a number of questions and statements that in hindsight, I wish were included in the survey. Some of these include:

1. What does your warmup/cool down routines consist of?

2. When describing the sensations/conditions of the parts of the playing apparatus, include aspects of weight, temperature and muscular tension.

3. When describing the movements of the parts of the playing apparatus describe its direction in reference to the body (toward, away), joint angles (increasing/decreasing) and muscular work (push/pull).

4. Are both hands suffering equally from pain/injury? Where are the differences?
5. Have you thought about this question before I asked it?

Despite these shortcomings, the data generated from this survey could be the basis for many more lines of inquiry and more detailed research going forward. I hope to publish in both performance, pedagogy, medical and science journals, as a deeper understanding of piano-playing could open understanding in areas far beyond the practice rooms, teaching studios and concert halls.

Chapter 9: Motor Control in Piano Playing: A Pilot Study of Wrist Orientation on Individual Fingers

In the domain of piano performance, the position of the musician's fingers and the orientation of the musician's wrist plays a key role in how effectively the musician can navigate a demanding piece of music to produce a performance that is both technically accurate and musically appealing. I call this effect of human physiology on piano performance our "quality" dimension. On the other hand, the rectangular shape of the piano and its immovable structure impose restrictions on how the musician can manipulate their instrument in order to avoid technical inefficiencies or long-term injuries to their body. I call this effect of the instrument's configuration the "quantity" dimension since it can impact the length of the musician's career.

One of the ways in which the human body operates most efficiently is through the concept of "ideal alignment." In other performing arts and in many athletic sports, science has revealed that performers produce more effective and efficient performance outcomes through the optimal alignment of body parts. The same holds true for pianists. In piano pedagogy, proper alignment of the fingers, wrist, lower arm, upper arm, shoulder and trunk has been anecdotally linked to efficient movement at the instrument, although there is still no consensus regarding the role of the wrist. Since the wrist is both the most mobile of these points of alignment as well as the gateway from the forearm into the hand, it possesses the potential to alter the ideal alignment of the other components of the physical apparatus. This perhaps explains why many piano-related injuries are situated in the wrist. The ideal alignment of the apparatus facilitates optimal finger strength and control; it stands to reason, therefore, that the orientation of the wrist has a direct impact on these dimensions of piano performance. Such wrist orientation can be explored both vertically and laterally in reference to any other point along the playing arm. Lateral movement of the wrist however is asymmetrical – favoring range of motion toward the ulnar rather than the radial side. It is therefore important to explore how this asymmetry impacts the fingers on an individual basis.

Aim 1a: To investigate the effects of lateral wrist orientation on maximum volume and control of fingers.

Hypothesis: I hypothesize that the thumb and index fingers will be strongest when the wrist is positioned away from the body, the middle finger will be strongest when the wrist is in a neutral position, and the fourth and fifth fingers will be strongest when the wrist is positioned toward the body.

Background: The wrist is the point in this pathway of alignment through which the extrinsic muscles of the forearm are connected to the fingers by way of tendons. It is at this point where these tendons pass through the wrist that they curve away from the straight line of the extrinsic muscles of the forearm and tendons before attaching to each finger. It is the curve of the tendons that compromises the maximum capabilities of force and control that could be exerted by each finger. Therefore, it stands to reason that the position of the wrist has a direct impact on the fingers as it relates to strength and control because changes in wrist position change the angle of the bend of each tendon. The closer a tendon can be to a straight line from the muscle to the finger, the more force can be exerted by that finger and the more stable that finger becomes.

Aim 1b: To investigate the differences between pianists and non-pianists in their finger strength and control.

Hypothesis: I hypothesize that pianists will show a higher ability in the strength and control of their fingers than non-pianists, but non-pianists will show similar trends to pianists related to the relationship of wrist position and finger strength and control.

Background: One of the goals of instrumental practice is to improve the independence of each finger both muscularly and neurologically. This is particularly so for pianists where all 10 fingers are used to produce sound. It is for this reason that most existing pedagogy utilizes a variety of exercises at the piano to achieve these ends. Non-pianists do not perform such exercises. This lack of training however does not change the underlying physiological and anatomical structures. It is unknown what is actually changing hence any differences between the two groups could be explained by the training involved in being a classical pianist.

Outline of Methodology

1. Study participants

My experimental group will comprise of classically trained pianists. My control group will comprise of non-pianists. Our power analysis shows that the number of participants in each group should be at least 11 for our statistical analysis. However, we plan to recruit 100 participants in each group considering drop-outs and other unforeseen issues.

2. Experimental design

Each participant will first sign on the consent form approved by University of Maryland IRB. They will then fill out a survey that asks general information as well as specific questions related to handedness, the number of years of training, and a history of injuries to their hands and other body parts. Those with a history of or current orthopedic injuries and neurological symptoms in upper extremities will be excluded from the study. Participants will then be asked to perform five motor tasks used typically in piano performance with each of their fingers individually (thumb, index, middle, ring and little fingers) on both hands. The same piano will be used for all subjects for consistency. These tasks are as follows:

1. Tapping the same key (C4) with the maximum force for the maximum loudness
2. 40 taps of the same key (C4) at 160 bpm
3. 40 taps of the same key (C4) at the maximum speed
4. 80 alternating taps of the same keys (C4 and D4) with all possible two-finger combinations at 320 bpm (TI, TM, TR, TL, IM, IR, IL, MR, ML, RL)
5. 80 alternating taps of the same keys (C4 and D4) with all possible two-finger combinations at the maximum speed.

Each of the tasks outlined above will be performed three times in three different wrist positions: neutral, toward the body and away from the body. Their performances will be audio recorded using Virtual Acoustic Environment Technology (Wenger Corporation; Syracuse, NY) and analyzed with respect to frequency (loudness) and time domains (consistency and speed) using LabView (National Instruments; Austin, TX).

3. Statistical analysis

Two-ways repeated measures ANOVA with two factors of GROUPS (2 levels: pianists vs. novice) and WRIST (3 levels: adduction, neutral, and abduction) for statistical analysis. The level of significance will be set at $p<.05$.

Expected Conclusion

From the wrist-finger study, I expect that the thumb and index fingers will be strongest when the wrist is away the body. As a result, those fingers will perform the various tasks at the piano best in that orientation. The ring and little finger will be strongest when the wrist is toward the body. I expect that a straight line from the extrinsic muscles of the lower arm to those particular fingers is associated with better performance through the straight tendons from the forearm to fingers. Subsequently, those fingers would be easier to control in those positions as well as capable of producing more sound by virtue of an unimpeded transfer of muscular force. From the survey study of pianists already discussed previously, it was noteworthy that very few pianists claim to use lateral wrist movement as part of their technical vocabulary. Such has also been the case, with a few exceptions, in the pedagogy of the last 300 years.

SUPPORTING MATERIALS

Fig. A

Fig. B

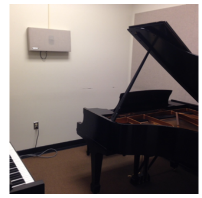


Fig. C

Fig. D

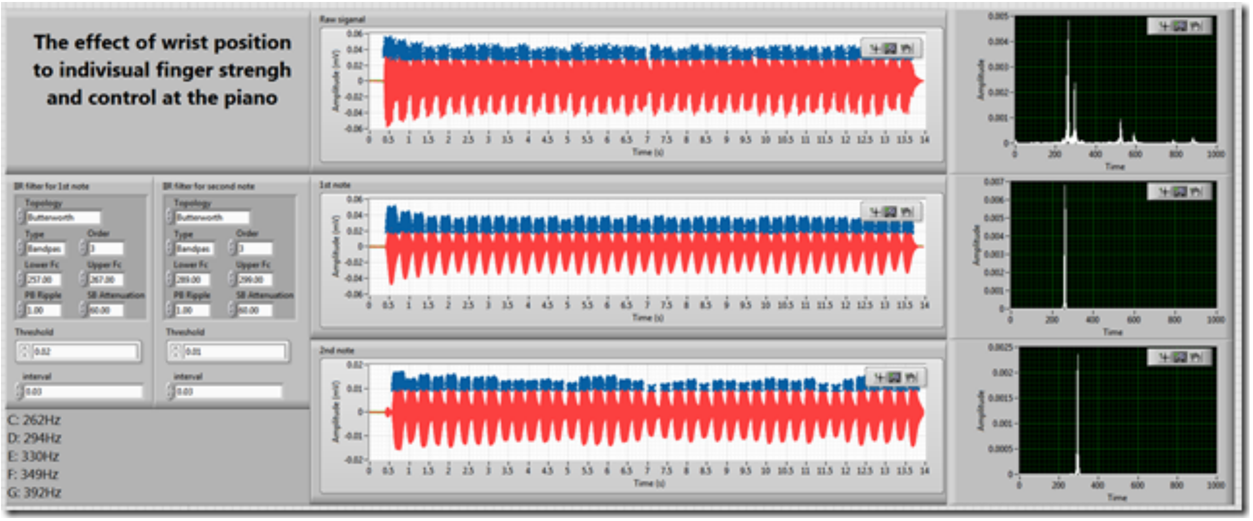
For these purposes, Room 3163 in the School of Music at the University of Maryland will be used as the lab for this study which has good sound proofing, built-in Virtual Acoustic Environment Technology as well as a Steinway B model piano.

Figure A is the piano that will be used for each person participating in the study.

Figure B is the microphone that picks up the sound produced by each subject. There are two positioned on opposite walls in this room.

Figure C is the general room setup.

Figure D is the device that records the sound files. These will be uploaded to computer for further analysis.



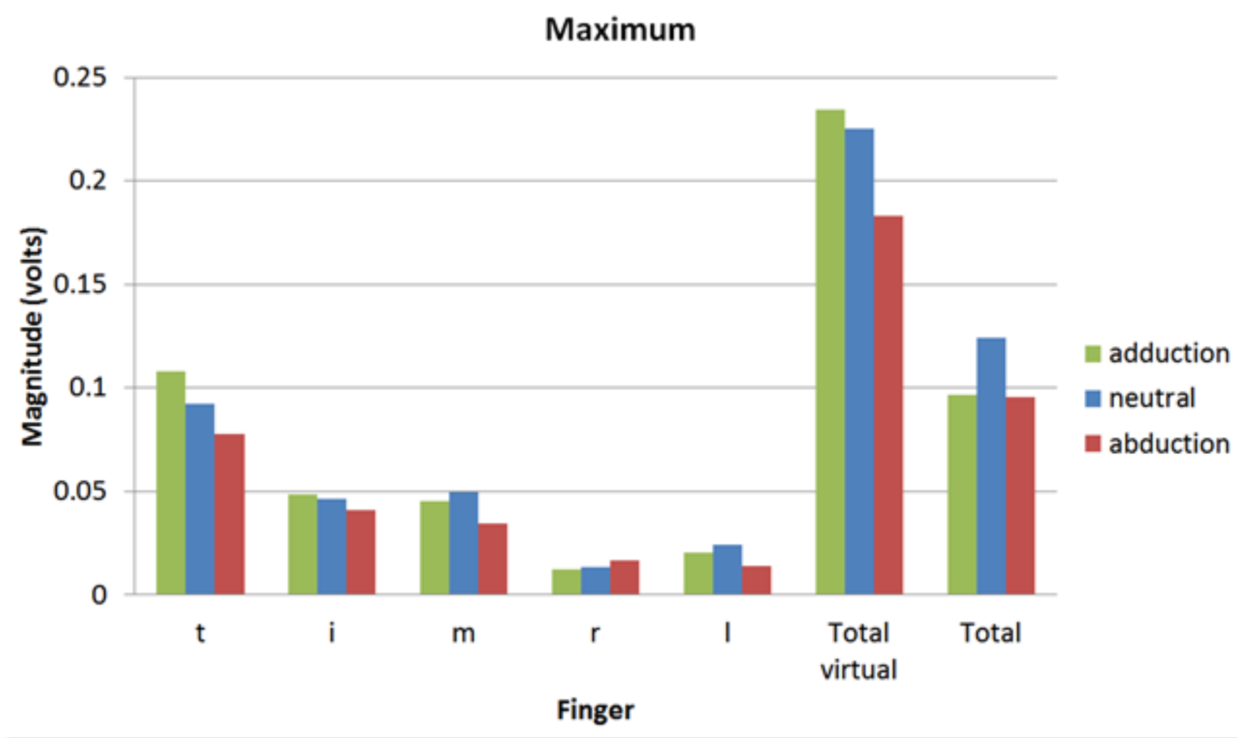
Custom LabView Software

A LabView program was written in order to analyze the data to be collected from the proposed study. The recorded auditory signals were analyzed in both time and frequency domains. Details of the software will not be described in order to protect the software designer's intellectual property.

Preliminary Data

We completed a preliminary experiment, using Task 1 to examine if the data supported any part of the hypotheses.

Condition 1: Maximum Intensity



This graph shows the maximum intensity of each finger, which was measured by the intensity of the sound produced at the piano. This shows that the thumb and index finger are able to exert the greatest force that the piano when the wrist is positioned laterally away from the body. This graph also shows the third finger is able to exert the greatest force when the wrist is in a neutral position and the ring finger is able to exert the greatest force when the wrist is positioned laterally toward the body. In each of the above conditions, it can be reasoned that by making the tendon a straighter line from the extrinsic muscles of the forearm to the respective fingers, the finger was able to exert its maximum force upon the piano and hence produce a more intense sound. Though it is a pilot study, it still reveals other trends including the relative strength of fingers and the overall impacts of a wrist orientation on the fingers overall.

Chapter 9: Conclusion

This work sought to initiate and improve the conversation around piano-playing, its pedagogy and fields that could help to advance the field that have historically not been included or considered. We have seen how non-consensus developed and continued from historical keyboard pedagogy through modern piano pedagogy. The emerging sciences have provided us with a treasure trove of information for our consideration as we reimagine piano playing and pedagogy. On the other hand, there is a treasure trove of information in studying pianistic movements for those emerging sciences. The lack of technological advances in the modern piano while living in the most technological age in history has revealed a significant gap in our understanding of the instrument as well as its limitations. The survey data collected from pianists, piano teachers and medical professionals through surveys, and a pilot study using laboratory tools to begin studying the impact of wrist orientation have shown the importance of data collection in decision making about best pedagogical and performance practices.

Section 1: Recommendations

In order to facilitate the scientific advancement of piano-playing and pedagogy, I offer the following recommendations:

1. Pianists and pedagogues, in partnership with kinesiology researchers, should commence a comprehensive scientific analysis of historical and modern piano pedagogy. It is important that we determine once and for all the jewels of wisdom contained within the over 300 years of piano pedagogical literature. It is only once we uncover which of these practices are authenticated by scientific principles that we can start the process of

building consensus, something that does not exist currently. There is no reason why the field needs to continue to operate in confusion.

2. Partnerships between pianists, pedagogues and the scientific research community need to be facilitated and supported. The disciplines of kinesiology, engineering, biomechanics and neuromechanics, amongst other fields, have a lot to offer the field of piano-playing and, by extension, instrumental performance as a whole. For example, their contributions could immediately assist us in developing a desperately needed vocabulary to describe both visible movement and the inner stresses of piano-playing. Meanwhile, piano-playing can help scientists to understand hand function in a general sense as piano-playing represents one of the most complex actions human beings can execute.

3. Partnerships need to be established between pianists, pedagogues and the medical community in developing the field of music medicine. Pianists need as many tools as other athletic pursuits in order to maintain their careers in a healthy way. Our survey data has shown a lack of trust of musicians toward medical professionals and more education and exposure on both ends would go a long way to understanding preventative and management strategies that could assist the field.

4. Partnerships need to be established between pianists, engineers and those involved technology in the reimagining of the piano's structure and function from performance, ergonomics and heath standpoints. History has shown us that even though an instrument or device works does not mean it cannot be improved. The modern acoustic piano, for all its positive qualities, is not a perfect instrument and these imperfections could be contributing to much of the challenges of piano technique and injury.

5. Partnerships need to be established with practices like Alexander Technique in order to create a culture of physical awareness making it equally important to musical awareness. Pianists, and I suspect many musicians, are not aware of what is being felt physically until it manifests itself in pain or injury. Practices like the Alexander Technique, centered in awareness of *misuse* of the human body, need to become part of the general education of musicians.

6. Pianists, piano teachers and pedagogues need courses in basic human physiology, biomechanics, injury prevention and management. It is sad that most musicians know very little about the physical tools with which they hope to make or continue their careers. A basic understanding of these areas would be of great value as it would make us more conscious and aware. It would also help us in our communication with scientific and medical partners moving forward.

7. Pianists, piano teachers and pedagogues need to create a culture of openness as it relates to pain and injury. Musicians should feel open to discuss something physically wrong, without fearing retribution from their teachers or losing opportunities for career advancement. Teachers, in turn, should not feel that an artist's injuries reflect poorly on their instruction. It is unacceptable for pianists to keep their pain and struggles silent, and for bad technique to be continually and thoughtlessly replicated. Technique should always be under consistent analysis and critique, especially given the wide repertoire of movement that every piece requires.

These recommendations will enhance the conversation between pianists, piano teachers, scientists and medical professionals and will make an enormous contribution to the field of piano pedagogy. This work and future interdisciplinary collaborations will further the discussion of piano pedagogy with a view towards the ultimate improvement of musical outcomes and the reduction of pain and injury. I believe the concept of ideal alignment in the pianistic context is a novel one and one that is a beginning to uncover many of the challenges of piano technique. A study involving pianists as human subjects would be one of only a few existing pedagogical studies that help authenticate concepts already understood in the fields of human physiology. Furthermore, such a study would deepen the concept of body alignment from a more general concept to being specific to wrist orientations at the piano. With new understanding, new pedagogical approaches could be developed, and more established ones strengthened that emphasize this newfound knowledge. By extension, this knowledge would also help to stem the tide of injuries at the wrist joint, because it would improve our understanding of the mobility required at the wrist joint in order to achieve optimal strength and control of each finger. More interdisciplinary efforts between musicians and scientists would also improve our understanding of wrist and hand function in a novel way, both in the context of instrumental performance and beyond.

Section 2: Practical Advice for Pianists and Teachers

Finally, I wish to offer some practical advice to pianists and teachers that are based on the findings and claims purported in this document. This list is nowhere near as exhaustive as it needs to be. Rather, it is a beginning to developing a comprehensive toolbox that pianists and teachers can apply directly within the particular contexts of their practice sessions, lessons, performances and self-care.

1. Piano-playing and pedagogy must begin with one's own body first. The repertoire can only be executed to the degree the pianists and the teacher has an

understanding of the anatomical, physiological and biomechanical traits with which they themselves possess. Particular attention must be given to areas inclusive of relative finger lengths, range of motion, flexibility of wrist joint and discrepancies between the right and left arms in terms of both structure and function.

2. Develop a regular warmup and cooldown routine. This involves activities both at the piano and away from the piano. Just like the muscles of elite athletes, the skeletomuscular tools involved in piano-playing need to be prepared for and recovered from.

3. Take breaks at regular intervals during practice sessions. One of the physiological disadvantages that pianists have, and by extension most instrumentalists, is the lack of blood supply to the most active body parts involved in playing. This means that metabolic waste products being produced in those areas of the anatomy are being cleared more slowly in comparison to more traditional athletic pursuits. This leaves those areas more easily susceptible to fatigue and tension. In fact, pianists should take relatively longer breaks in comparison to most traditional athletic pursuits. The prevalence of injuries in the extremities of not only pianists, but also those whose work involves significant use of technological devices, serves as evidence to this.

4. Engage in exercise and other non-piano activities that could benefit piano-playing but the body as a whole. Such practice like Alexander Technique, Feldenkrais and Yoga would certainly aid in increased proprioceptive awareness and flexibility. In addition, carefully targeted exercises geared toward strengthening various parts of the playing arm would assist in increasing dynamic range and delay the onset of fatigue in certain instances.

5. Have a healthy and balanced diet. Just as targeted nutrition contributes to optimal performance in elite athletics, it is equally as crucial in piano-playing. Of particular importance to the nutrition of a pianist are those foods and nutrients that strengthen and maintain the central and peripheral nervous systems. Motor control in piano-playing is predominantly neuromechanical in nature so the ability of neurons to fire correlates to control of musical areas like timing and dynamics. Nutrition that promotes increased blood flow is also important as there is less vascularization of the most active areas of the playing apparatus.

6. Become familiar with the scientific disciplines of anatomy, physiology and kinesiology with particular attention to the active areas of the playing apparatus. There are many scientific textbooks available that pianists can consult to advance their understanding in this area. This would assist in improving the clarity of communication between pianists, teachers and medical professionals.

7. Understand the peculiarities of the instruments that one is about to play on. Unfortunately for aspiring pianists, our success is largely determined by the proper mechanical and sonic functioning of the instrument. Before diving into repertoire, pianists should go through the instrument note by note to get a sense of the balance of the registers both in terms of sound production and weight. Such information is crucial in order to modify one's technical approach as well as tempering one's musical expectations – particularly in performance.

8. Have an 'off-season' period throughout a performance or teaching year. This is important both from a physiological and mental standpoint. The energy output that is put into preparation and performance is enormous. Therefore, I believe that the body and mind need time to rejuvenate from the heights of peak performance and teaching. Elite

athletes train for periods to peak for a short window of important performances and then go into off-season – a period where all training and competition ceases. How much more should we as musicians, who aim to peak for every single performance, take a similar break when we arguably tax both the body and the mind equally?

Much of the knowledge developed would be transferable to the pedagogical development of not only other instruments but other areas where fine motor skills are required like typing, swiping, painting and writing. Additionally, instruments and other technological devices that are high-quality, ergonomic and efficient would then be developed. But the work must commence with understanding the inherent possibilities and limitations of the hand itself. For these reasons, I believe that piano-playing stands alone as representing the pinnacle of complexity for finger-wrist orientation, condition and movement while also being the gateway for understanding so much more that makes us human.

Appendix I: Dates of Important Composers, Performers and Pedagogues

Bach, Johann Sebastian (1685-1750)

Bacon, Ernst (1898-1990)

Beethoven, Ludwig Van (1770-1827)

Brahms, Johannes (1833-1897)

Breithaupt, Rudolf Maria (1873-1945)

Caland, Elizabeth (1862-1929)

Chopin, Frederic (1810-1849)

Clementi, Muzio (1752-1832)

Couperin, Francois (1668-1733)

Cramer, Johann Baptist (1771-1858)

Czerny, Carl (1791-1857)

Deppe, Ludwig (1828-1890)

Diruta, Girolamo (1554-1610)

Fay, Amy (1844-1928)

Fleisher, Leon (b. 1928)

Forkel, Johann Nikolaus (1749-1818)

Friedham, Arthur (1859-1932)

Gabrilowitsch, Ossip (1878-1936)

Goode, Richard (b. 1943)

Gould, Glen (1932-1982)

Haydn, Franz Joseph (1732-1809)

Hipkins, Alfred James (1826-1903)

Hoffmann, Joseph (1876-1957)

Horowitz, Vladmir (1903-1989)

Hummel, Johann Nepomuk (1778-1837)

Lang, Lang (b. 1982)

Leschetizky, Theodore (1830-1915)

Lhevinne, Rosina (1880-1976)

Limon, Jose (1908-1972)

Liszt, Franz (1811-1886)

Matthay, Tobias (1858-1945)

Mendelssohn, Felix (1809-1847)

Mozart, Wolfgang Amadeus (1756-1791)

Ortmann, Otto (1889-1979)

Pratt, Awadagin (b. 1966)

Prentice, Thomas Ridley (1842-1895)

Rachmaninoff, Sergei (1873-1943)

Rameau, Jean-Philippe (1683-1764)

Sauer, Emil Von (1862-1942)

Schick, Robert D. (1929-1997)

Schultz, Arnold (1903-1972)

Schumann, Clara (1819-1896)

Schumann, Eugenie (1851-1938)

Schumann, Robert (1810-1856)

Scriabin, Alexander (1871-1915)

Taubmann, Dorothy (1917-2013)

Taylor, Franklin (1843-1919)

Vengerova, Isabelle (1877-1956)

Whiteside, Abby (1881-1956)

Wieck, Frederic (1785-1873)

Appendix II: Survey For Pianists

Introduction and Consent

The purpose of this study is to evaluate the current state of training in piano performance and pedagogy with regards to the medical, biomechanical, proprioceptive and psychological aspects of your craft to shed light on any available resources that could provide improvement in this area. This survey should take between 10-15 minutes to complete and is completely voluntary. You may choose to stop at any time if you wish to do so. There are no known risks associated with the completion of this survey. We will ask you to provide answers to questions about your craft as well as personal information such as age and location, however, individual responses will be recorded under a randomly assigned ID number in order to better protect your privacy. At the conclusion of the survey you will be given the option to provide your contact information for future participation in piano performance and pedagogy research conducted at the University of Maryland. You are not required to provide any information but if you do choose to do so, all personal information will be stored in a separate password protected file and will not be used for any additional purposes aside from contacting you about participation in future studies.

If you have any questions or concerns regarding this survey study please feel free to contact the principal investigator of this study or the University of Maryland IRB listed below.

Principal Investigator
Dion Cunningham
dcunni14@umd.edu

University of Maryland College Park
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College Park, Maryland, 20742
Email: irb@umd.edu
Telephone: 301-405-0678

Do you wish to continue with this survey?
a) YES
b) NO

Please state your gender
a) Male
b) Female
c) Other

Please state your age. (Give a numerical answer)

Please state your height. (Give a numerical answer in feet and inches)

Please state your weight. (Give a numerical answer in pounds.)

Please state your race.
a) White
b) Asian
c) Black
d) Hispanic
e) American Indian
f) Pacific Islander
g) Other___________________

Please state your city and state/country of residence.

Please state your handedness:
a) Left
b) Right
c) Equal

What is the length of your hand in comparison to the length of a US dollar bill? (Measure palm-side where the flesh of your palm meets the skin of your wrist to the tip of the little finger)
a) shorter
b) longer
c) as long

What is the distance from the tip of your outstretched thumb to the tip of your little finger in comparison to the length of a US dollar bill? (Measure palm-side from tip of thumb to the tip of your pinky)
a) shorter
b) longer
c) as long

What is the width of the palm of your hand in comparison to the long side of a debit card? (Measure palm-side at knuckle joint from index to little finger)
a) shorter
b) longer
c) as long

Training in Piano

How many years have you studied piano? (Enter value in years)

What standardized piano-playing assessment system(s) have you used in your training?
a) ABRSM
b) Trinity College of London
c) USMCE
d) RACE
e) Other

What grade level did you achieve in the respective system (Please enter a numerical answer.)

What degree in piano have you achieved?
a) Bachelor
b) Master's
c) DMA
d) Performance Diploma
e) Artist Diploma,
f) Other _______________

List the THREE most challenging etudes technically that you have performed.

List the THREE most challenging sonatas or other large scale works technically that you have performed.

List the TWO most challenging concerti you have performed.

How many piano teachers have you had over the course of your training? (Enter numerical value)

How many of your teachers would you consider to be technicians or technique-focused?

Select the components of a typical LESSON STRUCTURE with your current piano teacher.
a) warming up
b) technique/technical exercises
c) repertoire
d) cool down
e) other__________

Of those components selected, give the PERCENTAGE OF TIME devoted to each area.

On average, how many hours do you spend practicing on a daily basis? (Enter numerical value)

Select the components of your typical PRACTICE STRUCTURE:
a) warming up
b) technique/technical exercises

c) repertoire
d) breaks
e) cool down
f) other___________

Of those components selected, give the PERCENTAGE OF TIME devoted to each area.

Are you currently doing any exercises, training or activities AWAY FROM THE PIANO on a CONSISTENT BASIS specifically to aid your piano playing?
a) YES
b) NO

If YES, describe them and state the frequency (eg. hrs per day/week/month)

Have you done any exercises, training or activities AWAY FROM THE PIANO AT ANY POINT in your training specifically to aid your piano playing?
a) YES
b) NO

If YES, describe them.

In your piano training, have you studied areas of biology, physiology, psychology or piano technology?

If YES, please select the setting.
a) Private Piano Teachers,
b) Academic/Conservatory Courses
c) Workshops
d) Independently
d) Other

If YES, select the areas you have studied within the context of your piano training:
a) Skeletomuscular systems
b) Neurological systems
c) Circulatory systems
d) Kinesiology and Biomechanics
e) Psychology
f) Memory
g) Piano Technology
h) Other

Pain and Injuries

Are you CURRENTLY experiencing physical discomfort or pain while playing the piano or as a result of playing the piano?
a) YES
b) NO

IF YES, select the areas of YOUR body where physical discomfort or pain is felt while playing the piano or as a result of playing the piano.
a) fingers
b) wrists
c) forearm
d) elbow
e) upper arm
f) shoulder joint
g) chest
h) upper back
i) lower back
j) other _________________

Of those areas selected, list the areas of the body next to the sensations that best describe the discomfort or pain felt.
a) Achy
b) Burning
c) Cramping
d) Dull
e) Heaviness
f) Radiating
f) Soreness
g) Spasms
h) Stinging
i) Shooting
j) Stiffness
k) Stabbing
l) Tenderness
m) Tingling
n) Tightness

Have you experienced discomfort while playing piano AT ANY POINT IN YOUR PIANO-PLAYING HISTORY?

IF YES, select the areas of YOUR body where physical discomfort or pain is felt while playing the piano or as a result of playing the piano.
a) fingers
b) wrists
c) forearm
d) elbow
e) upper arm
f) shoulder joint
g) chest
h) upper back
i) lower back
j) other _________________

Are you CURRENTLY injured (<u>Definition:</u> discomfort or pain that impedes or halts your ability to play)?
g) YES
h) NO

If YES, describe your injury/injuries from the list below.
a) Carpal Tunnel Syndrome
b) Tendinitis
c) Bursitis
d) Tenosynovitis/DeQuervain's Syndrome
e) Tendinosis
f) Thoracic Outlet Syndrome
g) Myofascial Pain Syndrome
h) Cubital Tunnel Syndrome, and
i) Trigger Finger/Thumb
j) Other

From your selection, state how long you have had the injury. (Give a numerical answer and select the category).
A) weeks
B) months
C) years

Have you had an injury AT ANY POINT IN YOUR PLAYING HISTORY?
a) YES
b) NO

If YES, describe from the list below.
a) Carpal Tunnel Syndrome
b) Tendinitis
c) Bursitis
d) Tenosynovitis/DeQuervain's Syndrome
e) Tendinosis
f) Thoracic Outlet Syndrome
g) Myofascial Pain Syndrome
h) Cubital Tunnel Syndrome, and
i) Trigger Finger/Thumb
j) Other

Describe how you are managing (or managed) your discomfort/pain or injury.
a) Medication
b) Home Remedies
c) Therapy
d) Break from piano
e) Quitting piano
f) Other_______________

Are you changing (did you change) anything in your piano playing technique as a result of experiencing discomfort/pain or injury?
a) YES
b) NO
If YES, describe.

Is the discomfort/pain or injury a reoccurring one (has it ever reoccurred)?
a) YES
b) NO

Did you talk to anyone or about your past or present discomfort/pain or injury?
A) YES
B) NO

If YES, select the people you talked to.
a) Friends/Family
b) Other Pianists
c) Piano Teachers
d) Physicians/Medical Professionals
e) Other

In your training, have you studied areas related to INJURY PREVENTION in piano playing?
a) YES
b) NO

If YES, select the settings in which this study has this taken place:
a) University/Conservatory Courses
b) Private Lessons with piano teacher
c) Medical/Health Related Seminars and Workshops
d) Independently
e) Other

In your training, have you studied areas related to INJURY MANAGEMENT?
a) YES
b) NO

If YES, select the settings in which this study has this taken place:
a) University/Conservatory Courses
b) Private Lessons with piano teacher
c) Medical/Health Related Seminars and Workshops
d) Independently
e) Other

Body Awareness at the piano

Select the areas of the body that you believe are important to piano playing?
a) fingers
b) wrists
c) forearms
d) upper arm
e) shoulders
f) back
g) chest
h) neck
i) hips
j) knees
k) ankles
l) feet
m) other __________

Which areas of the body that you are CONSISTENTLY AWARE OF while in the act of piano- playing?
a) fingers
b) wrists
c) forearms
d) upper arm
e) shoulders
f) back
g) chest
h) neck
i) hips
j) knees
k) ankles
l) feet
m) none
n) other __________

When playing the piano, the height of your elbow is:
a) at key level
b) above key level
c) below key level
d) not sure

When playing the piano, your wrist joints are:
a) at the same height as your elbow
b) above the height of your elbow
c) below the height of your elbow
d) not sure

Your wrist joints when playing the piano are:
a) at the same height level as your knuckle joint

b) above the height level of your knuckle joint
c) below the height level of your knuckle joint
d) not sure

Your knuckle joints when playing the piano are:
a) at the same level as your proximal (nearest finger joint) finger joint
b) above the level of your proximal finger joint
c) below the level of your proximal finger joint
d) not sure

The condition of your distal finger joints (joint closest to finger tips) when playing the piano are:
a) neutral
b) curved
c) collapsed (caving inward)
d) not sure

Do your hands feel equally strong when playing?
a) YES
b) NO

If NO, which hand feels strongest?
a) LEFT
b) RIGHT

Do your fingers feel equally strong when playing?
a) YES
b) NO

If NO, rank your fingers from strongest (1) to weakest (5).
a) Thumb
b) Index
c) Middle
d) Ring
e) Little

Do your fingers feel equally fast when playing?
i) YES
j) NO

If not, rant your fingers from fastest (1) to slowest (5)

Do you have equal control over each finger?
a) YES
b) NO

If not, rank your fingers from easiest (1) to hardest to control (5)

When playing, do the piano keys feel:
a) light
b) heavy
c) other

Describe the physical condition of the following AS YOU ARE ABOUT TO PLAY THE PIANO (just prior to playing) (e.g. firm, relaxed, stiff, limp, tight, hard, soft, unstable, strong, weak, loose, light, heavy, etc.):
a) fingertips
b) finger joints
c) wrist joint
d) forearm
e) elbow

Describe the sensations felt in the following DURING PIANO PLAYING (same descriptors as previous questions as a guide):
a) fingertips
b) finger joints
c) wrist joint
d) forearm
e) elbow

Describe the movements used of the following while playing (vertical – up and down, lateral - side to side, rotary, pendulum-like, etc.):
a) fingertips
b) finger joints
c) wrist joint
d) forearm
e) elbow

Would you describe the alignment of your fingers to wrists when playing as:
a) fixed
b) constantly changing
c) Not sure

If YES to a) describe how it is fixed.
a) neutral
b) Oriented toward the thumb
c) Oriented toward the little (5^{th}) finger

If YES to b) what determines the alignment?
k) physical comfort
l) musical phrasing
m) other____________
d) Not sure

Is your seat height at the piano:
a) always fixed

b) always movable
c) not sure

Are you interested in providing your contact information for participation in future studies?
a) YES
b) NO

Please provide the following information so we may contact you for participation in future research studies. This information will not be used for any purpose aside from research purposes.

Name

Email

Appendix III: Survey For Piano Teachers

Introduction and Consent

The purpose of this study is to evaluate the current state of training in piano performance and pedagogy with regards to the medical, biomechanical, proprioceptive and psychological aspects of your craft to shed light on any available resources that could provide improvement in this area. This survey should take between 10-15 minutes to complete and is completely voluntary. You may choose to stop at any time if you wish to do so. There are no known risks associated with the completion of this survey. We will ask you to provide answers to questions about your craft as well as personal information such as age and location, however, individual responses will be recorded under a randomly assigned ID number in order to better protect your privacy. At the conclusion of the survey you will be given the option to provide your contact information for future participation in piano performance and pedagogy research conducted at the University of Maryland. You are not required to provide any information but if you do choose to do so, all personal information will be stored in a separate password protected file and will not be used for any additional purposes aside from contacting you about participation in future studies.

If you have any questions or concerns regarding this survey study please feel free to contact the principal investigator of this study or the University of Maryland IRB listed below.

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Telephone: 301-405-0678

Do you wish to continue with this survey?
a) YES
b) NO

Please state your gender
a) Male
b) Female
c) Other

Please state your age. (Give a numerical answer)

Please state your height. (Give a numerical answer in feet and inches)

Please state your weight. (Give a numerical answer in pounds.)

Please state your race.
a) White
b) Asian
c) Black
d) Hispanic
e) American Indian
f) Pacific Islander
g) Other___________________

Please state your city and state/country of residence.

Please state your handedness:
a) Left
b) Right
c) Equal

What is the length of your hand in comparison to the length of a US dollar bill? (Measure palm-side where the flesh of your palm meets the skin of your wrist to the tip of the little finger)
a) shorter
b) longer
c) as long

What is the distance from the tip of your outstretched thumb to the tip of your little finger in comparison to the length of a US dollar bill? (Measure palm-side from tip of thumb to the tip of your pinky)
a) shorter
b) longer
c) as long

What is the width of the palm of your hand in comparison to the long side of a debit card? (Measure palm-side at knuckle joint from index to little finger)
a) shorter
b) longer
c) as long

Teaching Experience and Practice

How many years have you been playing the piano? (Enter a numerical value)

How many years have you been performing as a pianist? (Enter a numerical value)

How many years have you been teaching? (Enter a numerical value)

How many masterclasses have you participated in as a student: (Enter a numerical value)

How many masterclasses have you participated in as a facilitator? (Enter a numerical value)

How many hours do you spend teaching per day? (Enter a numerical value)

Do you generally play with and/or for your students during these lessons?
n) YES
o) NO

As a teacher, would you consider yourself a technician or technique-focused?
a) YES
b) NO

Select the areas that best describe your pedagogical priorities in your piano lessons:
a) problem solving
b) score analysis
c) aurally analysis
d) historical performance practice
e) emotion/feeling/mood
f) technique
g) other________________
h) Not sure

How many hours do you recommend to your students that they should practice within a day? (Enter a numerical value)

How many days do you recommend to your students that they should practice within a week? (Enter a numerical value)

Do you have a recommended practice procedure or activity breakdown you give to students for their practicing?
a) YES
b) NO

If YES, describe up to 5 procedures/activities you recommend.

Select the important physical aspects that you believe are important to a good piano technique. Briefly elaborate on any of the points below.

a) Relaxation
b) Posture
c) Independence
d) Power/Strength
e) Speed
f) Touch
g) Physical structure
h) Other_______________

Do you recommend students do other exercises/training/activities away from the piano SPECIFIALLY TO AID THEIR PLAYING?

a) YES
b) NO

If YES, describe up to 5 of these activities you recommend.

Over the course of your career, have any of your students discussed with you concerns regarding discomfort, pain or injuries related to piano playing?

a) YES
b) NO

If YES, about what percentage of your students discuss such concern on a yearly basis?

IF YES, select the areas of the body that your students have complained about having physical discomfort or pain.

a) fingers
b) wrists
c) forearm
d) elbow
e) upper arm
f) shoulder joint
g) chest
h) upper back
i) lower back
j) other _________________

What do you recommend to your students if they are experiencing pain/injury?

a) Rest
b) Home remedies
c) Medication/Pharmaceuticals
d) Seeing a physician
e) Exercises/Stretches
f) Stop piano-playing for a period
g) Quit Plan
h) Other_____________

Is body awareness an essential component of your lessons and pedagogy?
a) YES
b) NO

If YES, select the common areas in the body that you remind students to be aware of.
a) fingers
b) wrists
c) forearms
d) upper arm
e) shoulders
f) back
g) chest
h) neck
i) hips
j) knees
k) ankles
l) feet
m) none
n) other __________

Have you studied aspects of biology, physiology, psychology or piano machine mechanics related to piano-playing?
a) YES
b) NO

IF YES, in what setting and the key concepts learned?
a) University/College course
b) University/College seminar
c) Health/Medical seminar or workshop
d) Private Teacher
e) Independently
f) Other_______________

If YES, is this information an essential aspect of your lessons and pedagogy?
a) YES
b) NO

If YES, select the areas you focus on within the context of your piano lessons with students:
a) Skeletomuscular systems
b) Neurological systems
c) Circulatory systems
d) Kinesiology and Biomechanics
e) Psychology
f) Memory
g) Piano Technology
h) Other

Have you studied injury prevention?
a) YES
b) NO

If YES, in what setting and describe up to 5 key concepts learned?
a) University/College course
b) University/College seminar
c) Health/Medical seminar or workshop
d) Private Teacher
e) Independently
f) Other_______________

Select the injuries that you have knowledge of or experience in as a result of such study.
a) Carpal Tunnel Syndrome
b) Tendinitis
c) Bursitis
d) Tenosynovitis/DeQuervain's Syndrome
e) Tendinosis
f) Thoracic Outlet Syndrome
g) Myofascial Pain Syndrome
h) Cubital Tunnel Syndrome
i) Trigger Finger/Thumb
j) Other_____________________

Do you REQUIRE your students to study aspects of biology, physiology, psychology or piano machine mechanics related to piano-playing?
a) YES
b) NO

Do you ENCOURAGE your students to study aspects of biology, physiology, psychology or piano machine mechanics related to piano-playing?
a) YES
b) NO

Are you interested in providing your contact information for participation in future studies?
a) YES
b) NO
Please provide the following information so we may contact you for participation in future research studies. This information will not be used for any purpose aside from research purposes.

Name

Email

Appendix IV: Survey For Medical Professionals

Introduction and Consent

The purpose of this study is to evaluate the current state of training in piano performance and pedagogy with regards to the medical, biomechanical, proprioceptive and psychological aspects of their craft to shed light on any available resources that could provide improvement in this area. This survey should take between 10-15 minutes to complete and is completely voluntary. You may choose to stop at any time if you wish to do so. There are no known risks associated with the completion of this survey. We will ask you to provide answers to questions about your craft, history with pianists and other musicians as well as personal information such as age and location, however, individual responses will be recorded under a randomly assigned ID number in order to better protect your privacy. At the conclusion of the survey you will be given the option to provide your contact information for future participation in piano performance and pedagogy research conducted at the University of Maryland. You are not required to provide any information but if you do choose to do so, all personal information will be stored in a separate password protected file and will not be used for any additional purposes aside from contacting you about participation in future studies.

If you have any questions or concerns regarding this survey study please feel free to contact the principal investigator of this study or the University of Maryland IRB listed below.

Principal Investigator
Dion Cunningham
dcunni14@umd.edu

University of Maryland College Park
Institutional Review Board Office
1204 Marie Mount Hall
College Park, Maryland, 20742
Email: irb@umd.edu
Telephone: 301-405-0678

Do you wish to continue with this survey?
a) YES
b) NO

Please state your gender
a) Male
b) Female
c) Other

Please state your age. (Give a numerical answer)

Please state your height. (Give a numerical answer in feet and inches)

Please state your weight. (Give a numerical answer in pounds.)

Please state your race.
a) White
b) Asian
c) Black
d) Hispanic
e) American Indian
f) Pacific Islander
g) Other___________________

Please state your city and state/country of residence.

Practice and Experience with Musicians and Pianists

How many years have you been practicing in this area of specialty? (Enter a numerical value)

How many musicians do you treat on average per year? (Enter a numerical value)

From your practice, select the musical instrumentalists have you seen the most frequently for discomfort/pain/injury.
a)
b)
c)
d)
e)

From your selection, select the 3 most common injuries/ailments for each instrumentalist
a) Carpal Tunnel Syndrome
b) Tendinitis
c) Bursitis
d) Tenosynovitis/DeQuervain's Syndrome
e) Tendinosis
f) Thoracic Outlet Syndrome
g) Myofascial Pain Syndrome
h) Cubital Tunnel Syndrome, and
i) Trigger Finger/Thumb
j) Other_______________

OF PIANISTS that you've seen in your practice, select the areas on the body that seem to be the most problematic.
a) fingers
b) wrists
c) forearm

d) elbow
e) upper arm
f) shoulder joint
g) chest
h) upper back
i) lower back
j) other _________________

Select the most common piano-related injuries seen in your practice.
a) Carpal Tunnel Syndrome
b) Tendinitis
c) Bursitis
d) Tenosynovitis/DeQuervain's Syndrome
e) Tendinosis
f) Thoracic Outlet Syndrome
g) Myofascial Pain Syndrome
h) Cubital Tunnel Syndrome, and
i) Trigger Finger/Thumb
j) Other

Of the injuries selected, what are the common treatments you've recommended for each injury?

Of the pianists treated, what percentage are returning/repeat patients to your practice? (Enter a numerical value)

From your experience in treating pianists, rank the following underlying root causes that IN YOUR PROFESSIONAL OPINION are the cause of injuries:
p) Physical structure
q) Disease
r) Genetic predispositions
s) Incorrect training
t) Over practicing
u) Fatigue
v) Other

On a scale of 1-10, rank your knowledge of the biomechanics of piano playing.

Have you studied the biomechanics of ANY MUSICAL INSTRUMENT?
a) YES
b) NO

If YES, please list the instruments.

Do you believe that musical instrument biomechanics should be part of medical/therapeutic training?
a) YES
b) NO

If NO, what training is being given in medical study that afforded medical professionals similar knowledge in this area?

In your medical studies, did you have training specifically targeted to pianists' injuries?
a) YES
b) NO

If NO, do you believe that such study would have enhanced your abilities?
a) YES
b) NO

If NO, what training is being given in medical study that afforded medical professionals similar knowledge in this area?

Have you studied pianists' injuries specifically in ANY FORUM?
w) YES
x) NO

If YES, select the settings in which this has taken place.
a) University/College course
b) University/College seminar
y) Health/Medical seminar/workshop
z) Private Tutor
aa) Independently
bb) Other_______________

Are you interested in providing your contact information for participation in future studies?
a) YES
b) NO

Please provide the following information so we may contact you for participation in future research studies. This information will not be used for any purpose aside from research purposes.

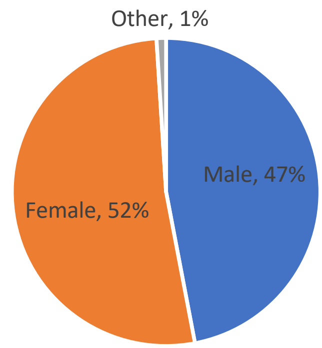
Name

Email

Appendix V: Results of Survey For Pianists

<u>*Section 1: Demographical Data*</u>

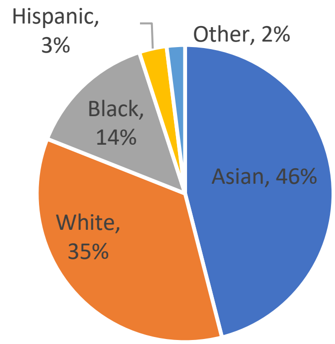
Fig. 1. Participants By Gender



Survey Question
Please state your gender
a) Male
b) Female
c) Other

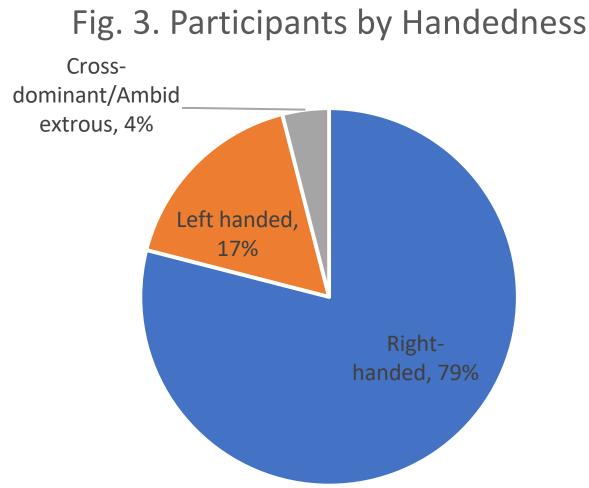
Fig.1. This figure describes the demographics of participants according to their selected gender. Percentages were calculated based on the number of participants answering this question. Females participants at 52% only slightly outnumbered male participants at 47%.

Fig. 2. Participants by Race



Survey Question
Please state your race.
a) White
b) Asian
c) Black
d) Hispanic
e) American Indian
f) Pacific Islander
g) Other

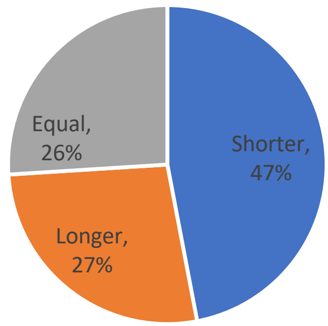
Fig.2. This figure describes the demographics of participants according to their selected race. Percentages were calculated based on the number of participants answering this question. Participants identifying as Asian at 47% outnumbered those identifying as White (35%), Black (14%) and Hispanic (3%).



Survey Question
Please state your handedness:
a) Left
b) Right
c) Equal

Fig.3. This figure describes the demographics of participants according to their handedness. Percentages were calculated based on the number of participants answering this question. Participants identifying as right-handed (79%) far outnumbered those identifying as left-handed (17%) and ambidextrous/cross dominant (4%). There are many interesting lines of inquiry that this particular result brings up i.e. dominant handedness/repertoire correlations, RH/LH neuromechanical development and injury correlations.

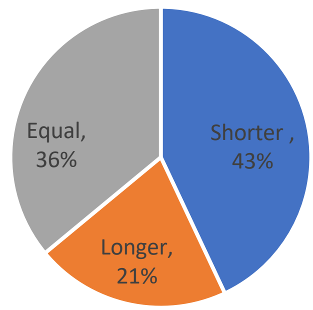
Fig. 4. Participants by Hand Length compared to length of 2 adjacent credit/ID cards



Survey Question
What is the length of your hand in comparison to the length of 2 debit card/id lengths? (Measure palm-side where the flesh of your palm meets the skin of your wrist to the tip of the little finger)
cc) shorter
dd) longer
ee) as long

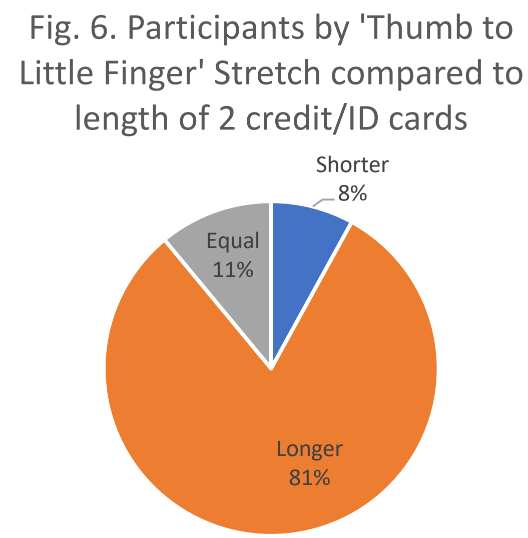
Fig.4. This figure describes participants according to the length of their hand when compared to the length of 2 credit/id cards. Percentages were calculated based on the number of participants answering this question. Participants describing their hand length as shorter (47%) virtually doubled those claiming their hand was longer (27%) or as long (26%).

Fig. 5. Participants by Palm Width compared to length of 1 credit/ID card



Survey Question
What is the distance from the tip of your outstretched thumb to the tip of your little finger in comparison to the length of a US dollar bill? (Measure palm-side from tip of thumb to the tip of your pinky)
a) shorter
b) longer
c) as long

Fig. 5. This figure describes participants according to the reach/stretch of their hands when compared to the length of 2 credit/id cards. Percentages were calculated based on the number of participants answering this question. Participants describing their reach as longer (81%) far outnumber those describing their reach as shorter (8%) or as long (11%).

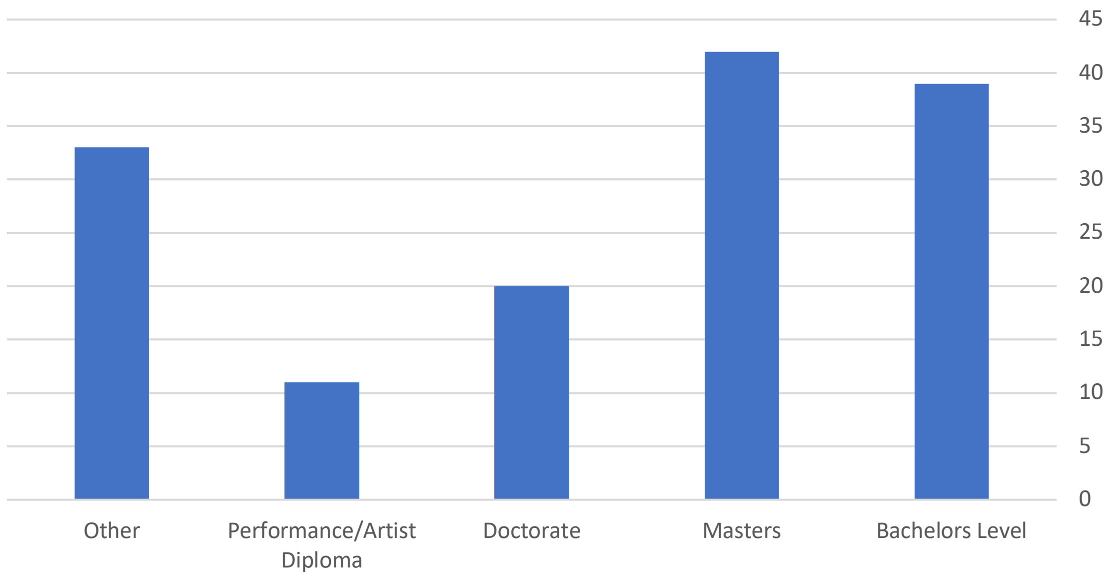


Survey Question
What is the width of the palm of your hand in comparison to the long side of a debit card? (Measure palm-side at knuckle joint from index to little finger)

d) shorter
e) longer
f) as long

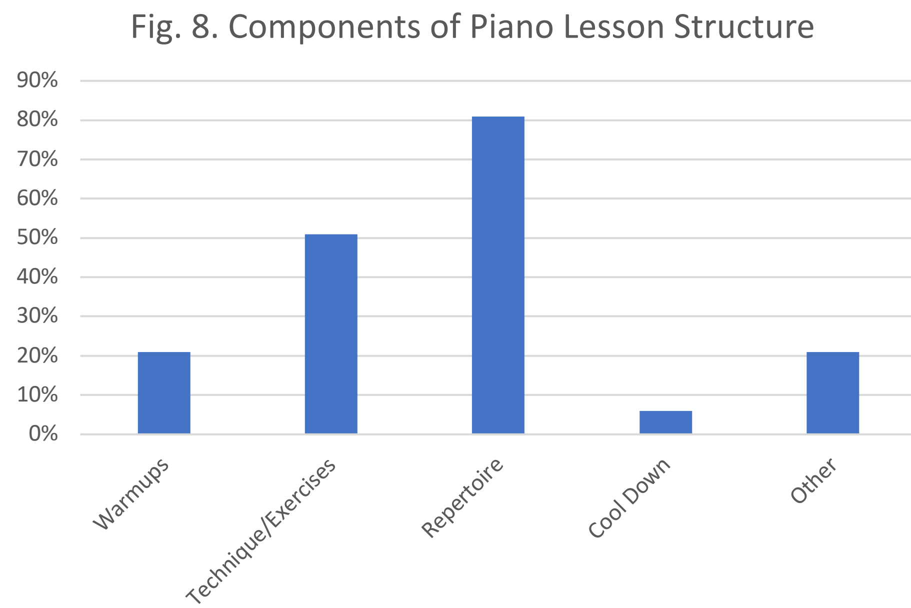
Fig.6. This figure describes participants according the width of their palms when compared to the length of 1 credit/id card. Percentages were calculated based on the number of participants answering this question. Participants describing their palm width as shorter (43%) outnumber those describing their palm width as longer (21%) or equal (36%).

Fig. 7. Participants Level of Training



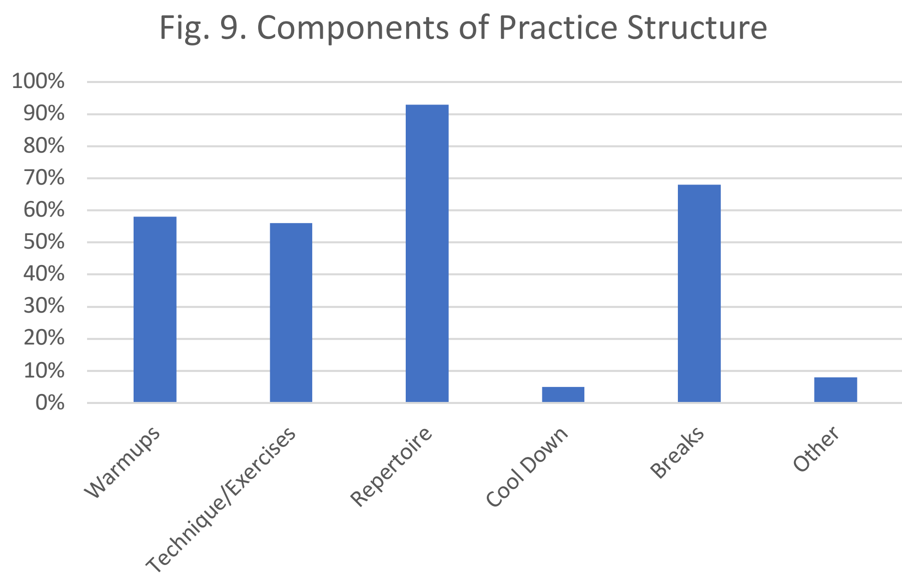
Survey Question
What degree in piano have you achieved?
g) Bachelor
h) Master's
i) DMA
j) Performance Diploma
k) Artist Diploma,
l) Other _______________

Fig.7. This figure describes participants according to the degree in piano they have achieved. Raw numbers of participants were presented here. Masters (42) and Bachelors (39) degree recipients represent the biggest populations of participants. Other (33) represent another significant population with the majority of those doing some kind of certificate/graded examinations. Doctorate degree (20) and Artist Diploma (11) round out the various levels of achievement in piano.



Survey Question
Select the components of a typical LESSON STRUCTURE with your current piano teacher.
a) warming up
b) technique/technical exercises
c) repertoire
d) cool down
e) other__________

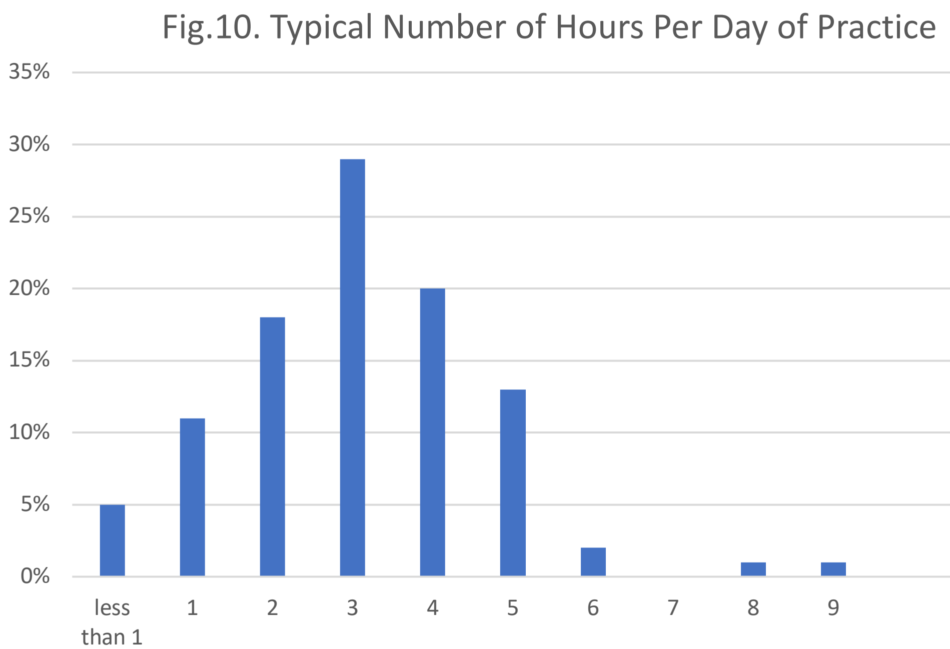
Fig.8. This figure describes the components of a typical lesson structure of participants with their teachers. Percentages were calculated based on the number of participants selection of a particular component as part of their lesson structure. A vast majority (80%) selected repertoire as a component of their lessons. Technique/Exercises were also significant (51%) whereas few selected warmups (20%) and cooldown (6%) as part of their lesson structure.



Survey Question
Select the components of your typical PRACTICE STRUCTURE:

a) warming up
b) technique/technical exercises
c) repertoire
d) breaks
e) cool down
f) other___________

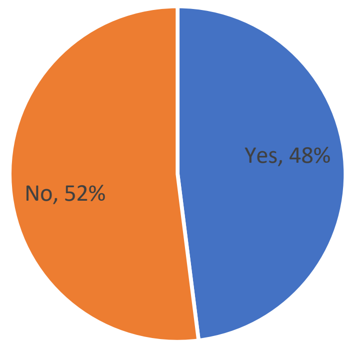
Fig.9. This figure describes the components of a typical practice structure of participants. Percentages were calculated based on the number of participants selection of a particular component as part of their practice structure. Repertoire was the chief component of the majority of participants at over 90%. Warmups (58%), Technique (55%) and Breaks (69%) also represented significant components of the practice structure of participants. Cool down at 5% on the other hand was not part of the practice structure of most participants.



Survey Question
On average, how many hours do you spend practicing on a daily basis? (Enter numerical value)

Fig.10. This figure describes the number of hours on average that participants practice on a daily basis. Percentages were calculated based on the number of participants selection of a numerical value. A majority of participants at 29% practice on average three hours/day, with significant percentages practicing four hours/day (20%), two hours/day (18%), five hours/day (13%) and one hour/day (11%).

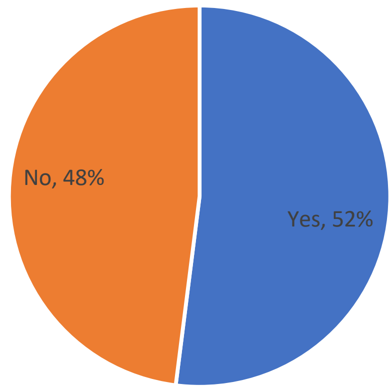
Fig. 11. Participants who do non-piano exercises/practices to aid piano-playing



Survey Question
Are you currently doing any exercises, training or activities AWAY FROM THE PIANO on a CONSISTENT BASIS specifically to aid your piano playing?
a) YES
b) NO

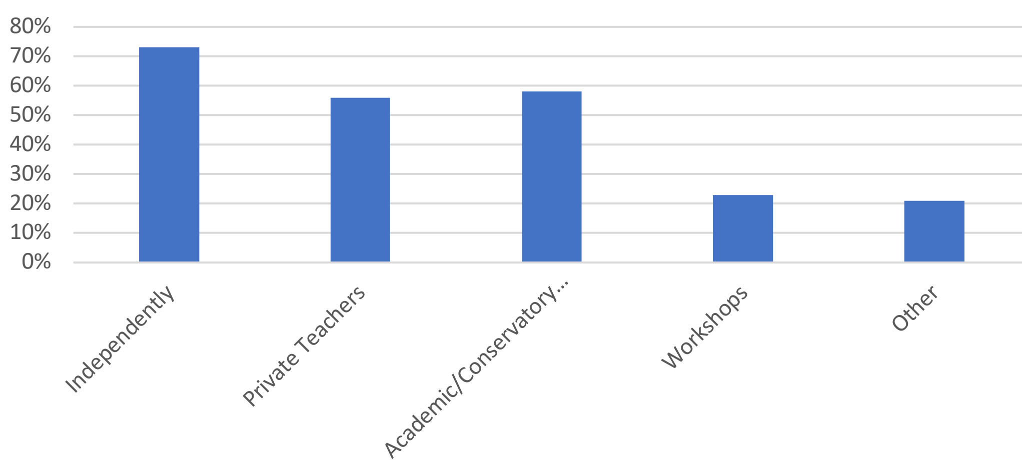
Fig.11. This figure describes the number of participants who do any extra-piano activities or other supportive practices to aid their piano playing. Percentages were calculated based on the number of participants answering this question. Participants answering negatively at 52% only slightly outpaced those answering positively (48%). These results could lead to other lines of inquiry – specifically drawing correlations to physical activity, supportive practices and injury.

Fig. 12. Participants who studied piano-related sciences/technology



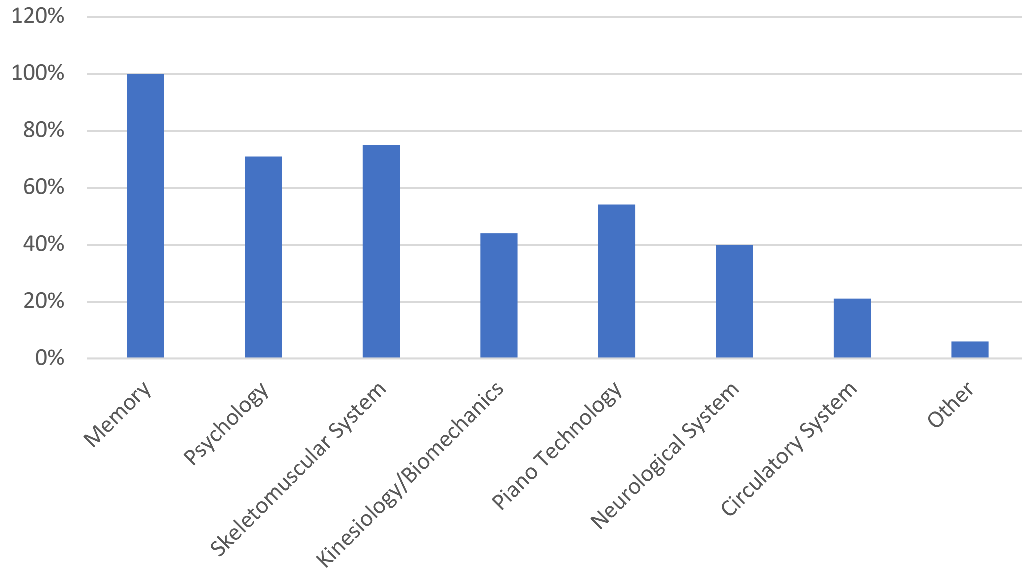
Survey Question
In your piano training, have you studied areas of biology, physiology, psychology or piano technology?
a) YES
b) NO

Fig. 13. Forum for study of piano-related science/technology areas



Survey Question
If YES, please select the setting.
a) Private Piano Teachers,
b) Academic/Conservatory Courses
c) Workshops
d) Independently
d) Other

Fig. 14. Piano-related areas of science/technology studied

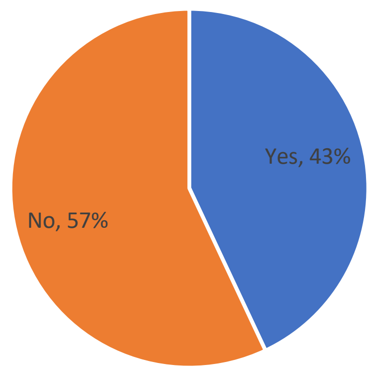


Survey Question
If YES, select the areas you have studied within the context of your piano training:
a) Skeletomuscular systems
b) Neurological systems
c) Circulatory systems
d) Kinesiology and Biomechanics
e) Psychology
f) Memory
g) Piano Technology
h) Other

Figs.12-14. These figures describe participants who have studied areas of sciences or technology related to piano-playing, the forums in which they took place and the areas of study focused on. Percentages were calculated based on the number of participants answering this question. Participants answering positively to having studies areas of science/technology (52%) only slightly outpaced those responding negatively (48%) (See Fig.12). Independent study was the most popular forum of study (72%) with private teachers (55%) and academic courses (52%) also significant forums for participants education in these areas (See Fig. 13). Memory was the most popular area of study with 100% of participants who have studied areas of science/technology selecting this area. The study of skeletomuscular system and psychology were also significant at over 70% in those areas. On the other hand, biomechanics at just over 40% was not a popular choice (See Fig. 14).

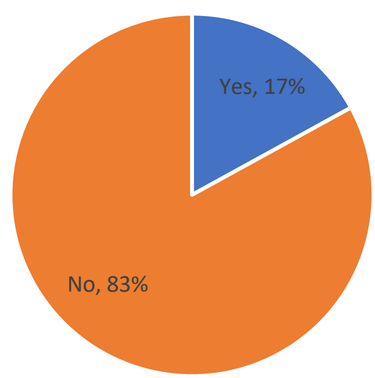
Section 3: Injury Data

Fig.15. Participants that Studied Injury Prevention



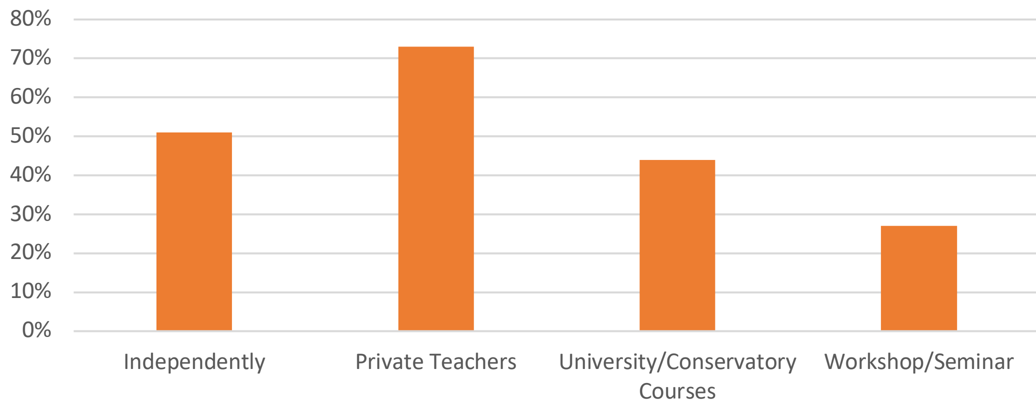
Survey Question
In your training, have you studied areas related to INJURY PREVENTION in piano playing?
a) YES
b) NO

Fig.16. Participants that studied Injury Management



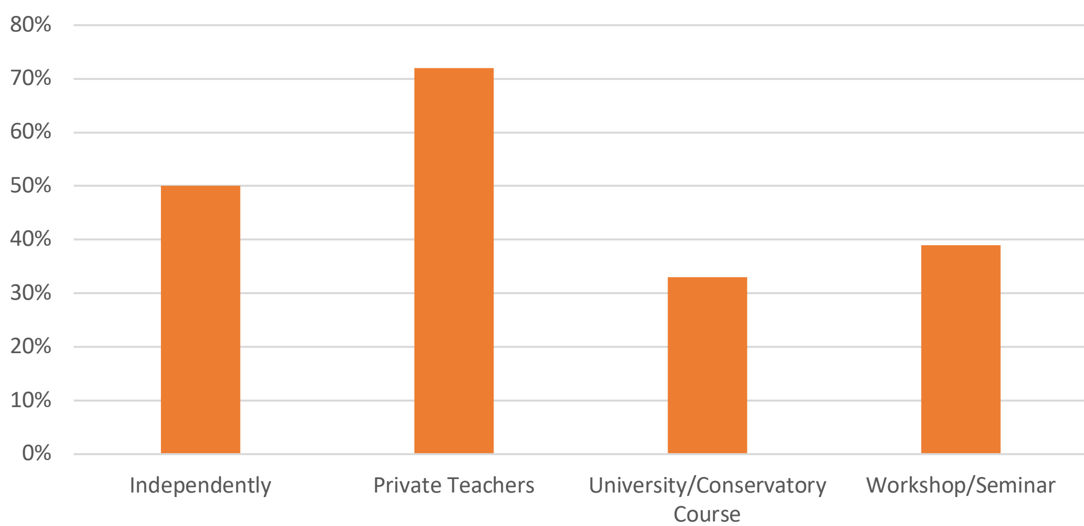
Survey Question
In your training, have you studied areas related to INJURY MANAGEMENT?
a) YES
b) NO

Fig.17.Forums For Studying Injury Prevention



Survey Question
If YES, select the settings in which this study has this taken place:
a) University/Conservatory Courses
b) Private Lessons with piano teacher
c) Medical/Health Related Seminars and Workshops
d) Independently
e) Other

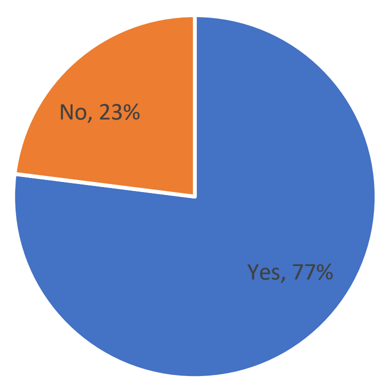
Fig. 18. Forums for Studying Injury Management



Survey Question
If YES, select the settings in which this study has this taken place:
a) University/Conservatory Courses
b) Private Lessons with piano teacher
c) Medical/Health Related Seminars and Workshops
d) Independently
e) Other

Fig.15-18. These figures describe participants who have studied injury prevention, injury management and the forums in which this study took place. Percentages were calculated based on the number of participants answering this question. Participants responding negatively to the injury prevention question (57%) significantly outweighed those responding positively (43%) (See Fig.15). The negative response was even more pronounced to the injury management question with (81%) of participants admitting to never having studied injury management as opposed to 19% claiming to have studied this area (See Fig. 16). The results related to the forum in which study took place in both prevention and management closely mirror each other with private teachers being the overwhelming resource at over 70% in each area with independent study also being a significant resource at around 50% in each case as well (See Fig. 17-18).

Fig. 19. Participants who discussed their injuries with others

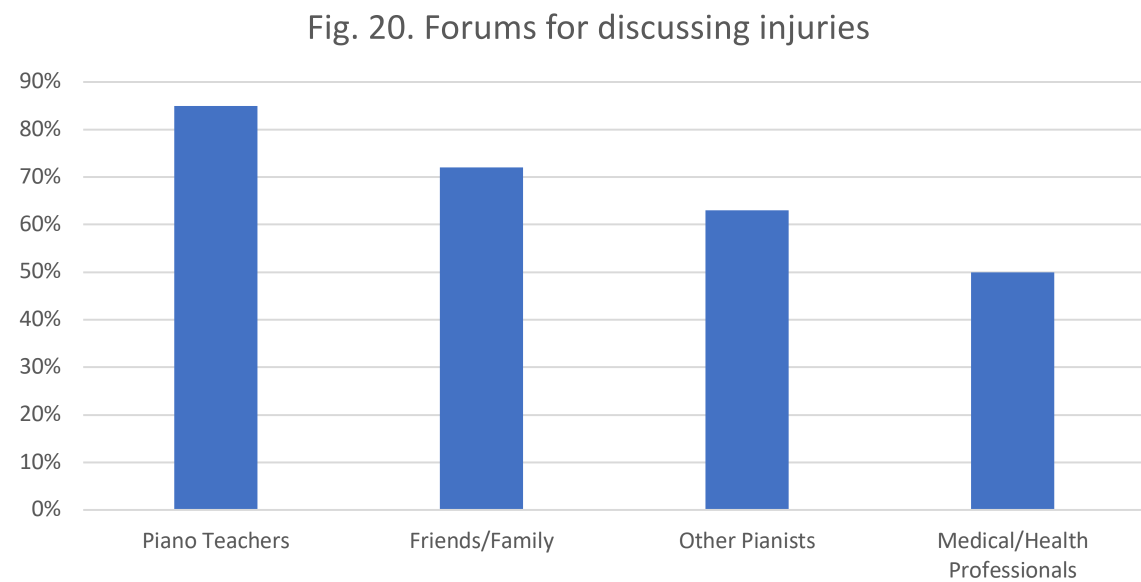


Survey Question

Did you talk to anyone or about your past or present discomfort/pain or injury?

A) YES

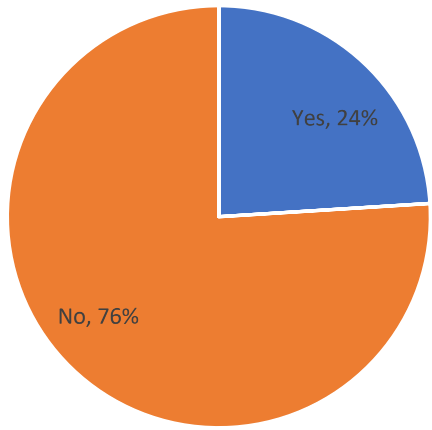
B) NO



Survey Question
If YES, select the people you talked to.
a) Friends/Family
b) Other Pianists
c) Piano Teachers
d) Physicians/Medical Professionals
e) Other

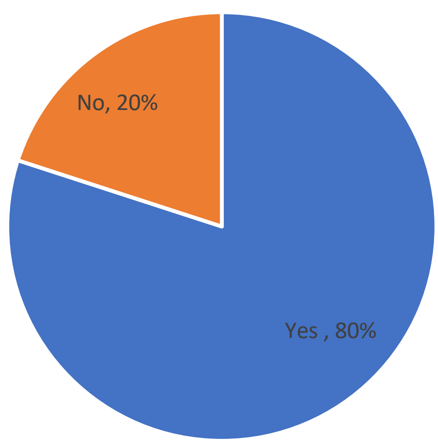
Figs.19-20. These figures describe participants who have discussed their own pain/injury when it occurred and with whom. Percentages were calculated based on the number of participants answering this question. A majority of participants (77%) admit to discussing their injuries versus 23% opting not to discuss their injuries (See Fig 19). Piano teachers represent the popular point of contact for injuries at 84%. Medical professionals represent the least popular option at just 50% (See Fig.20).

Fig.21. Participants Currently in Pain from Piano Playing



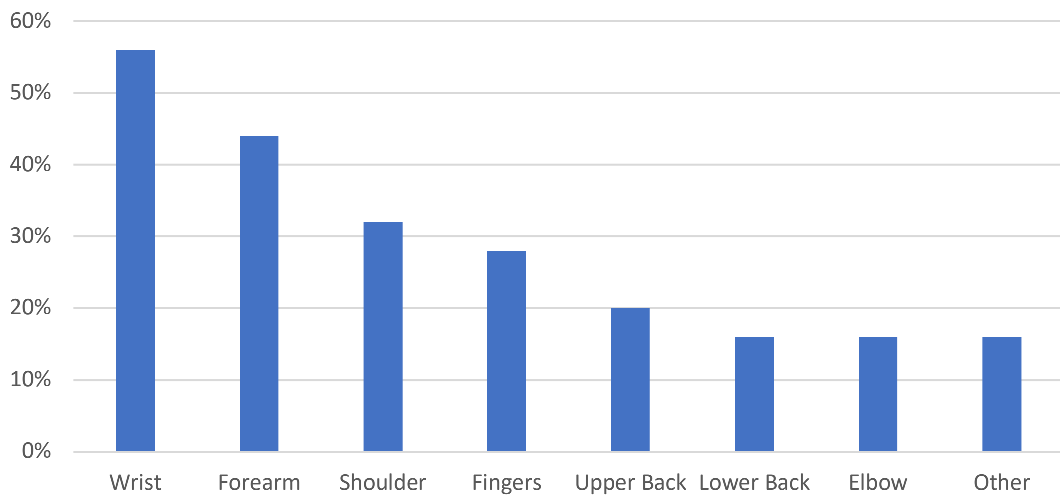
Survey Question
Are you CURRENTLY experiencing physical discomfort or pain while playing the piano or as a result of playing the piano?
a) YES
b) NO

Fig. 22. Participants having experienced pain from Piano Playing



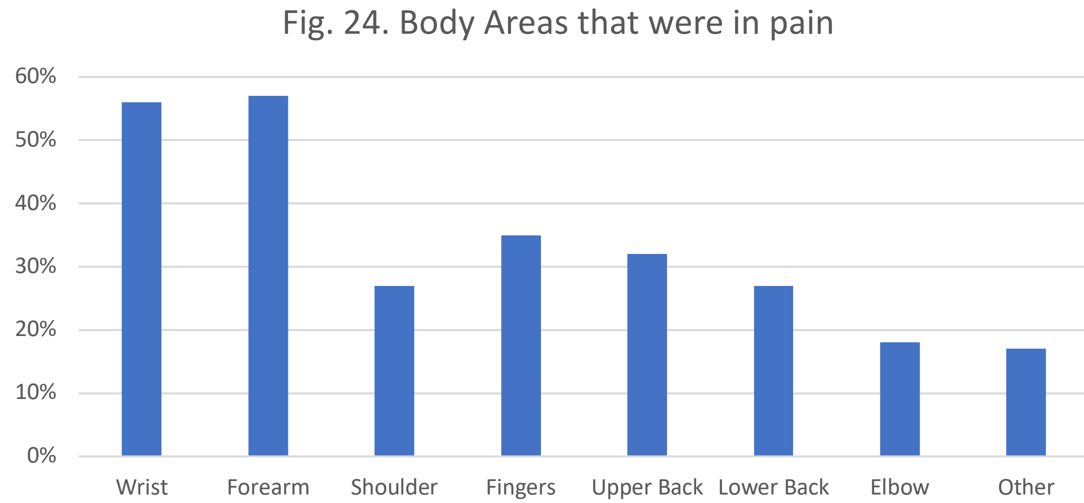
Survey Question
Have you experienced discomfort while playing piano AT ANY POINT IN YOUR PIANO-PLAYING HISTORY?

Fig. 23. Body Areas currently in pain



Survey Question
IF YES, select the areas of YOUR body where physical discomfort or pain is felt while playing the piano or as a result of playing the piano.

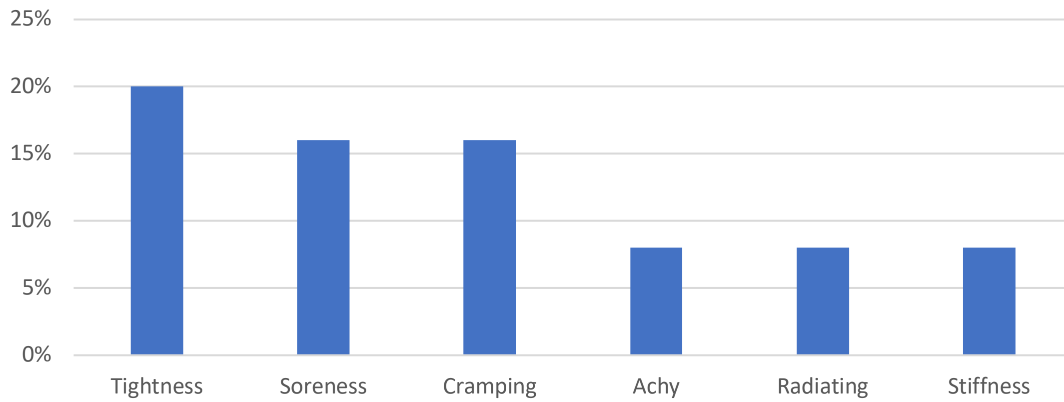
a) fingers
b) wrists
c) forearm
d) elbow
e) upper arm
f) shoulder joint
g) chest
h) upper back
i) lower back
j) other ___________________



Survey Question
IF YES, select the areas of YOUR body where physical discomfort or pain is felt while playing the piano or as a result of playing the piano.

k) fingers
l) wrists
m) forearm
n) elbow
o) upper arm
p) shoulder joint
q) chest
r) upper back
s) lower back
j) other __________________

Fig. 25. Description of the Pain

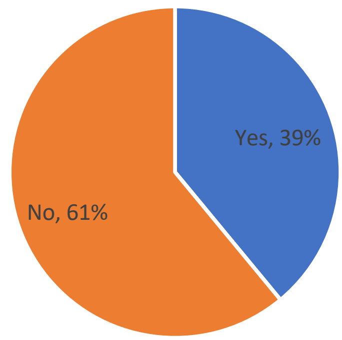


Survey Question
Of those areas selected, list the areas of the body next to the sensations that best describe the discomfort or pain felt.

a) Achy
b) Burning
c) Cramping
d) Dull
e) Heaviness
f) Radiating
f) Soreness
g) Spasms
h) Stinging
i) Shooting
j) Stiffness
k) Stabbing
l) Tenderness
m) Tingling
n) Tightness

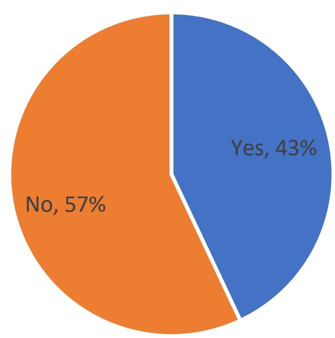
Figs.21-25. These figures describe the experience of participants with pain related to piano playing. While a majority of participants replying that they are currently not in pain (76%) (See Fig. 21) a vast majority claim to have had pain in the past as a result of piano playing (80%) (See Fig.22). Regardless of whether the pain was present or past, the responses to the areas of the body in pain pretty closely mirror each other with the wrist being the most selected area of the body at over 50% (See Fig.23-24). Forearms (43% and 57%), fingers (28% and 35%) and shoulders (32% and 28%) and upper back (20% and 31%) also represent significant sites of pain related to piano playing. In participants' description of the pain tightness, soreness and cramping were the most popular adjectives used to describe the pain at 20%, 16% and 16% respectively (See Fig.25).

Fig. 26. Participants that have been Injured



Survey Question
Have you had an injury AT ANY POINT IN YOUR PLAYING HISTORY? (Definition: discomfort or pain that impedes or halts your ability to play)?
a) YES
b) NO

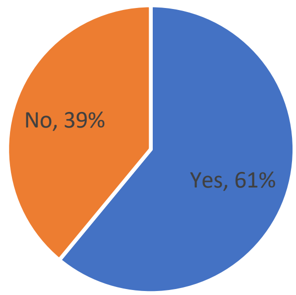
Fig. 27. Participants who's injury/pain reoccured



Survey Question
Is the discomfort/pain or injury a reoccurring one (has it ever reoccurred)?
a) YES
b) NO

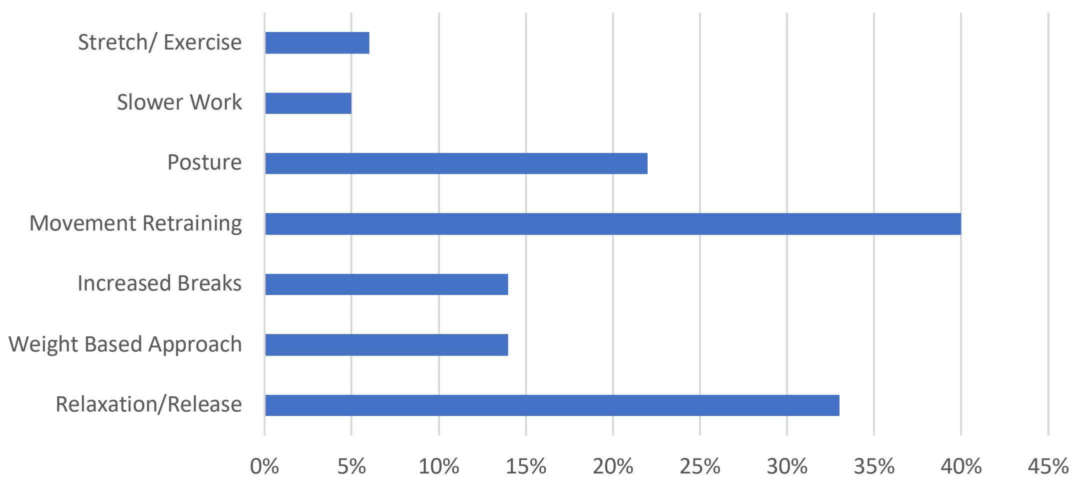
Figs.26-27. These figures describe the experience of participants with injuries related to piano playing. Percentages were calculated based on the number of participants answering this question. A majority of participants replied negatively to having had an injury as defined by the terms in the first question here (61% versus 39%). Though a slightly lesser majority claimed to never have the injury reoccur (57%) a significant percentage claim to have had the injury reoccur (43%).

Fig. 28. Changed Technique because of pain/injury



Survey Question
Are you changing (did you change) anything in your piano playing technique as a result of experiencing discomfort/pain or injury?
a) YES
b) NO

Fig. 29. Changes to Technique Implemented

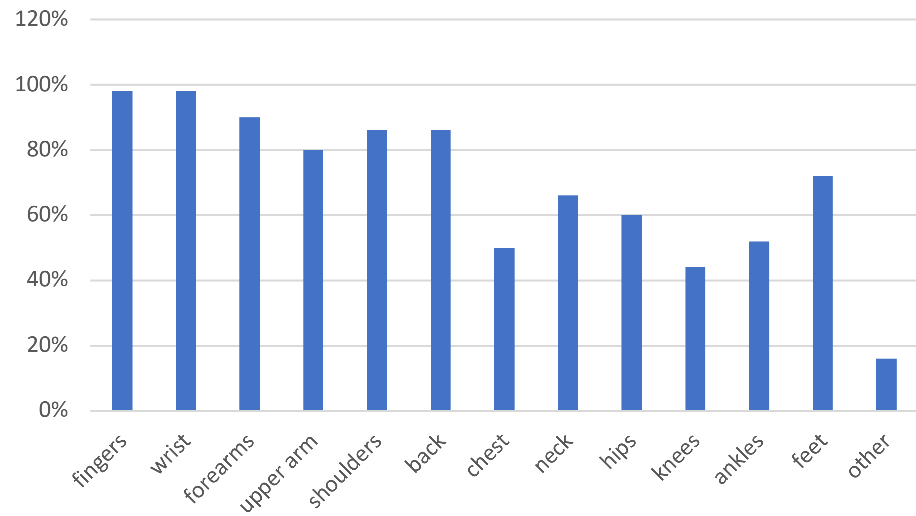


Survey Question
If YES, describe.

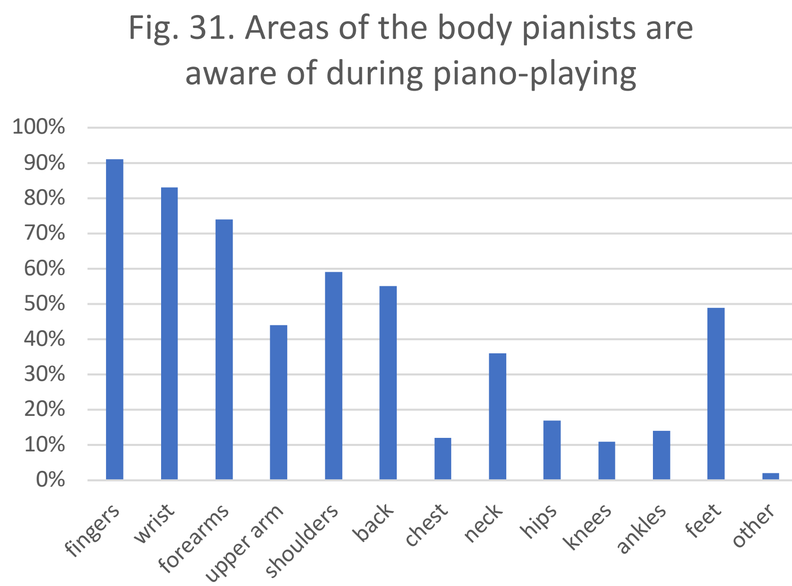
Figs.28-29. These figures describe changes in technique correlated to the pain/injury experienced by participants. Percentages were calculated based on the number of participants answering this question. A majority of participants who have experienced pain did change technical aspects in their playing (61%). Still a significant percentage did not (39%) (See Fig. 28). Of those that did implement changes, qualitative analysis revealed that changes related to movement retraining (40%), relaxation/release of muscular tension (33%) and postural adjustments (22%) were the most popular technical changes implemented (See Fig. 29).

Section 4: Awareness Data

Fig. 30. Areas of the body believed to be important in piano-playing

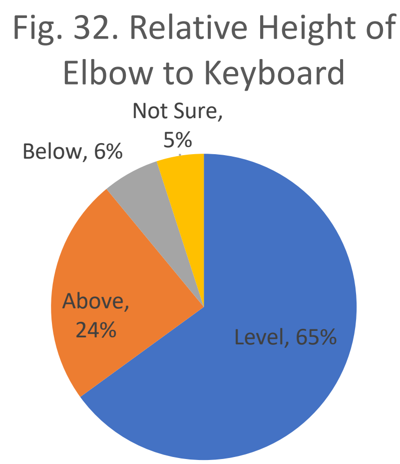


Survey Question
Select the areas of the body that you believe are important to piano playing?
a) fingers
b) wrists
c) forearms
d) upper arm
e) shoulders
f) back
g) chest
h) neck
i) hips
j) knees
k) ankles
l) feet
m) other __________

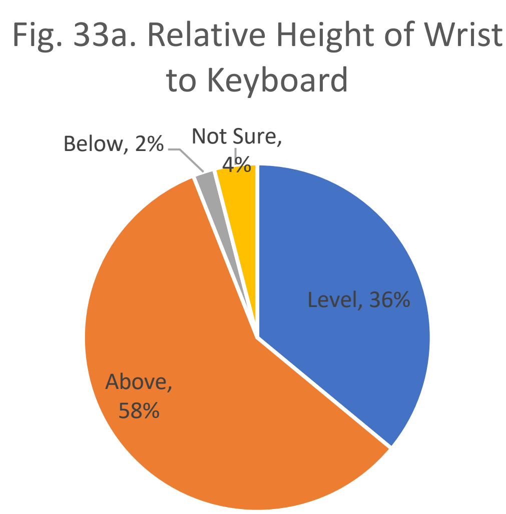


Survey Question
Which areas of the body that you are CONSISTENTLY AWARE OF while in the act of piano- playing?
a) fingers
b) wrists
c) forearms
d) upper arm
e) shoulders
f) back
g) chest
h) neck
i) hips
j) knees
k) ankles
l) feet
m) none
n) other _________

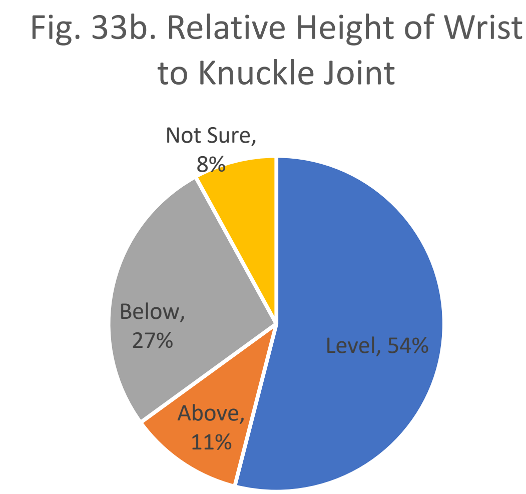
Fig.30-31. These figures describe the areas of the body that participants believe are important to the body and the areas they are aware of when playing the piano. Percentages were calculated based on the number of participants selecting each area of the body compared to the overall number of participants answering the question. Fingers and wrists at 98% were the most unanimously agreed upon areas important to piano playing. The knees (44%) and chest (50%) ranked lowest in importance. These trends were similar in the areas participants were aware of with fingers and wrists at 91% and 83% respectively. The knees (11%) and chest (12%) ranked lowest in awareness.



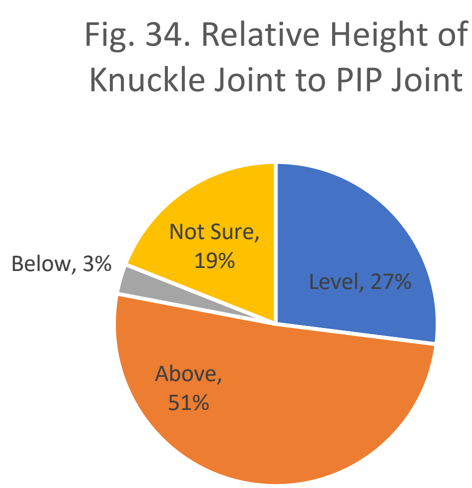
Survey Question
When playing the piano, the height of your elbow is:
a) at key level
b) above key level
c) below key level
d) not sure



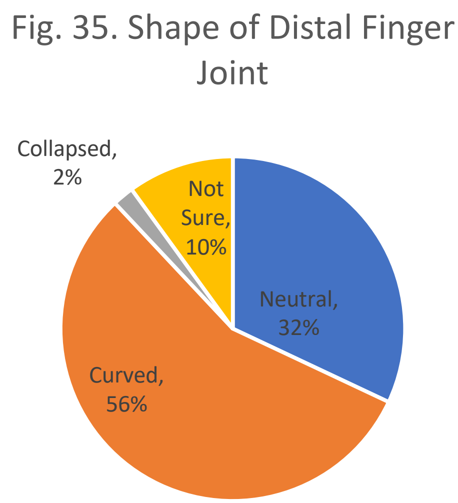
Survey Question
When playing the piano, your wrist joints are:
a) at the same height as your elbow
b) above the height of your elbow
c) below the height of your elbow
d) not sure



Survey Question
Your wrist joints when playing the piano are:
a) at the same height level as your knuckle joint
b) above the height level of your knuckle joint
c) below the height level of your knuckle joint
d) not sure



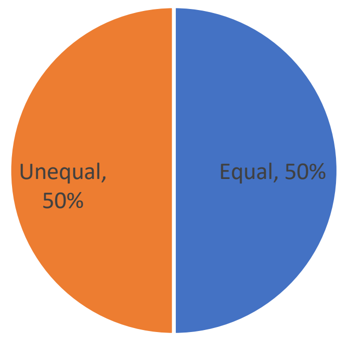
Survey Question
Your knuckle joints when playing the piano are:
a) at the same level as your proximal (nearest finger joint) finger joint
b) above the level of your proximal finger joint
c) below the level of your proximal finger joint
d) not sure



Survey Question
The condition of your distal finger joints (joint closest to finger tips) when playing the piano are:
a) neutral
b) curved
c) collapsed (caving inward)
d) not sure

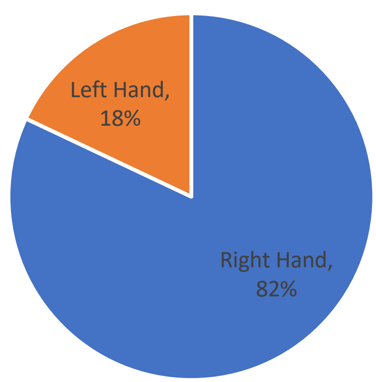
Figs. 32-36. These figures describe the relative positions of the parts of the playing apparatus in relation to each other as well as the piano of participants. Percentages were calculated based on the number of participants answering this question. A majority of participants (65%) report that their elbows are level with the keyboard. A lesser but still significant percentage of participants claim their elbows are higher than the level of the keyboard (24%) (See Fig. 32). In relation to the height of the wrist joint when compared to the keyboard, a majority of participants claim their wrist joint to be above the level of the keyboard (58%). A lesser percentage report that their wrist joints are level with the keyboard (36%) (See Fig. 33a). In relation to the height of the wrist in comparison to the knuckle joint, a majority of participants claim their wrist joint to be level with the knuckles (54%), while the second largest group of participants report their wrist joints to be lower than the knuckles (27%) and a smaller percentage claim their wrist joints to be above the level of their knuckles (11%) (See Fig. 33b). In relation to the height of the knuckles in comparison to the proximal (nearest) finger joint, a majority claim their knuckles to be higher (51%) whereas 27% claim their knuckles to be level with the proximal finger joint. 19% interestingly claimed not to be sure what the relative positions of the knuckles to the finger joint were (See Fig. 34). In relation to the condition of the distal (furthest) finger joint, a majority of participants claim to have a curved joint (56%). A smaller but significant percentage (32%) claimed to have a neutral joint (See Fig. 35). This series of results could go through further analysis to make further correlations between positions of the playing apparatus and injury susceptibility.

Fig. 36. Relative Strength of Hands



Survey Question
Do your hands feel equally strong when playing?
a) YES
b) NO

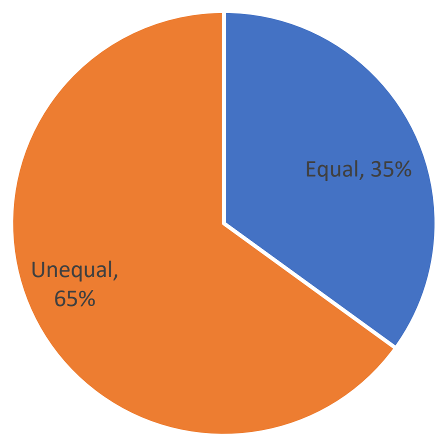
Fig. 37. Strongest Hand



Survey Question
If NO, which hand feels strongest?
a) LEFT
b) RIGHT

Figs. 36-37. These figures describe participants' perception of strength in their hands when playing the piano. Percentages were calculated based on the number of participants answering this question. Participants were equally divided on the question of hands being equally strong with 50% believing the hands were equally strong and 50% believing the hands were unequal in terms of strength (See Fig. 37). Of those believing the hands were unequal, a vast majority (82%) believed the right hand to be the stronger of the two (See. Fig. 38.

Fig. 38. Relative Strength of Fingers



Survey Question
Do your fingers feel equally strong when playing?
a) YES
b) NO

Fig. 39. Strongest Finger

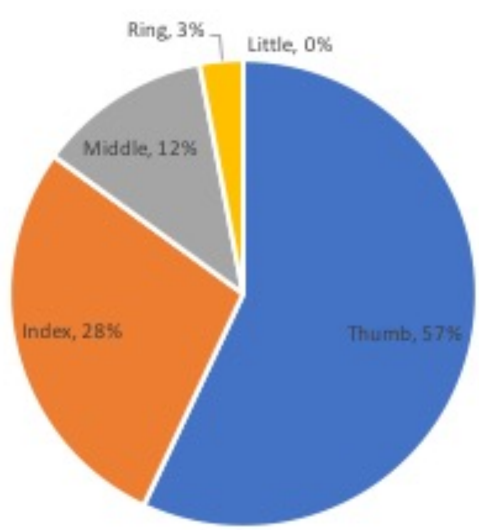


Fig. 40. Second Strongest Finger

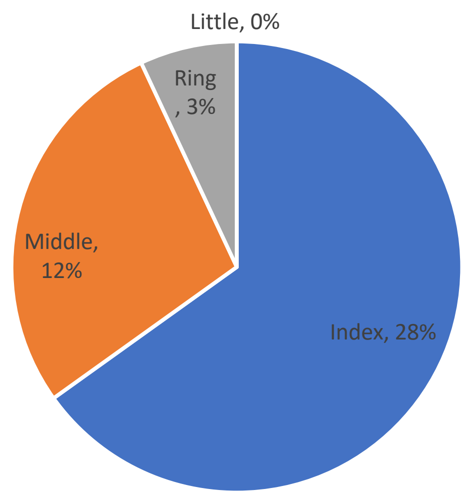


Fig. 41. Third Strongest Finger

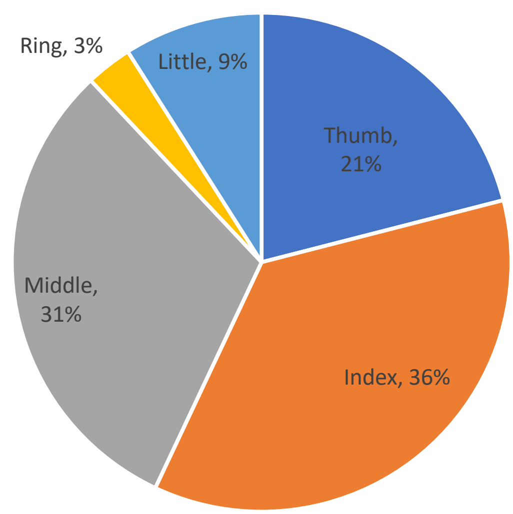


Fig. 42. Fourth Strongest Finger

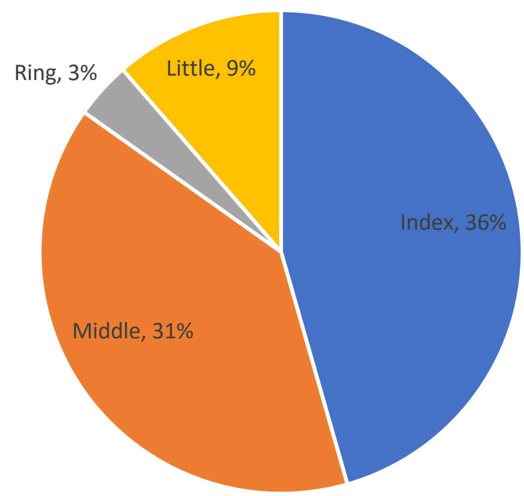
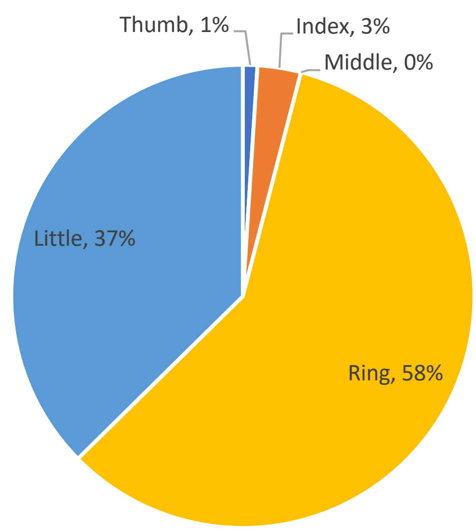


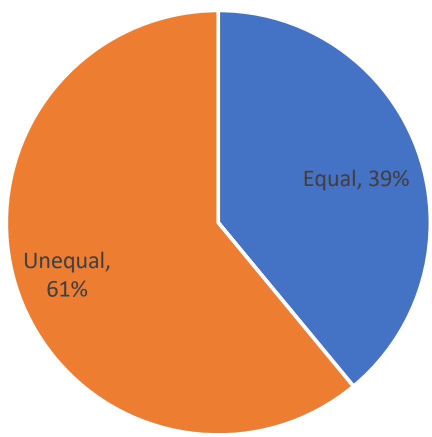
Fig. 43. Weakest Finger



Survey Question
If NO, rank your fingers from strongest (1) to weakest (5).
a) Thumb
b) Index
c) Middle
d) Ring
e) Little

Figs. 38-43. These figures describe participants perception of strength of their fingers when playing the piano. Percentages were calculated based on the number of participants answering this question. A majority of participants believed that the fingers were unequally strong (65%) versus 35% believing that the fingers were equal in terms of strength (See Fig. 39). Of those that believed the fingers to be unequal in terms of strength, the majority believed the thumb to be the strongest (57%) with a smaller percentage believing the index finger to be the strongest (28%) (See Fig. 40). The middle finger is believed to be the second strongest (49%) by a majority with 30% believing the index to be the second strongest (See Fig. 41). The index finger has a slight majority in terms of being the third strongest (36%) with the middle finger at 31% (See Fig. 42). The little finger is reported to be perceived as the fourth strongest finger (48%) with the ring finger close behind at 36% (See Fig. 43). A larger majority believe the ring finger to be the weakest finger (58%) with a second majority believing the little finger to be the weakest at 37% (See. 44).

Fig. 44. Relative Speed of Fingers



Survey Question

Do your fingers feel equally fast when playing?

a) YES

b) NO

Fig. 45. Fastest Finger

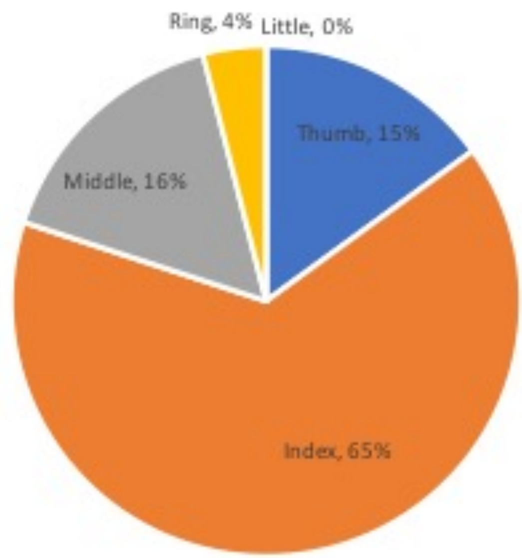


Fig. 46. Second Fastest Finger

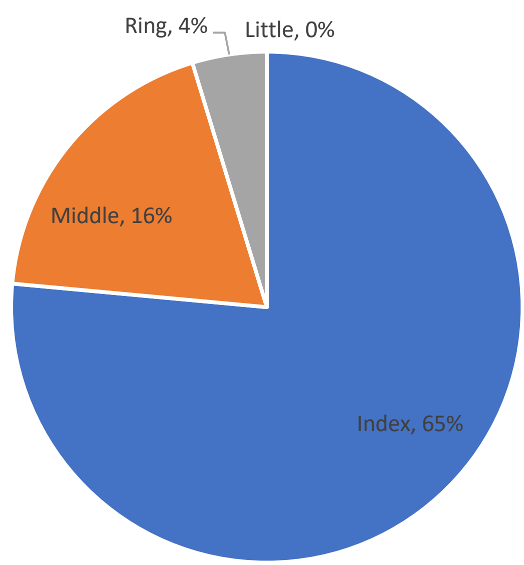


Fig. 47. Third Fastest Finger

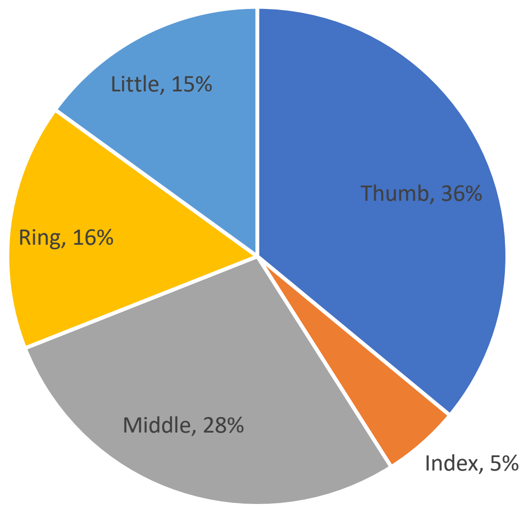
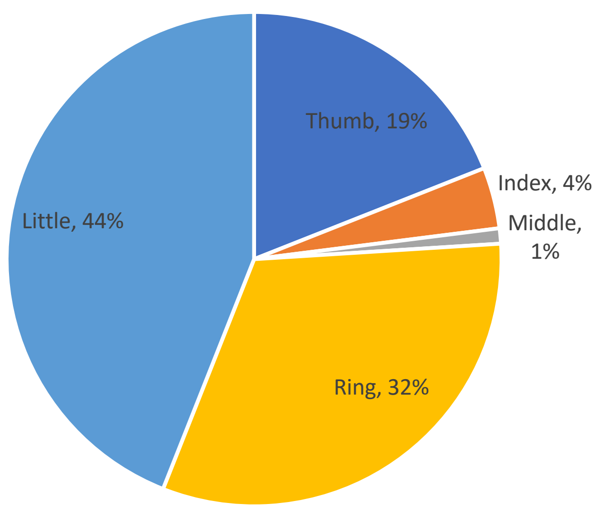
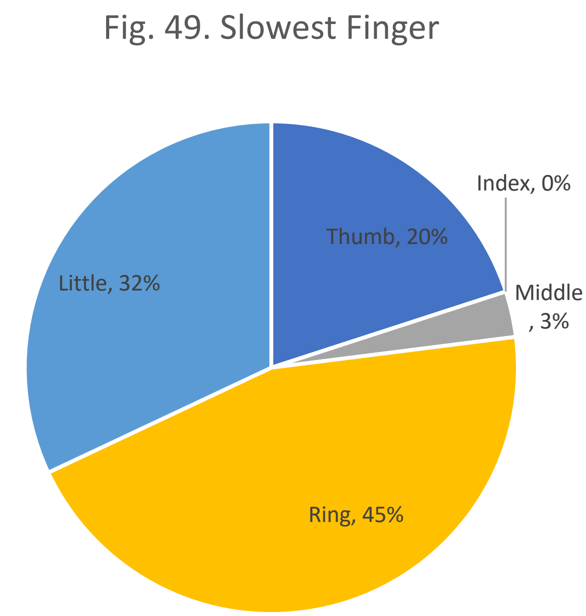


Fig. 48. Fourth Fastest Finger

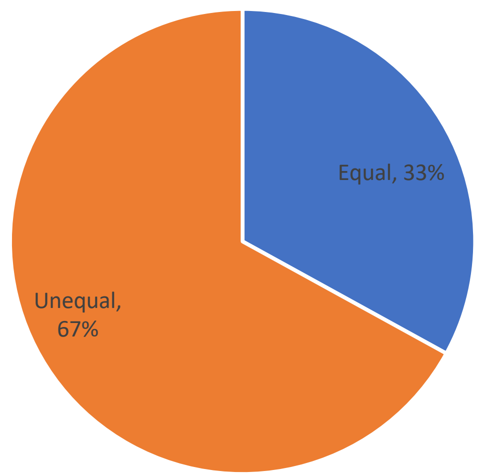




Survey Question
If not, rant your fingers from fastest (1) to slowest (5)

Figs.44-49. These figures describe participants' perception of speed of their fingers when playing the piano. Percentages were calculated based on the number of participants answering this question. A majority of participants believed that the fingers were unequal in terms of speed (61%) versus 39% believing that the fingers were equal in terms of speed (See Fig. 45). The vast majority of participants believe their index finger to be superior at 65% with the middle finger a distant second majority at 16% (See Fig. 46). The middle finger was reported by the majority to be the second fastest finger (52%) with the index finger closest to it at 26% (See Fig. 47). The thumb is believed by the majority to be the third fastest (36%) but only slightly more than the middle (28%) (See Fig. 48). The little finger is reported to be the fourth fastest at 44% with the ring finger following closely behind at 32% (See Fig. 49). These positions are reversed for the slowest finger with the ring finger believed to be the slowest at 45% and the little finger at 32% (See Fig. 50).

Fig. 50. Relative Control of Fingers



Survey Question
Do you have equal control over each finger?
a) YES
b) NO

Fig. 51. Best-Controlled Finger

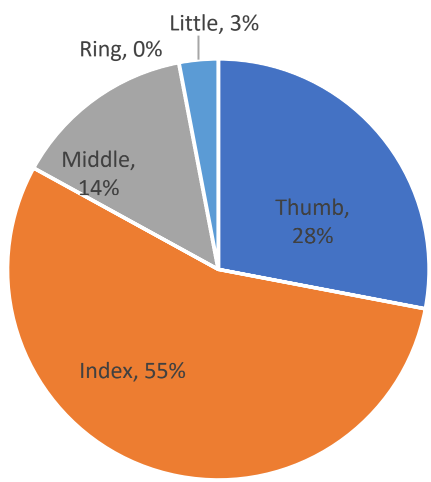


Fig. 52. Second Best-Controlled Finger

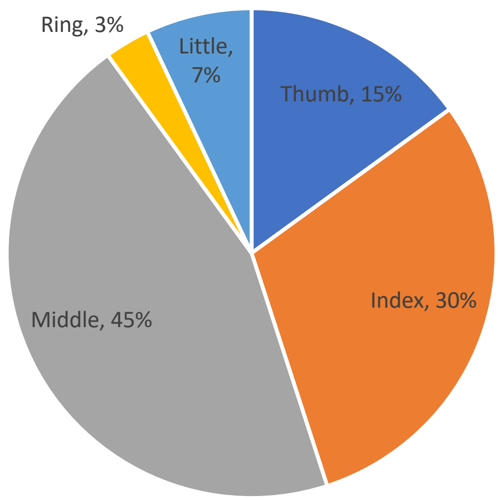


Fig. 53. Third Best-Controlled Finger

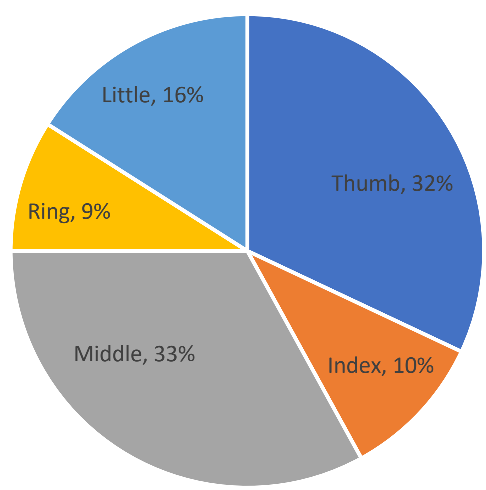


Fig. 54. Fourth Best-Controlled Finger

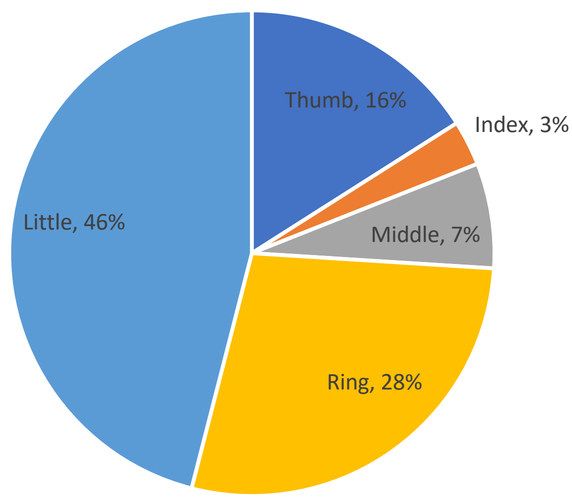
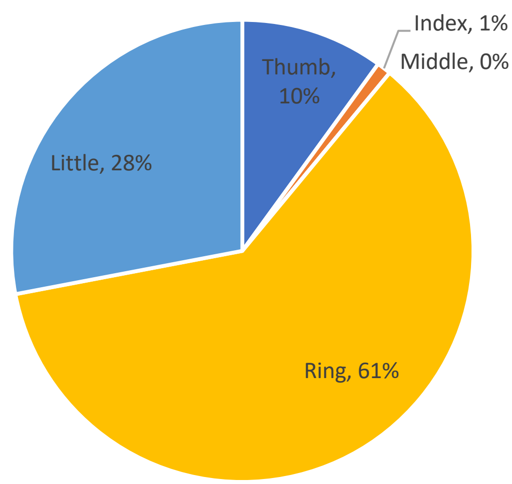


Fig. 55. Worst-Controlled Finger



Survey Question
If not, rank your fingers from easiest (1) to hardest to control (5)

Figs. 50-55. These figures describe participants' perception of control of their fingers when playing the piano. Percentages were calculated based on the number of participants answering this question. These results closely mirror those of the results of finger speed. A majority of participants believed that the fingers were unequal in terms of control (67%) versus 33% believing that the fingers were equal in terms of control (See Fig. 51). A majority believe the index to be the best controlled finger (55%) (See Fig. 52). The middle finger is believed to be the second best controlled at 45% with the index finger following at 30% (See Fig. 53). The middle finger and thumb are basically even for the third best controlled finger at 33% and 32% respectively (See Fig. 54). The little finger is reported by a majority to be the fourth best controlled finger (46%) (See Fig. 55) and the ring finger is reported to be the worst controlled finger at 61% (See Fig. 56).

Fig. 56. Fingertip Sensations Before Playing

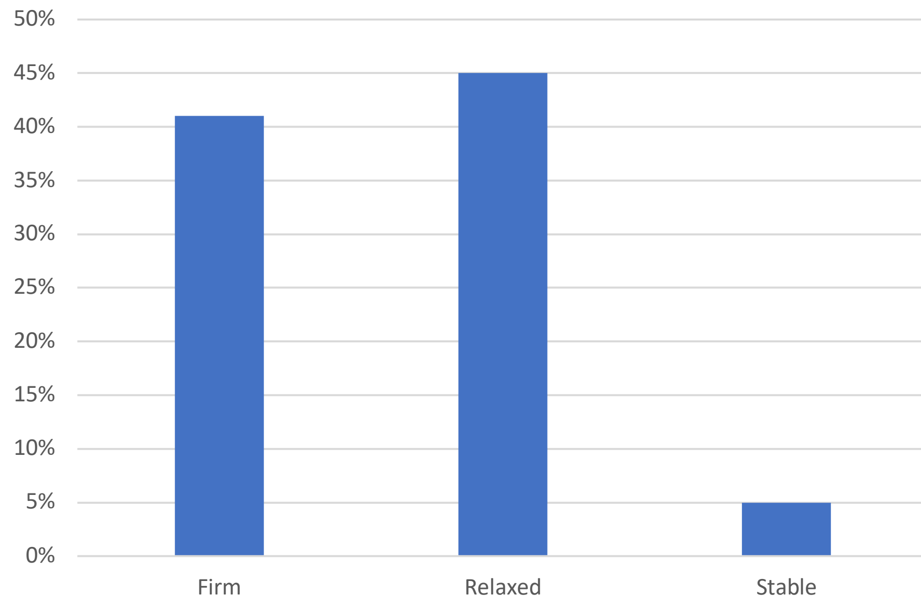
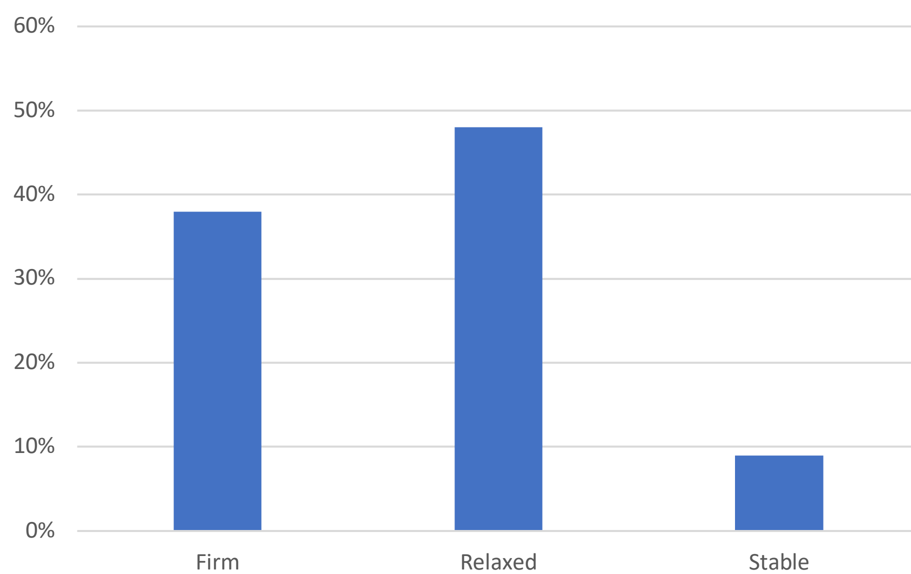


Fig. 57. Fingerjoints Sensation Before Playing



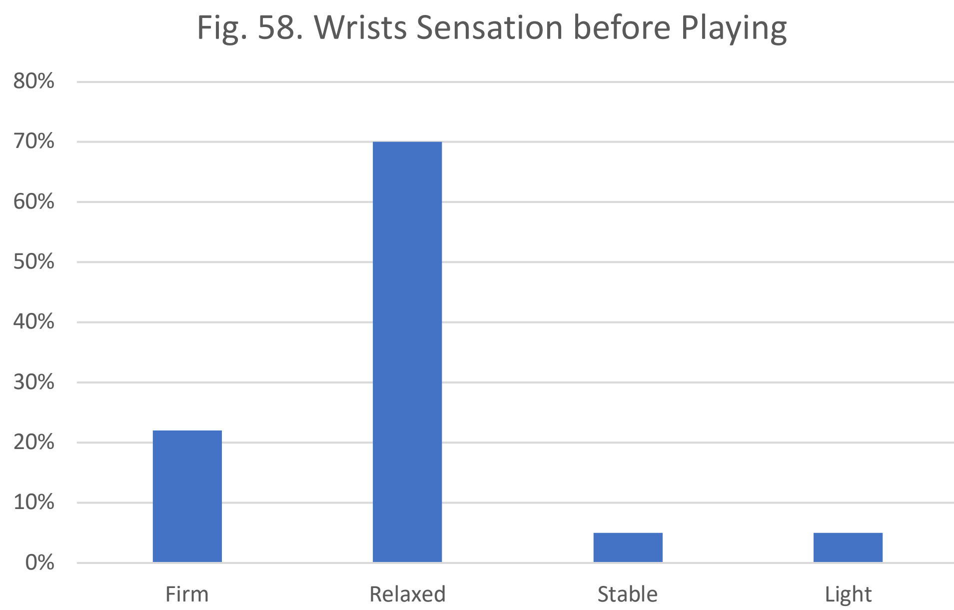


Fig. 58. Wrists Sensation before Playing
80%
70%
60%
50%
40%
30%
20%
10%
0%
Firm
Relaxed
Stable
Light

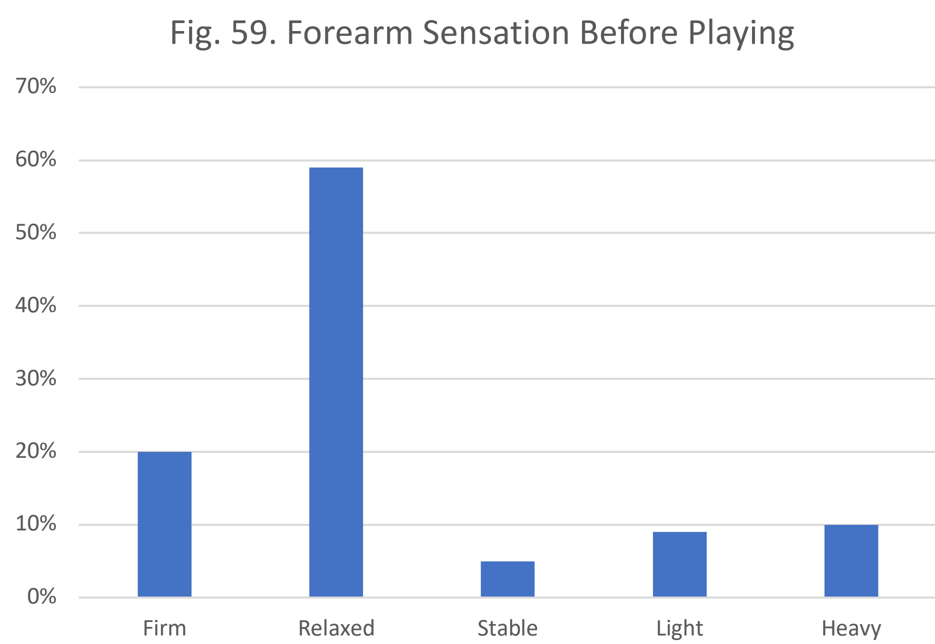
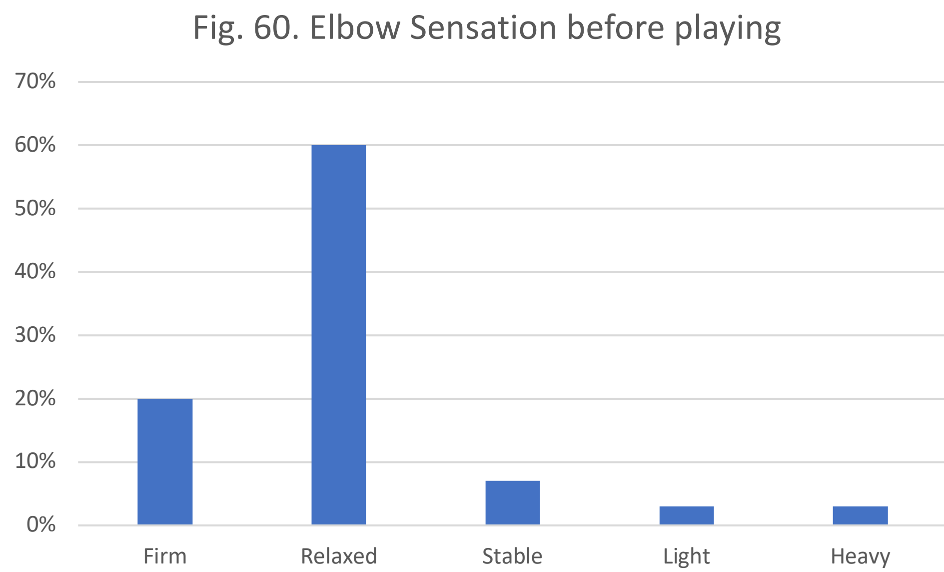


Fig. 59. Forearm Sensation Before Playing
70%
60%
50%
40%
30%
20%
10%
0%
Firm
Relaxed
Stable
Light
Heavy



Survey Question
Describe the physical condition of the following AS YOU ARE ABOUT TO PLAY THE PIANO (just prior to playing) (e.g. firm, relaxed, stiff, limp, tight, hard, soft, unstable, strong, weak, loose, light, heavy, etc.):
a) fingertips
b) finger joints
c) wrist joint
d) forearm
e) elbow

Figs. 56-60. These figures describe participants' perceptions of the inner physical conditions of various parts of the playing apparatus as they are about to play the piano. Participants responses underwent qualitative analysis, categories were subsequently generated, and percentages were then calculated from the categories relative to the number of participants. In relationship to fingertips, the popular replies were *relaxed* and *firm* at 45% and 41% respectively (See Fig. 57). These descriptors continued to describe the conditions of the other parts of the playing apparatus. *Relaxed* was the again the popular choice for the fingerjoints at 48% (See Fig. 58), with *firm* at 38%. In describing the wrist, *relaxed* was the choice of a vast majority at 70% (See Fig. 59). *Relaxed* was also the top choice of the forearm and elbow at 59% and 60% (See Figs. 60-61).

Fig. 61. Fingertip Sensation during Playing

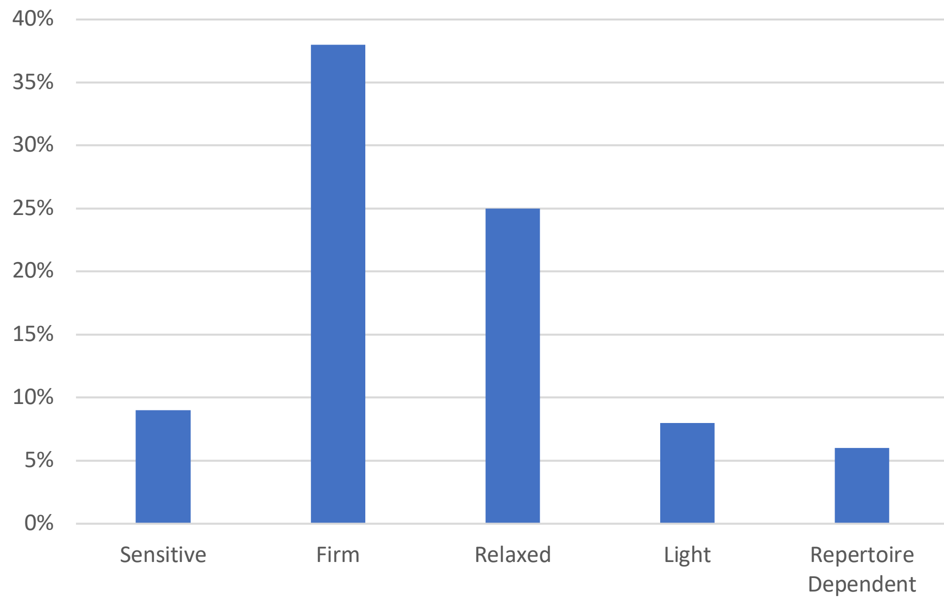


Fig. 62. Fingerjoints Sensations during Playing

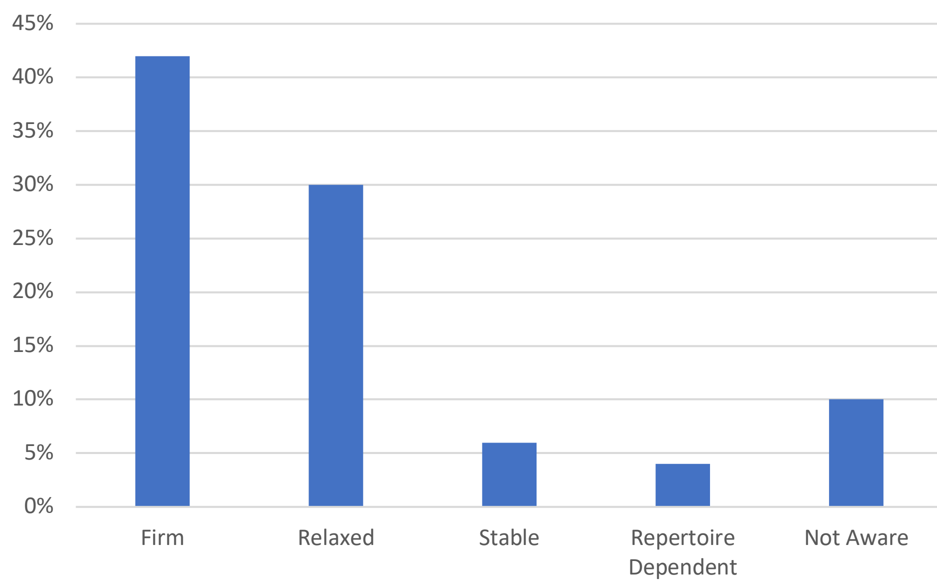


Fig. 63. Wrist Sensations During Playing

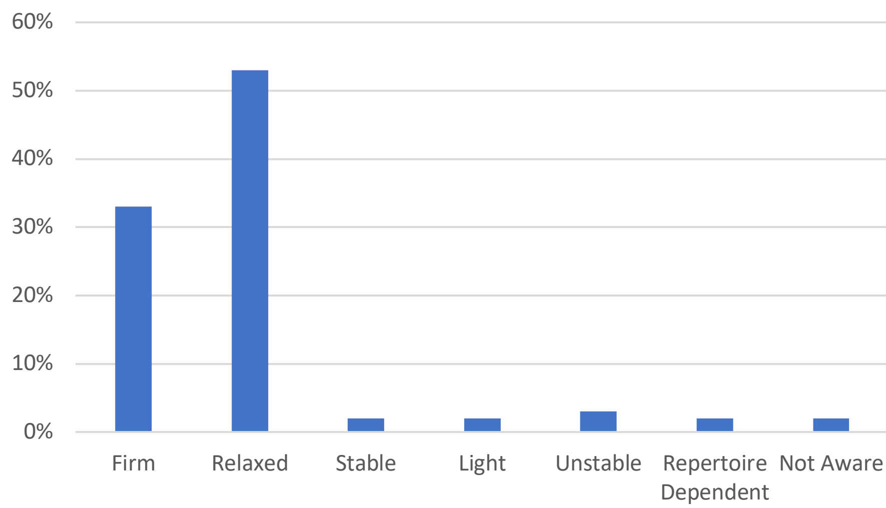
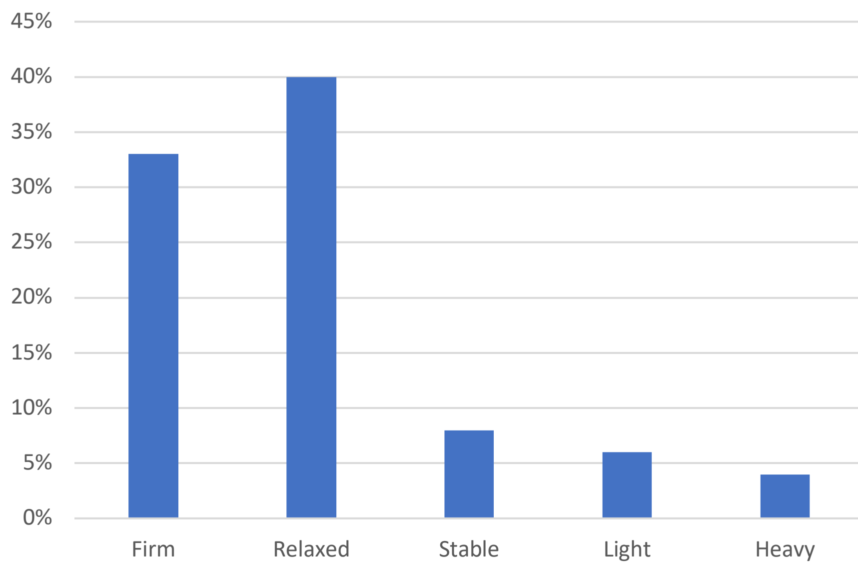
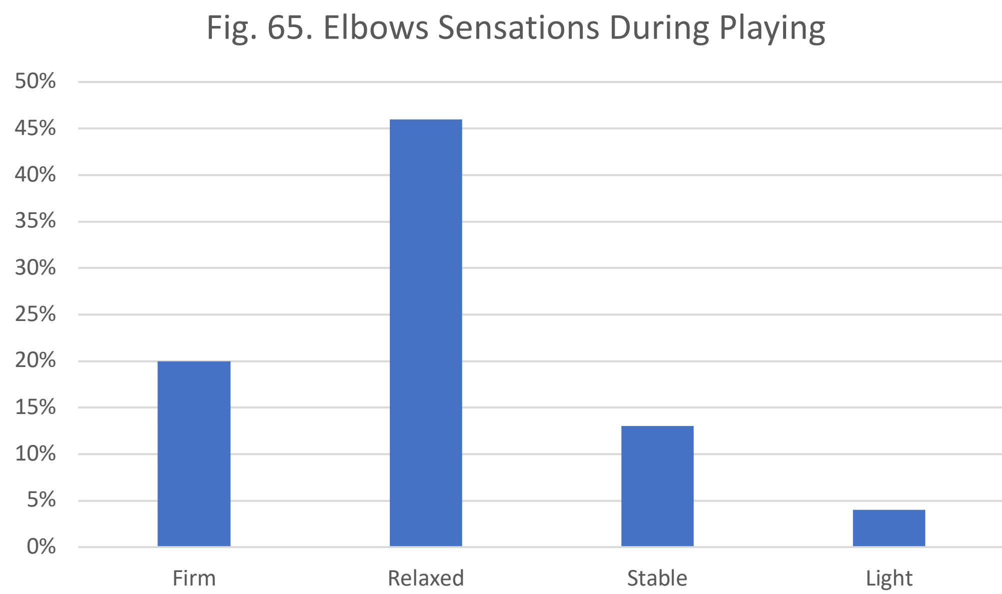


Fig. 64. Forearm Sensations During Playing





Survey Question
Describe the sensations felt in the following DURING PIANO PLAYING (same descriptors as previous questions as a guide):
a) fingertips
b) finger joints
c) wrist joint
d) forearm
e) elbow

Figs. 61-65. These figures describe participants' perceptions of the inner physical conditions of various parts of the playing apparatus during piano playing. Participants responses underwent qualitative analysis, categories were subsequently generated, and percentages were then calculated from the categories relative to the number of participants. The words *relaxed* and *firm* again featured prominently here. The popular response to fingertips was *firm* at 38% with *relaxed* following relatively close at 25% (See Fig. 62). *Firm* was also the top choice for fingerjoint sensations (42%) (See Fig. 63). This reversed for the wrists, forearms and elbows with *relaxed* being the unanimous choice at 53%, 40% and 46% respectively (See Figs 64-66). This data, with some further analysis could reveal correlations between inner sensations, pain and injury susceptibility.

Fig. 66. Fingertip Movements During Playing

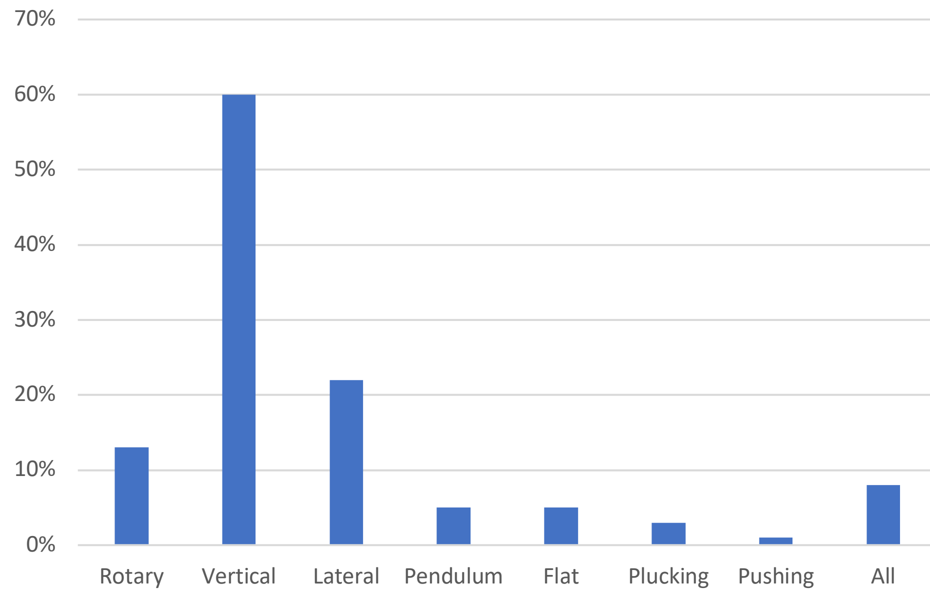


Fig. 67. Fingerjoints Movement During Playing

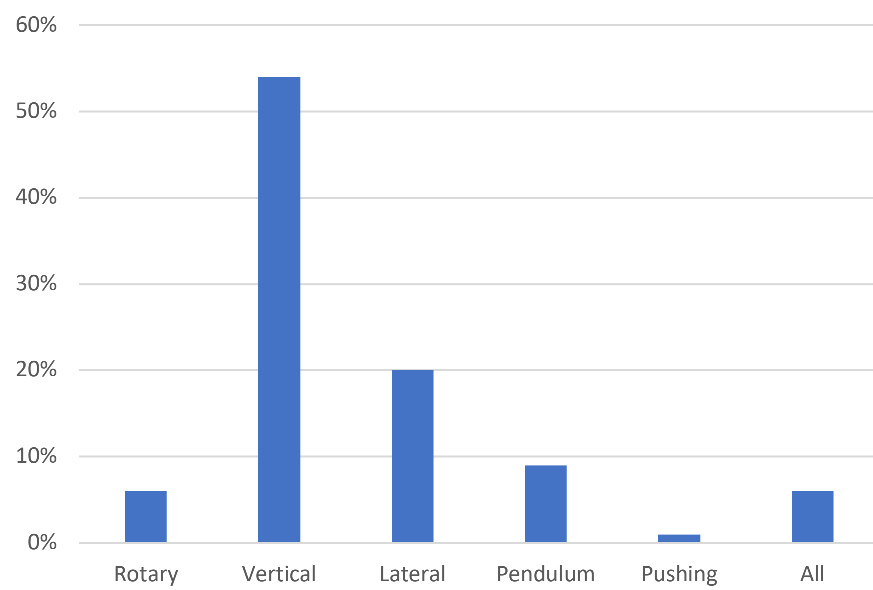


Fig. 68. Wrists Movement During Playing

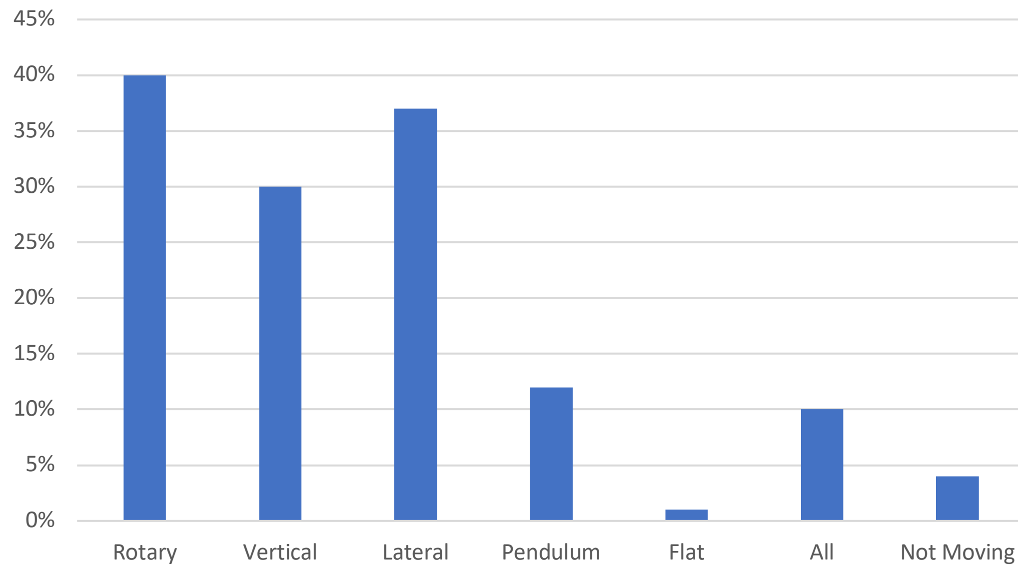
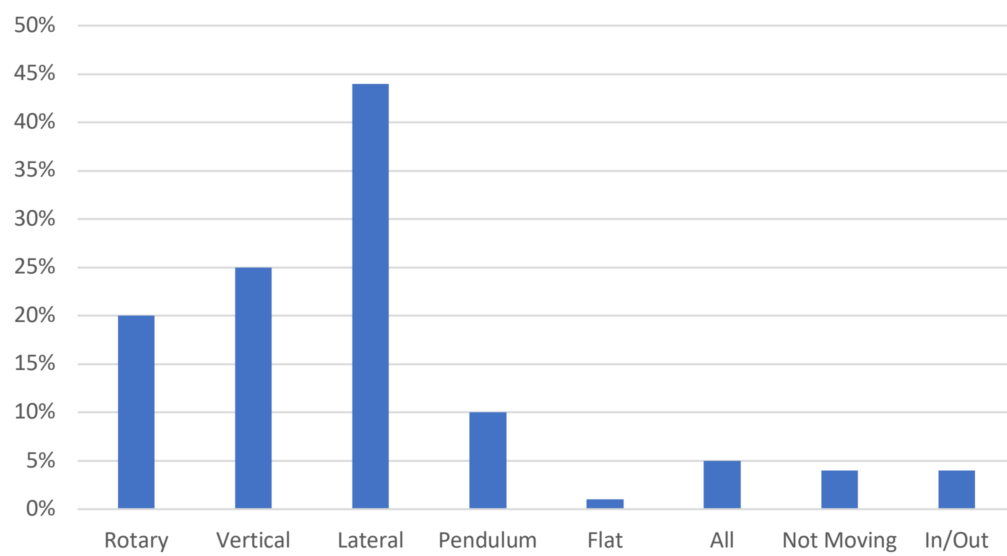
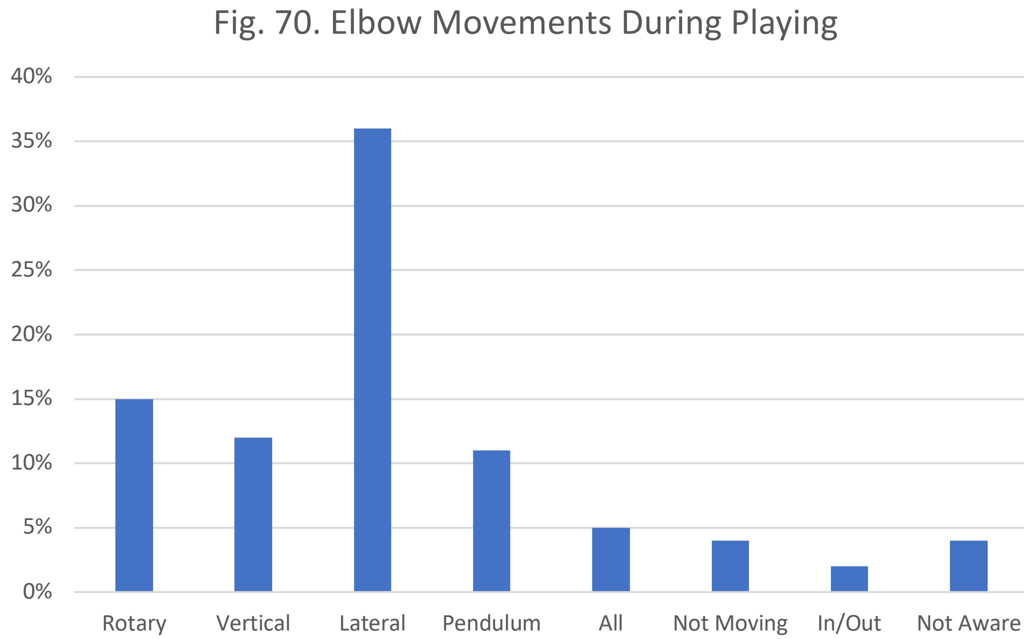


Fig. 69. Forearm Movements During Playing

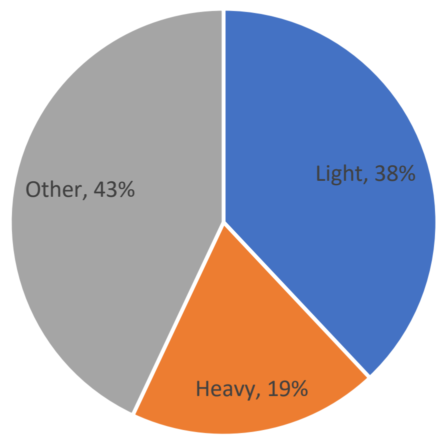




Survey Question
Describe the movements used of the following while playing (vertical – up and down, lateral - side to side, rotary, pendulum-like, etc.):
a) fingertips
b) finger joints
c) wrist joint
d) forearm
e) elbow

Figs. 66-70. These figures describe participants' perceptions of the movements of various parts of the playing apparatus during piano playing. Participants responses underwent qualitative analysis, categories were subsequently generated, and percentages were then calculated from the categories relative to the number of participants. Participants believed *vertical* movement of the fingertip was the predominant one at 60% (See Fig. 67). This trend of *vertical* movement continued for the fingerjoints at 54% (See Fig. 68). A majority of participants believed *rotary* movement was the predominant one (40%) with *lateral* and *vertical* movement also significant choices at 37% and 30% respectively (See Fig. 69). *Lateral* movement was the top choice for describing forearm movements (44%) with rotary (20%) and vertical movements (25%) also popular choices (See Fig. 70). Lateral movement was also the predominant choice for elbow movements at 36% (Se Fig. 71).

Fig. 71. Sense of Weight of the Piano Keys



Survey Question
When playing, do the piano keys feel:

a) light
b) heavy
c) other

Fig. 71. This figure describes participants perception of the weight of the piano keys when playing the piano. Percentages were calculated based on the number of participants answering this question. A majority of participants selected *other* (43%) claiming that it really depended on the piano. *Light* was the second most popular choice at a close 38% with *heavy* the least selected option at 19%.

Fig. 72. Alignment of Wrist

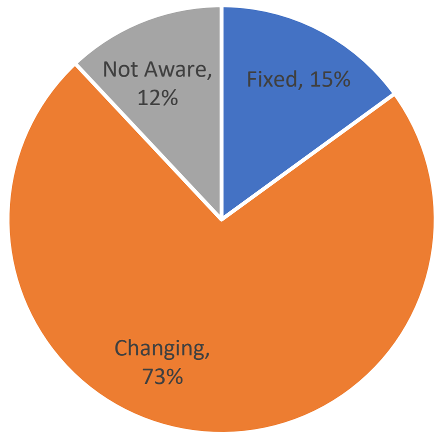
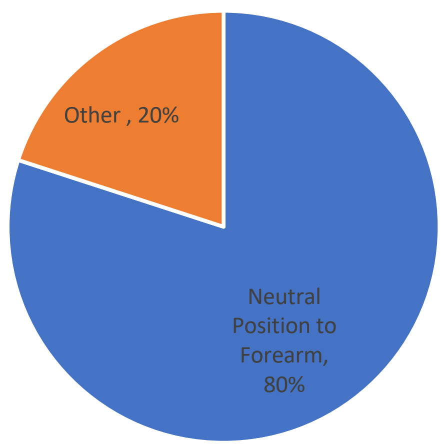
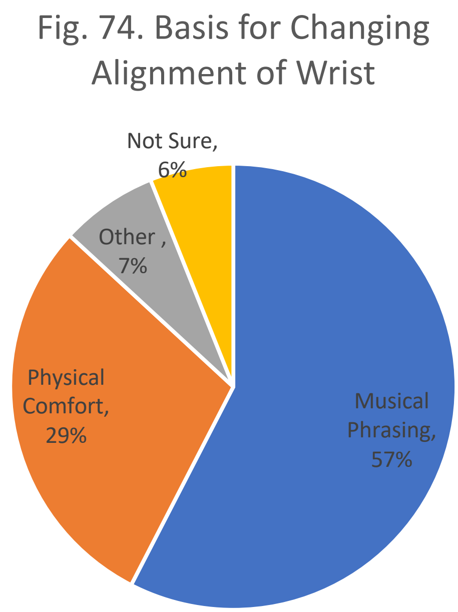


Fig. 73. Description of Fixed Alignment





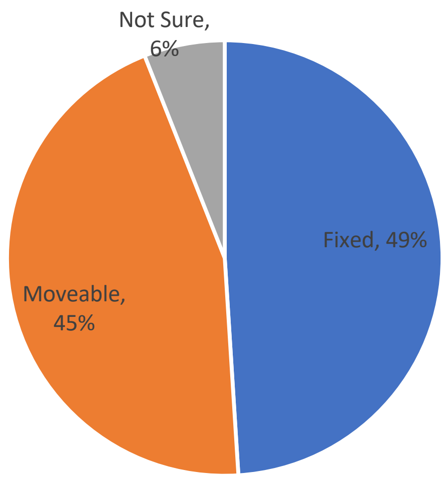
Survey Question
Would you describe the alignment of your fingers to wrists when playing as:
a) fixed
b) constantly changing
c) Not sure

If YES to a) describe how it is fixed.
a) neutral
b) Oriented toward the thumb
c) Oriented toward the little (5th) finger

If YES to b) what determines the alignment?
- a) physical comfort
- b) musical phrasing
- c) other____________
- d) Not sure

Figs. 72-74. These figures describe the alignment of participants fingers and wrist when playing the piano. Percentages were calculated based on the number of participants answering these questions. A vast majority (73%) report that their finger-wrist alignment is *constantly changing*, with *fixed alignment* and *not sure* far behind at 15% and 12% (See Fig. 73). For participants that selected the fixed alignment, a vast majority report that their wrist remains in a *neutral* position relative to the fingers (80%) (See Fig. 74). For those participants selecting constantly changing alignment, a majority claim that the basis for that changing alignment has to do with musical phrasing (57%) with physical comfort being the second choice at 29% (See Fig. 75).

Fig. 75. Seat Height at the Piano



Survey Question
Is your seat height at the piano:
a) always fixed
b) always movable
c) not sure

Fig. 75. This figure describes the seat height of participants when playing the piano. Percentages were calculated based on the number of participants answering this question. A slight majority claim to have a fixed seat height (49%) with those reporting a changing seat height at 45%. 6% of participants claim to be unsure.

Fig. 76. Miscellaneous Results
Mean Age: 30.09 years
Median Age Range: 24-29 years
Average Years of Study: 20 years
Average Number of Teachers: 5
Average Number of Technique-Focused Teachers: 2
Average Number of Daily Practice Hours: 3.1 hours
Median Daily Practice Hours Range: 3-5 hours
Percentage of Practice Sessions Devoted to Breaks: 10%
Most Prevalent Injury: Tendonitis (50%)
Most Popular Remedy for Pain/Injury: Break from piano (95%)
Most Challenging Etudes: Op. 25 No. 6, Op. 10. 2, Op 25. No. 11 (Composer: Frederic Chopin)

Survey Questions
Please state your age. (Give a numerical answer)

How many years have you studied piano? (Enter value in years)

How many piano teachers have you had over the course of your training? (Enter numerical value)

How many of your teachers would you consider to be technicians or technique-focused?

Select the components of your typical PRACTICE STRUCTURE:
a) warming up
b) technique/technical exercises
c) repertoire
d) breaks
e) cool down
f) other___________

Of those components selected, give the PERCENTAGE OF TIME devoted to each area.

Have you had an injury AT ANY POINT IN YOUR PLAYING HISTORY?
a) YES
b) NO

If YES, describe from the list below.
a) Carpal Tunnel Syndrome
b) Tendinitis
c) Bursitis
d) Tenosynovitis/DeQuervain's Syndrome
e) Tendinosis
f) Thoracic Outlet Syndrome
g) Myofascial Pain Syndrome

h) Cubital Tunnel Syndrome, and
i) Trigger Finger/Thumb
j) Other

Describe how you are managing (or managed) your discomfort/pain or injury.
a) Medication
b) Home Remedies
c) Therapy
d) Break from piano
e) Quitting piano
f) Other_______________

List the THREE most challenging etudes technically that you have performed.

Fig. 76. This figure describes participants' responses to various questions relative to various parameters. These figures were calculated using both quantitative and qualitative analysis techniques. In terms of age, the mean age of participants was 30.09 and the median age range was 24-29 years. 20 years was the average years of study for participants. The average number of piano teachers that participants reported was five and participants believed that 2 of the 5 on average were technique-focused. Participants practiced 3.1 hours/day and the median practice hours/day was between 3-5 hours. According to participants, 10% of total practice sessions were devoted to breaks. The most prevalent injury suffered by participants was tendonitis accounting for 50% of all playing-related injuries. Taking a break was the most popular remedy/practice for participants suffering from pain or injury. Participants believed that the most challenging etude were those of Chopin – particularly the Op. 25 No. 6, Op. 10. No. 2 and Op. 25 No. 11.

Glossary

Abduction: the movement of a limb or other part away from the midline of the body or away from another part.

Actuator: a component of a machine that is responsible for moving and controlling a mechanism or system.

Adduction: the movement of a limb or other part towards the midline of the body or towards another part.

Anatomy: concerned with the study of the structure of organisms and their parts.

Analysis of Variance (ANOVA): a collection of statistical models used to analyze the differences among group means in a sample.

Arm Levers: third class lever system where its applied force (muscle) is situated between the load (piano) and fulcrum (elbow/shoulder.

Articular: relating to the connecting part of a joint or the joints.

Base: the non-moving part of the body connected to the moving body.

Biaxial joint: allow movements in two planes. It allows movement of the hand from side to side and forward and backward.

Biomechanics: the science of movement of a living body, including how muscles, bones, tendons, and ligaments work together to produce movement.

Bowstringing: when the flexor tendon moves away from the center of rotation of the joint, thus increasing the flexion moment arm. Caused by loss of proximal pulleys.

Central Nervous System (CNS): the complex of nerve tissues that controls the activities of the body. In vertebrates it comprises the brain and spinal cord.

Circulatory System: network consisting of blood, blood vessels, and the heart. This network supplies tissues in the body with oxygen and other nutrients, transports hormones, and removes unnecessary waste products.

Circumduction: refers to a conical movement of a body part. It's a combination of flexion, extension, adduction and abduction.

Contraction/Relaxation Rate: the speed with which muscle contraction and relaxation occurs.

Co-contraction: the simultaneous activation of antagonist muscles around a joint.

Covariation: a measure of the joint variability of two random variables.

Distal: situated nearer to the center of the body or the point of attachment.

Distal Interphalangeal Joint (DIP): the joint between the second (intermediate) and third (distal) phalanges of the fingers.

Eccentric/Concentric muscle action: concentric contractions causes muscles to shorten, thereby generating force. Eccentric contractions cause muscles to elongate in response to a greater opposing force

Empirical studies: a way of gaining knowledge by means of direct and indirect observation or experience.

Enthesopathy: a disorder involving the attachment of a tendon or ligament to a bone.

Ergonomics: the study of people's efficiency in their working environment.

Exertions: movements generated by muscular force.

Extension: a movement that increases the angle between two body parts.

Extensor Tendon: tendons that lie next to the bone on the back of the hands and fingers and straighten the wrist, fingers and thumb.

Etiologies: the cause, set of causes, or manner of causation of a disease or condition.

Flexion: a movement that decreases the angle between two body parts.

Flexor Digitorium Superficialis/Profundus (FDS/FDP): extrinsic flexor ***muscles*** in the forearms that flexes the fingers.

Frontal plane: Hypothetical plane used to divide the human body into left and right.

Kinesiology: the scientific study of human or non-human body movement.

Kinesthetic Stimuli: a thing or event that evokes a specific functional reaction in an organ or tissue.

Lever: a simple machine consisting of a beam or rigid rod pivoted at a fixed hinge, or fulcrum and capable of rotating on a point on itself.

Metacarpophalangeal joints (MCP): situated between the metacarpal bones and the proximal phalanges of the digits.

Motor Skills: a learned ability to cause a predetermined movement outcome with maximum certainty.

Neural/Nervous System: a network of nerves and cells that carry messages to and from the brain and spinal cord to various parts of the body.

Neuromechanics: an area that attempts to combine the efforts of muscles, sensory organs, pattern generators in the brain, and the central nervous system itself to explain motion.

Nomenclature: the devising or choosing of names for things, especially in a science or other discipline.

Orthopedic: relating to the branch of medicine dealing with the correction of deformities of bones or muscles.

Pearson correlation analysis: a measure of the linear ***correlation*** between two variables X and Y.

Physiology: the scientific study of the functions and mechanisms which work within a living system.

Playing-Related Musculoskeletal Disorder (PRMD): painful, chronic and disabling conditions which are prevalent among musicians.

Playing Apparatus/Playing Limb: parts of the human body directly involved in the movements needed for instrumental performance.

Pons asinorum: the point at which many learners fail, especially in a theory or formula that is difficult to grasp.

Pronation: when the distal end of the radius rotates around the ulna from its position on the lateral side of the wrist to the medial side of the wrist. This action turns the hand, wrist, and forearm almost 180 degrees so that the palm faces posteriorly or inferiorly, depending on the position of the arm.

Pronator Teres: a muscle located in the forearm that serves to pronate the forearm (turning it so that the palm faces posteriorly when from the anatomical position).

Proprioception: the sense of the relative position of one's own parts of the body and strength of effort being employed in movement.

Proximal Interphalangeal Joint (PIP): the joint between the first (also called proximal) and second (intermediate) phalanges of the fingers.

Proximal: situated away from the center of the body or from the point of attachment.

Qualitative studies: a <u>scientific method</u> of <u>observation</u> to gather <u>non-numerical data</u>. It is used to gain an understanding of underlying reasons, opinions, and motivations.

Quantitative studies: the systematic empirical investigation of observable phenomena via statistical, mathematical, or computational techniques.

Radial Deviation: the movement of bending the wrist to the little finger, or ulnar bone, side.

Radio-ulnar joint: a joint between the two bones in the forearm; the radius and ulna.

Radioulnar joint capsule: tissues that act as a stabilizer of the distal radioulnar joint.

Relaxations: movements generated by relaxation of muscles.

Sagittal plane: hypothetical plane used to divide the human body into back and front.

Sub-occipital muscles: group of muscles that are located below the occipital bone (base of the skull).

Scientific Method: a method of procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses.

Small muscles of the forearm: smaller muscles located within the hand itself capable of producing finger motion

Strong muscles of the forearm: the muscle belly located on the forearm responsible for the flexion and extension of the fingers and wrist.

Supination: when the distal end of the radius rotates around the ulna from its position on the medial side of the wrist to the lateral side of the wrist. This action turns the hand, wrist, and forearm almost 180 degrees so that the palm faces posteriorly or inferiorly, depending on the position of the arm.

Touch/sense organs: an organ of the body which responds to external stimuli by conveying impulses to the sensory nervous system.

Transverse Carpal Ligament: a fibrous band on the palmar side of the hand near the wrist. It arches over the carpal bones of the hands, covering them and forming the carpal tunnel.

Transverse Plane: Hypothetical plane used to divide the body into cranial/top and caudal/bottom.

Ulnar Deviation: the movement of bending the wrist to the thumb, or radial bone, side.

Vinculae/viniculum: a band of connective tissue, similar to a ligament, that connect a flexor tendon to a phalanx bone

Viscoelasticity: the property of materials that exhibit both viscous (thick, sticky consistency between solid and liquid) and elastic characteristics when undergoing deformation.

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