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https://orcid.org/0000-0002-6327-9630

Paulina Tworko

Grażyna and Kiejstut Bacewicz University of Music in Łódź

Physiology and Ergonomics of Piano Playing

Abstract

Much has been said about performance, styles, and interpretation. However, we should ask ourselves where they come from, what they depend on, and what factors influence them. The answer proves very complex. This article deals with the problem of piano technique as an element on which interpretation, sound and expression depend to a large extent. The piano is an instrument with incredible tonal possibilities, but it requires fingering skills, the ability to 'feel' the keys and a certain physical strength which is directly related to the technique we use. Achieving a high level in playing requires years of diligent work, perseverance, and determination. Technical proficiency, in turn, facilitates expression and appropriate interpretation, in line with the style of a given musical period and the feelings of the pianist-performer. We are thus talking about two things that inexorably influence each other: technique and its results. The latter depend largely on the former. This article explores the knowledge of piano technique which needs to be acquired so that in the end nothing

comes in the way of communication between performers, listeners, and the music.

Keywords

Piano-playing technique, piano skills, pianist's hand

On the Technique

Piano technique is an extremely complex issue, dependent on individual anatomical and morphological constitution, the influence of teachers, pianists' own explorations, observations, and experiences, as well as the ability to draw appropriate conclusions from the latter. Technique facilitates attaining absolute mastery over the sound, which helps obtain the desired musical result with minimum physical effort.

One may ask why some pianists enjoy success performing highly demanding works with relative ease, while others do not achieve such satisfying results despite dedicating dozens of hours to practice. Inborn talent plays a big role; however, apart from a small proportion of those who reach technical perfection with relative ease, there are many gifted musicians who encounter problems. These may result from inappropriate habits of movement, derived from an insufficiently formed or untrained musical intuition and reinforced by practice. Another frequent cause is the teacher, who exerts a huge impact on the development of the pupil's technique. The teacher's oversights or negligence, especially in the early stages of training, but also later, may hinder the performer. Unfavourable anatomical and morphological constitution may also prove a disadvantage, as has been mentioned above. This concerns the size and span of the hand, length of fingers, work efficacy, as well as the muscular and tendon tissues' ability to regenerate. This is directly related to the functioning of the nervous system (which triggers muscle contractions) and the vascular system (which supplies the organism with oxygen and nutrients as well as eliminating harmful metabolites). Some of these factors are independent of our will and effort – for instance, the size of the hand and finger length. The others may be directly and indirectly influenced.

Technique in the Past and Today

The problem of piano technique has been frequently discussed over the ages, as evident from the large number of more or less pertinent publications on this subject.[1] Points of view have been changing along with the evolution of the piano and the stylistic changes in newly produced repertoire. The keyboards on the early instruments were smaller, the mechanism – lighter, and the literature – mainly based on the so-called 'small' finger technique. With time, pianos grew larger, and their sound power increased, which entailed changes in playing technique. The instrument built by Bartolomeo Cristofori in 1709 and considered as the prototype of a piano[2] had in fact relatively little in common with today's concert pianos.

The late nineteenth and early twentieth centuries particularly abounded in mutually contradictory views concerning piano technique. Both the 'exclusive finger method' and the 'arm-weight method' had numerous followers in that period, who opted for various techniques of training, fingering, and hand position on the keyboard. Since medicine was much less advanced than nowadays, many guidelines concerning hand action were based on intuition, correct in some cases, while in others they proved to be a dead end. Our present-day knowledge makes it possible to examine piano technique in much more detail from the point of view of how our body works as the playing apparatus whose effective functioning contributes to achieving the desired musical effect. The final result is the sum total of small-scale factors such as the precise finger, hand and forearm movements, made possible by the coordinated work of the complicated human body mechanism. Excellent Polish pianist and teacher Józef Hofmann once claimed that 'in the course of a piano recital – actual playing time approximated eighty minutes – a pianist makes well over a hundred thousand different motions.'[3] A detailed description of each of them would be impossible. Nevertheless, the awareness of their types and role in achieving the expected final effect ought to be

[1] Let me only mention here Fryderyk Chopin's *Projet de méthode*, Tobias Matthay's *The Visible and Invisible in Piano Technique*, and Otto Ortmann's *The Physiological Mechanics of Piano Technique*.

[2] M. Kowalska, *ABC historii muzyki* (2001), 232.

[3] A. Földes, *Keys to the Keyboard: A Book for Pianists* (1968), 40.

part and parcel of a good pianist's (and especially a piano teacher's) education.

Owing to the enormous sound possibilities afforded by present-day pianos, the characteristics of contemporary music, and high demands placed on the performers, pianists must dedicate a lot of time to practice. Side effects such as muscle fatigue or even injury are frequent. All of us would like our playing to be both effective and impressive, so that music is produced in an unrestrained and efficient manner. This can be achieved with good technique. At this point let me quote Hofmann's words: 'Technique is like a toolbox, from which an artist conscious of his or her aims draws the right tool at the right time.'[4] Eminent English pianist and teacher James Ching defined technique as a set of purposeful and well-coordinated movements characterised by a definite direction, performed in a suitable manner and with appropriate force.[5] This is a compact and accurate description of the essence of the subject, which, unfortunately, is largely neglected in Polish music education. Though the very word 'technique' is frequently read and heard, this does not translate into the adequate scope of practical guidelines. Many pianists complain about the lack of sufficient knowledge passed down by teachers concerning the correct technical posture and position. This neglect impacts the quality of performance and may increase the risk of overstraining the muscles and tendons.

How, then, should technique be developed? What practices should be eliminated as inefficient, and which should be promoted for the final effect to be musically attractive without overexerting our playing apparatus? The type of sound, which has a strong bearing on the effect, is closely related to the type of touch and control over the way in which individual notes are combined into longer sequences.

Effective playing fundamentally depends on the right choice of movements, on the force they generate, and the part of the limb involved. In this context we can see that music and technique are inextricably linked. We must definitely cultivate and develop the latter, because without a good technique responsive to our intentions, performing the work in accordance with our artistic vision will prove considerably more difficult. Besides, incorrect use of the playing apparatus may trigger the already mentioned unwanted side effects. As one

4 C. Sielużycki, *Ręka pianisty: Fizjologiczne podstawy techniki* (1982), 17.
5 Sielużycki, *Ręka pianisty…*, 18.

study demonstrates, fifty per cent of health problems among musicians affects those playing keyboard instruments.[6] In a questionnaire carried out by Bruno Savino, Antonio Lorusso, and Nicola L'Abbate in 2008, approximately forty percent of pianists admitted to experiencing discomfort or pain in relation to playing the instrument.[7] Those complaints, from mild to highly troublesome, concerned various parts of the body, from the back and neck to the wrist and hand. Unfortunately, musicians' professional medicine, suited to the specific qualities of this occupation, such as the frequent repetitions of the same gestures, frequently involving considerable force, is virtually non-existent in Poland, though musicians need preventive care no less than sportspersons. Prevention is the first and undoubtedly the most effective way of avoiding overexertion. Knowledge of how to use the hands effectively while playing is essential to obtaining the right musical effect; it should therefore constitute an obligatory element of every good piano teacher's and pianist's work. Instead, many things are still done exclusively 'by the ear' and intuitively, which may cause musicians to fall into bad habits and consequently strain their muscles. Long hours wasted on fruitless practice lead to a feeling of discouragement and exhaustion, while the expected musical effect remains unattainable.

The 'Instrument' of a Pianist's Work

The playing apparatus consists of our upper limb, complete with the back and shoulder. Knowledge of their anatomy and structure will make it possible to understand the mechanism of movement necessary for piano playing. Two types of elements can be distinguished: the passive (bones and joints) and the active (muscles) ones.

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6 N.S. Grant, 'Arts Medicine: When Practice Turns To Pain', *Keyboard*, February 1988, 90; quoted after: B. Wristen, *Overuse Injuries and Piano Technique: A Biomechanical Approach, A Dissertation in Fine Arts* (1998), 174, https://ttu-ir.tdl.org/handle/2346/10941?show=full, accessed 6 Feb. 2020.

7 S. Bruno, A. Lorusso, N. L'Abbate, 'Playing-related disabling musculoskeletal disorders in young and adult classical piano students', *International Archives of Occupational and Environmental Health*, 81 (2008), 855–860; quoted after: L. Mengyuan et al., 'Assessing Injury Risk in Pianists', *MTNA e-JOURNAL* 2015, https://www.eldertech.missouri.edu/wp-content/uploads/2016/06/Assissing-Injury-Risk-in-Pianists.pdf, accessed 18 May 2020.

The upper limb consists of: the pectoral girdle (comprising the clavicle and scapula) which connects the movable section to the torso, and the movable section (the humerus, the forearm bones: ulna and radius, and the hand). The hand is made up of:[8]

- the complex of eight carpal bones arranged in two transverse rows;
- five long metacarpal bones corresponding to each of the fingers; their bases are fixed to the rigid row of carpal bones, while their heads are attached the metacarpophalangeal joints, visible on the surface of the hand as the so-called knuckles. This protuberant shape, as Chopin already observed, increases the flexibility of the hand, and especially of the fingers, which serve as pillars or supports through which the energy necessary to press the keys flows from the arm and the forearm; this flexibility, however, decreases as we splay our fingers wider and wider;[9]
- the digital bones, which consist of three phalanges (proximal, intermediate, and distal – in fingers 2 to 5), except for the thumb, which only comprises a proximal and a distal phalanx.

All the bones are connected in the joints, which makes movement in many planes possible. The joints essential for piano playing are:[10]

- the shoulder joint, which connects the limb to the torso and makes it possible to move along the keyboard at any angle;
- the elbow joint with the radial and ulnar collateral ligaments, responsible for the pronation of the hand (with the palm facing down); this makes playing the piano possible, also allowing for forearm rotation at up to 150–170 degrees, necessary to produce tremolos, trills, moderate-range leaps, as well as arpeggios;[11]
- joints of the hand, comprising several elements:
    1 The wrist joint is responsible for the circumduction movements (combining flexion and extension, adduction and abduction). The hand can only rotate up to 15–20 degrees thumb-wise, but about 45 degrees little-finger-wise. This plays a major role in piano playing, letting the fourth and fifth fingers to lead voices more freely as well as efficiently and rapidly 'reach out' for the

[8] B. Marecki, *Anatomia funkcjonalna w zakresie studiów Wychowania Fizycznego i Fizjoterapii* (2004), 80–83.
[9] Sielużycki, *Ręka pianisty…*, 75.
[10] Marecki, *Anatomia funkcjonalna…*, 66–67, 72–74, 80–83, 88–90.
[11] Sielużycki, *Ręka pianisty…*, 73.

sounds of the melody or the bass. Oblique hand movements, executing polyphonic textures, performing chords, harmonic progressions, and octaves – are only possible because of these joints. Their function consists in transmitting frequently huge force from the forearm, arm, and sometimes even the torso. For this reason, these joints need to be particularly resilient.

2 The carpometacarpal joints (CMC) that link the distal row of carpal bones to the metacarpus. These joints have a tense (restricted) articular capsule, additionally reinforced with a set of ligaments, which significantly limits their flexibility. One exception is the carpometacarpal joint of the thumb, whose relaxed articular capsule makes adduction and abduction movement possible within 35–40 degrees, and opposition of the thumb within the range of 45–60 degrees. The latter type of movement, which we refer to as 'gripping' in everyday life, in piano playing makes it possible to oppose the thumb movement to those of the other fingers, which finds its application in rotation, trills, and tremolo figurations. Finger opposition makes it easier to control them in the process of voice leading. The farther the fingers are situated from each other, the more independent they become, and the more possibilities of diversifying the music it affords. The thumb plays the key role in this respect because of its structure and position. Awareness of this relation can be useful while choosing the right fingering.

3 The metacarpophalangeal joints, connecting the metacarpus to the proximal phalanges, popularly known as knuckles because of the bones protruding from the top of the hand. It is these joints that do most of the work related to finger motion in piano playing. They perform flexion and extension movements (up to c. 110 degrees) as well as adduction and abduction (the range of the latter depends on the degree at which the finger is bent). For this reason, while playing octaves and large chords we tend to raise the wrist, which allows us to strengthen the fingers a bit more.[12]

4 Interphalangeal joints, which perform flexion and extension movements. These include the proximal interphalangeal joint, which can bend up to 120 degrees (significant flexibility) and

[12] Wristen, *Overuse Injuries…*,174.

the distal one (bends within c. 70 degrees). They are connected by the individual phalanges. Owing to the lack of the middle phalanx, the thumb only has one interphalangeal joint, bending at c. 90 degrees. The bones and joints of the hand (represented on the illustration below) are additionally stabilised and reinforced by a complex system of ligaments. One needs to emphasise the importance of the metacarpophalangeal joints as well as the carpometacarpal joint of the thumb, which perform a leading role in piano playing.

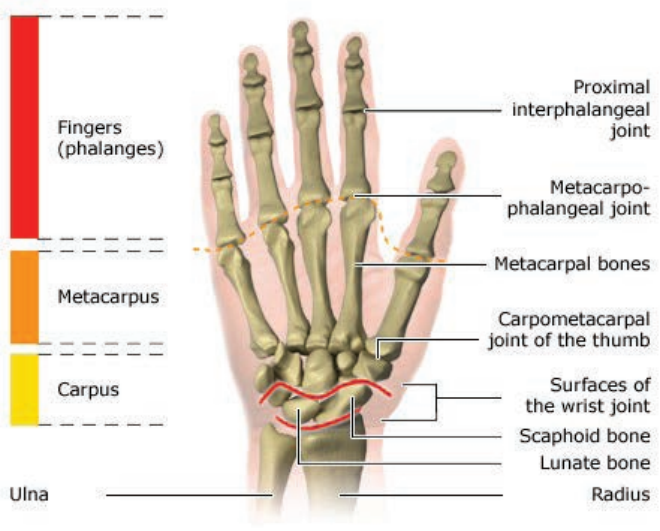


Fig. 1. The bones and joints of the hand, graphic representation by Stephan Spitzer, Atelier für Medizinische Illustration, after https://www.informedhealth.org/how-do-hands-work.html.

The active elements are the muscles and tendons, which are grouped in functional sets coordinating the work of the individual sections of the limb. Each section is controlled by the muscles belonging to the segment above it. Specifically, the arm is moved by the muscles of the torso and the shoulder, the forearm – by those of the arm, the fingers – by the muscles of the hand and forearm.[13] The muscles of the torso and

[13] Sielużycki, *Ręka pianisty…*, 79–81.

the shoulder also stabilise the movements of the sections of the limb situated farther from the shoulder. A fixed position of the shoulder joint makes possible the free movement of the smaller elements. It also supports the limb by 'taking the weight off the fingers', which makes their fast work possible. This group of muscles includes the kite-shaped trapezius (taking up much of the human back's surface, from the neck down) and the rhomboids (situated next to the scapula). These muscles make it possible to maintain an upright posture, which facilitates the movements of the upper limb. They draw the scapula, at the same time pushing the chest forward.[14] They allow the pianist to use the arm as a long lever in case we need more force, as when we play *forte* chords or octaves. Backache, a common complaint among pianists, frequently results from the accumulation of tension in the above-listed muscles, which is caused by overstrain, sometimes additionally aggravated by arching the back or bending too much forward.[15] In such situations, it is recommended to take a break from the practice, which gives the muscles of the back some time to regenerate.

The forearm and the elbow carry out a major function in piano playing. They are moved by the muscles situated above them, in the arm, while the muscles that control the hand and the fingers start at the elbow. The elbow joint performs flexion and extension movements, as well as rotary ones (up to 150–170 degrees), which are essential for a pianist.[16] The wrist bends the hand forwards (flexion), backwards (extension), inwards towards the thumb (radial flexion) and outwards towards the little finger (ulnar flexion). A combination of these movements makes it possible to perform rotary (circular) movements. Finger movement is possible at three joints (for the thumb – at two joints). Two types of muscles determine the action of the hand and finger joints:

- longus muscles starting at the elbow, which end in tendons that lead to the fingertips;
- brevis muscles located in the hand.

The fingers and the wrist are equipped with a set of flexors situated on the inside of the forearm, and extensors, which run along the surface of the forearm. When we move our fingers, we can see how these

[14] Sielużycki, *Ręka pianisty…*, 71.
[15] L. Deahl, B. Wristen, *Adaptive Strategies for Small-Handed Pianists* (2017), 41.
[16] Deahl, Wristen, *Adaptive Strategies…*, 73.

muscles move inside the forearm. There are many groups of muscles working synergistically (that is, moving simultaneously in the same direction).[17]

Techniques of Touch on the Piano

How is sound produced? What does type of sound result from in piano playing? How can we influence it? Much depends on the complicated mechanism of the piano, responsible for major differences between the various instrument brands and even, as we know, between pianos manufactured by the same piano maker but differing in the degree of wear and tear of its many parts and in how and by whom are maintained. Sound itself, however, can only be produced by the pianist, who sets this mechanism in motion. The quality and characteristics of piano sound depend on the type of touch. There is a very broad palette of possible sound types, from intense, aggressive and loud to subtle, soft and song-like. Type of touch depends in turn on the movement we perform: its speed, span, and the part of the limb which performs this motion. All these factors, however, ultimately come down to the variable force applied by the pianist to the surface of the key. This was demonstrated by Otto Ortmann, a researcher who conducted laboratory tests on pianists.[18] In more recent times, dynamometric experiments concerning the application of force in piano playing were conducted by Professor Hartmut Riehle and Henriette Gärtner in 2010.[19]

Playing the piano requires the movement and work of the whole limb, and sometimes even of the torso. Different manners of attack are made possible by the coordinated work of the various parts of our playing apparatus. Many authors apply their own terminology concerning the technique of key attack, using varying criteria. In practice, there are many types of touch, depending on the span and speed of limb motion as well as the part of the limb involved. This variety is further enhanced by various combinations of types, as well as the individual traits of each pianist. Predictably, describing all these types

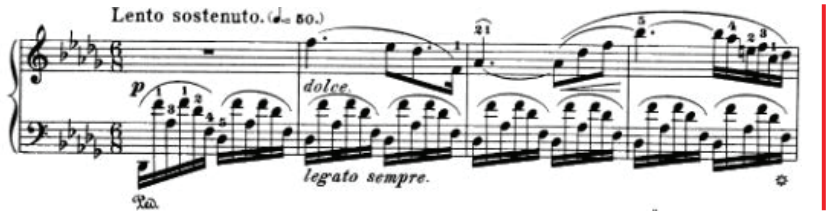
[17] Marecki, *Anatomia funkcjonalna*…, 83–88.

[18] O. Ortmann, *The Physiological Mechanics of Piano Technique* (1929), 3, https://archive.org/details/in.ernet.dli.2015.89583/page/n7/mode/2up, accessed 12 Apr. 2020.

[19] Information from direct contact with the researcher who conducted those tests.

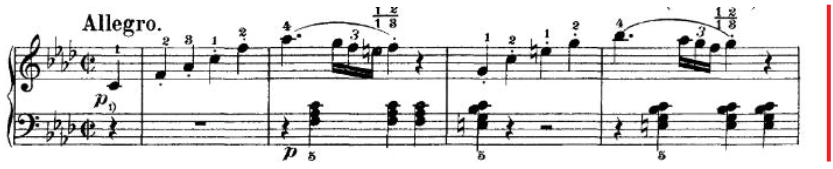
is impossible in practice. It is important, however, to be aware of the existence and the qualities or the various categories of movement in piano playing technique, out of which their countless combinations are subsequently formed.

The individual parts of the limb work together during playing. We can distinguish, however, those that initiate movement and play the dominant role in the given technical problem. We thus speak of arm playing, forearm playing, from-the-wrist, and finger playing technique. It should be stressed that 'arm playing' naturally does not exclude the participation of the fingers and hand. Playing the piano is the result of extremely complex coordinated movements which involve all the parts of the upper limb to a varying degree and within a varying span.



Ex. 1. F. Chopin, *Nocturne in D-flat major* Op. 27 No. 2, mm. 1–4.[20]

Leading the melody in the right hand depends here on an arm-weight-playing legato technique. The slow tempo affords the pianist time for gradual and controlled 'release' of weight, relaxed hand movements, and control over the song-like quality and sound colour.

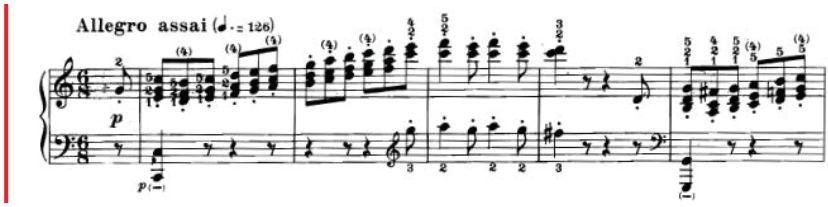


Ex. 2. L. van Beethoven, *Sonata in F minor* Op. 2 No. 1, mov. I, mm. 1–4.[21]

[20] Source: https://ks.imslp.net/files/imglnks/usimg/4/4b/IMSLP47190-PMLP02305-Chopin_Nocturnes_ Schirmer_Mikuli_Op_27.pdf, accessed 17 Apr. 2020.

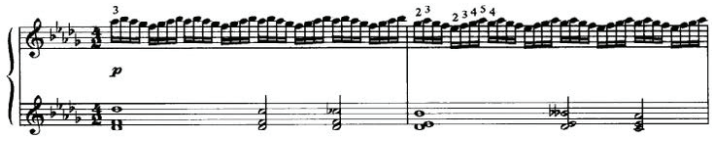
[21] Source: https://imslp.hk/files/imglnks/euimg/6/63/IMSLP621777-PMLP01446-E621557_4-19-beethoven--sonatas-vol1.pdf, accessed 10 June 2020.

In the above-presented fragment we can see single note progressions performed *staccato* in the right hand, typically played from the forearm. This is one of the most effective and frequently applied types of *staccato*, as many authors confirm.



Ex. 3. L. van Beethoven, *Sonata in C major* Op. 2 No. 3, mov. IV, mm. 1–5.[22]

The delicate, fast, and not-too-long *staccato* chord progressions are a classic example of 'from-the-wrist' playing, in which the tempo limits the range of the movement, and the *piano* dynamics do not call for the use of substantial force.



Ex. 4. M. Moszkowski, *Étude de Virtuosité in D-flat major* Op. 72 No. 12, mm. 1–2.[23]

The example above is an excellent illustration of finger playing. The light peal of the sixteenth progressions calls for fast and precise finger work. The arm needs to be suspended above the keyboard and held up by the shoulder muscles, which allows the fingers to play at ease. After each touch, the finger muscles ought to relax at least partly for a split second.

[22] Source: http://ks4.imslp.net/files/imglnks/usimg/9/96/IMSLP243110-PMLP01414-Beethoven,_Ludwig_van-Werke_Breitkopf_Kalmus_Band_20_B126_Op_2_No_3_scan.pdf, accessed 20 Apr. 2020.

[23] Source: http://ks4.imslp.net/files/imglnks/usimg/e/ee/IMSLP112168-PMLP07151-Moritz_Moszkowski_-_15_Etudes_De_Virtuosite,_Op_72.pdf, accessed 20 Apr. 2020.

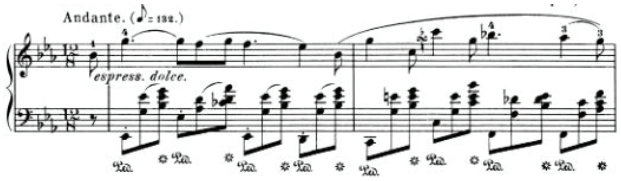
Please note that there are two basic vehicles of movement: muscle work (that is, contractions) and weight.[24] In piano playing both are applied simultaneously, but the proportions between them vary. Using muscle contractions as the only source of force applied to the keys might quickly lead to muscle strain and fatigue, while the music itself would sound 'stiff', and the intensity of sound – limited. The use of weight (gravity), suitably coordinated with muscle work, allows them to work more effectively, and to some extent reduces their necessary effort.

At the end of the nineteenth century, in which the 'small' finger technique enjoyed much popularity, especially with some pianists and composers (such as Czerny), there came the era of 'weight playing', whose numerous adherents included the German teacher-composer Rudolf Breithaupt.[25] The latter technique, which took advantage of gravity force, seemed to answer both to the demands of that period's pianos (characterised by a less responsive mechanism, not as light as before) and those of the new repertoire, based to a much greater extent on massive chordal textures and high sound volume (suffice it to compare works by Mozart and Rachmaninoff). Today, however, we are aware that neither of these sources of force should be the dominant one, and both of them are applied, frequently in conjunction.

Movement in piano playing can be classified depending on speed, span, and the mutual ratio of muscle contractions to weight use.[26] The span and speed of the movement mutually complement each other. Both should be adjusted to the character and tempo of the given music piece. Broad gestures are suitable in slow fragments or in passages with numerous rests, but in fast sections there is no time to make them. The pianist's motion can be classified as follows with regard to its span:[27]

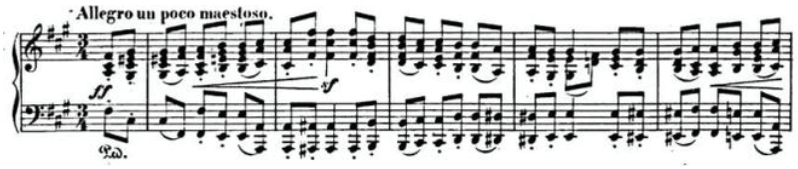
- 'pressure' motion 'from the key': The finger is in contact with the key already before pressing it, so the element of swing is missing. This makes it possible better to control the quality and features of the resulting sound. In the example below, unbroken contact of the right hand (leading the melody) with the keys creates wide possibilities for controlling sound intensity and colour.

[24] G. Sandor, *On Piano Playing: Motion, Sound, and Expression* (1981), 37-51.
[25] Sandor, *On Piano Playing…*, 37–51.
[26] Sielużycki, *Ręka pianisty…*, 140.
[27] Sielużycki, *Ręka pianisty…*, 141. The author distinguishes four types of motion depending on the span of hand's swing and the combination of swing and pressure; my classification is based on the presence of swing or its lack.



Ex. 5. F. Chopin, *Nocturne in E-flat major* Op. 9 No. 2, mm. 1–2.[28]

- 'swinging' motion: Pressing the key is preceded by a swing from a smaller or greater distance towards the keys. Such motion is usually applied when greater force is needed. The weight of the limb can be used more effectively due to the element of distance.



Ex. 6. R. Schumann, *Sonata in F-sharp minor* Op. 11, mov. IV, mm. 1–5.[29]

Performing chord and octave progressions in *staccato* articulation and with *fortissimo* dynamics requires maintaining a certain distance from the keyboard, attained by performing a preparatory motion before attack (which makes the swing possible) and a rebound motion (after attack).

With respect to speed, we should consider its two aspects: The rate of successive note progressions and the rate of individual key attack. One should also mention in this context the element of force, which is the joint effect of limb weight at the moment of attack and key speed.[30] Starting with the former, it must be emphasised that, contrary to appearances, weight is not constant, but dependent on the section of the hand which initiates the movement in the context of a given technical problem. In other words, the longer the lever (from fingertips upwards to the wrist, elbow or, the longest possible, to the shoulder), the greater

[28] Source: https://ks.imslp.net/files/imglnks/usimg/7/7d/IMSLP50496-PMLP02312-Chopin_Nocturnes_Schirmer_Mikuli_Op_9.pdf, accessed 12 Apr. 2020.

[29] Source: https://ks.imslp.net/files/imglnks/usimg/4/4f/IMSLP78924-PMLP02193-Schumann_Werke_5_Peters_Op_11_filter.pdf, accessed 10 June 2020.

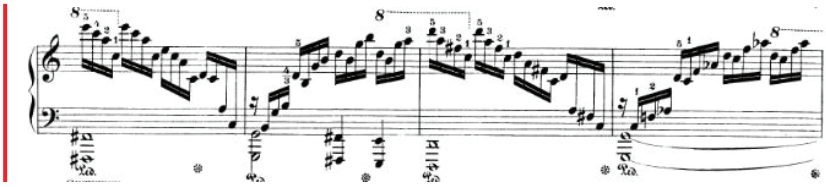
[30] Deahl, Wristen, *Adaptive Strategies…*, 68.

its weight. As the intensity of sound grows, ever longer sections are involved in the playing: the hand, the forearm, the arm, the shoulder, and the torso. This, however, also has its downside. Greater mass means greater inertia (i.e. the object's tendency to remain in the current state). This tendency needs to be overcome for the object to be stopped or set in motion.[31] For instance, it takes more strength and time to move a stone weighing 100 kg than a small ball weighing 500 g. In piano playing this means that we use long levers (the arm and the shoulder) to give force to the sound. However, the large mass and inertia of these sections of the limb translate into slower reactions. For this reason, arm playing is advisable in sections with high dynamics and slow or moderately fast tempi. The fingers, which have little weight but are small and fast, are ideal for spectacular scale or passage progressions performed at breakneck speeds.[32]

The phrase 'weight use in playing' has been part of the piano playing terminology for more than a century. Its meaning has been changing throughout that time along with the progress of science and of the musical art. What, then, is 'weight'? In physics, it is the colloquial term for the force of gravity, which relates mass to acceleration in the context of gravitation. Any downward motion, as in piano playing, draws on this quality. Apart from weight, though, acceleration may be caused by muscle contractions alone. Newton's Second Law of Motion, defining force as the product of mass and acceleration, has an important application in piano playing. To exert greater force, we need either to accelerate our motion or add more mass by using a longer lever, such as the arm rather than only the hand.[33] The traditional notion of weight in piano playing thus refers mainly to the application of larger sections of the hand, characterised by more substantial mass, combined, depending on the expected effect, with some smaller or greater swing. Broad swing creates force by accelerating the movement towards the keyboard; in this way, the laws of physics are employed rather than exclusively muscle work. Let me stress once again that weight is not applied incidentally but is strictly controlled in piano playing by muscle tension, which gives this weight its direction and impacts key speed. Without muscle control, the limb would fall freely along the torso. That

[31] Deahl, Wristen, *Adaptive Strategies…*, 31.
[32] Deahl, Wristen, *Adaptive Strategies…*, 31.
[33] Deahl, Wristen, *Adaptive Strategies…*, 32.

this does not happen is made possible by coordinated relaxation of the muscles, which hold the hand up in a given position above the keyboard.[34] The term 'weight' is usually applied with reference to the arm or sometimes the forearm, which have a large weight by themselves, while small and light units, such as the hand and fingers, normally only serve to transmit that weight, which means that their muscles need to provide strong support by maintaining appropriate tension.[35] If the fingers are placed in a bent line with their forearm muscles and tendons, this energy is partly lost. The 'weight-playing' technique is highly effective since it makes muscle work less strenuous.[36] This is also due to the fact that the force of key attack is transmitted by the bones, tendons and joints as well, which additionally spares the muscles.[37]



Ex. 7. F. Chopin, *Étude in C major* Op. 10 No. 1, mm. 4–7.[38]

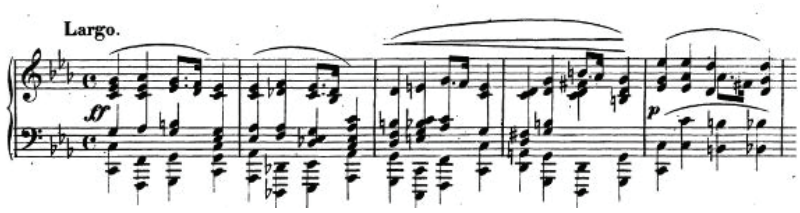
The octaves in the left hand are maintained in this fragment in *forte* dynamics and in long rhythmic values, which affords enough time for the limb's 'free fall' and makes it possible to attain a high sound volume without straining the muscles.

Even though the muscles work in conjunction with weight, there are situations in which the use of weight becomes less important. The types of movement which require greater muscular effort are variously called pressure, thrust or impulse by different authors. They are triggered by a sudden and fast contraction which generates the force necessary to produce sound.[39] These can be the so-called 'from-the-key' motion, in

[34] Sielużycki, *Ręka pianisty…*, 120–121.
[35] Sielużycki, *Ręka pianisty…*, 133.
[36] Sandor, *On Piano Playing…*, 54.
[37] Deahl, Wristen, *Adaptive Strategies…*, 69.
[38] Source: https://ks.imslp.net/files/imglnks/usimg/5/59/IMSLP60294-PMLP01969-Chopin_Etudes_ Schirmer_Mikuli_Op_10_filter.pdf, accessed 14 Apr. 2020.
[39] Sandor, *On Piano Playing…*, 108–114.

which the fingers are, so to speak, 'glued' to the keyboard before pressing the keys, or else movements preceded by a swing from a greater distance. This technique is frequently used while playing at high dynamics or performing accents and *sforzati*, when some notes need to be highlighted more than others, and this requires greater muscular effort. Depending on the expected sound effect, the impulse may originate in different sections of the limb. A very intense stroke most frequently has its source in the powerful shoulder and torso muscles whose lightning thrust can generate the force necessary for *fortissimo* playing.

All the hand and finger joints must be tense enough to be able to transmit this force. If its application is not controlled, however, especially in case the element of swing is involved, this may result in an unpleasant, strident, percussive type of sound.[40] Sound quality can better be controlled when the finger has contact with the key before key attack.



Ex. 8. F. Chopin, *Prelude in C minor* Op. 28 No. 20, mm. 1–5.[41]

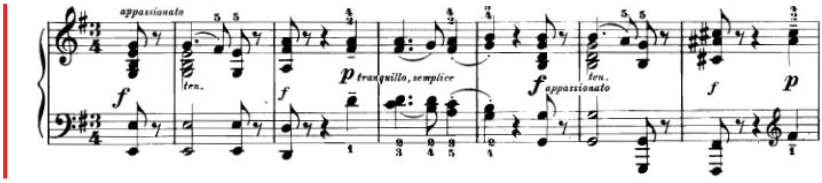
This fragment is maintained in *fortissimo* dynamics. The right hand leads the melody in huge *legato* chords. A wide swing is therefore undesirable, and the fingers remain close to the keyboard. To attain an appropriately massive sound, we need to apply fast active muscle work: contractions and impulses originating in the arm or the shoulder.

Both these factors (muscle contractions and weight) are sometimes equally important to sound production. In such cases, the element of distance which makes the use of swing possible coordinates with the impact of weight reinforced by strong impulses coming from the muscles. This combination is described by many authors who refer to

[40] Sandor, *On Piano Playing…*, 108–114.

[41] Source: http://ks4.imslp.net/files/imglnks/usimg/9/95/IMSLP85374-PMLP02344-Chopin_Op_28_Breitkopf_6088_first.pdf, accessed 15 Apr. 2020.

it as 'contraction-and-weight' or 'pressure-and-swing' motion, 'thrust impulses', or 'free fall of the fingers'. The movement is initiated by a strong and sudden contraction of the flexors, which accelerates the mass of the hand.[42] The technique is considered extremely effective by many teachers, pianists, and researchers.[43] It is in effect an efficient combination of muscle work and the laws of physics. Two components play a major role here: contraction and relaxation; the latter allows the muscles to rest for a moment after pressing the key.[44] The effect was mentioned by eminent German teacher Kurt Leimer, who published several texts with his pupil, the pianist Walter Gieseking. Leimer stressed the importance of relaxing the muscles whenever possible.[45] Effective application of the muscles' contracting and relaxing mechanism allows pianists to perform fast progressions of individual notes or chords, especially at high dynamics.



Ex. 9. L. van Beethoven, *Sonata in E minor*, Op. 90, mov. I, mm. 1–6.[46]

The above-presented fragment of Beethoven's *Sonata in E minor* illustrates this kind of technique very well. Chords and octaves in *forte* dynamics call for a certain elasticity and 'space' before pressing the key and rebounding from it. Strong brief impulses, in combination with fast attack, facilitate the proper dynamic effect.

[42] Sielużycki, *Ręka pianisty…*, 136.
[43] Sielużycki, *Ręka pianisty…*, 142.
[44] Sielużycki, *Ręka pianisty…*, 136.
[45] W. Gieseking, K. Leimer, *Piano Technique Consisting of Two Complete Books: The Shortest Way to Pianistic Perfection and Rhytmics, Dynamics, Pedal and Other Problems of Piano Playing* (1972), 13, http://waltercosand.com/CosandScores/Composers%20E-/Gieseking,%20Walter/Gieseking%20&%20Leimer %20-%20Piano%20Technique.pdf, accessed 2 Feb. 2020.
[46] Source: https://ks.imslp.net/files/imglnks/usimg/7/79/IMSLP51799-PMLP01484-Beethoven_Werke_ Breitkopf_Serie_16_No_150_Op_90.pdf, accessed 17 Apr. 2020.

The essential role of the fingers as that section of the limb which has direct contact with the keyboard need not be explained here. The quality of sound depends on the precise work of the fingers and the type of touch. The fingers are also important as transmitters of large forces from the other sections of the limb. They must therefore be resilient and capable of quickly relieving the tension after pressing the key. The sound depends on finger position. English teacher, researcher and pianist Tobias Matthay distinguished two fundamental extremes of finger attitude, 'bent' (strongly) and 'flat' (i.e. forming a very gentle arch)[47]. The former facilitates the production of a more strident and energetic, *brilliant*-type sound, associated with faster muscle work. The latter produces a milder, more song-like tone, relying more on the use of mass and weight, whose controlled 'release' takes a longer time than an energetic muscle contraction. In the latter case, the fact that the fingers are relatively more straight supports the function of the long lever (in case we transmit the weight of the arm or forearm). This lever is more flexible than with strongly bent fingers, which enhances the song-like quality. The prolonged contact of fingers with the keys at the moment of touch helps control the sound quality and colour.

Fig. 2. (Strongly) bent finger attitude.

47 T. Matthay, *The Act of Touch in All Its Diversity. An Analysis and Synthesis of Pianoforte Tone Production*, (1903), 166–167, https://archive.org/details/actoftouchinallio09163mbp/mode/2up, accessed 21 May 2020.

Fig. 3. Flat finger attitude (a very gentle arch).

The Efficacy of the Playing Apparatus

It has been known for a long time that the fingers are not equal with respect to independence and force. The practice of artificial finger stretching, in some cases even by means of surgery, aimed to increase the independence of the fingers. We now know that this not only did not bring the expected results but frequently led to permanent damage of the hand's internal structures. It was Chopin's innovative contribution to make pianists realise that, rather than fighting with these individual inequalities, we should look for ways of using our anatomy appropriately and harmonising our technique with it.[48] It is true, however, that we may to some extent influence our fingers' stretchability by means of training, but this is only possible at a young age, when the hand's internal structures are still developing and can be moulded. This element is one of the arguments in favour of beginning piano education in childhood.[49]

[48] F. Chopin, *'Esquisses pour une méthode de piano'. Textes réunis et présentés par…*, J.-J. Eigeldinger, ed. (1993).

[49] C. Sielużycki, *Wybrane wiadomości z anatomii i fizjologii do użytku nauczycieli i uczniów szkół muzycznych*, 4, *Ręka, jako główny narząd ruchu w grze na*

Finger action is possible, let me recall, thanks to the longus muscles starting at the elbow and the brevis muscles of the hand, which are responsible, among others, for stretching the fingers. The fourth finger is the least independent one owing to strong intertendon tissue binding it to the tendons of the third and the fifth finger. The movement of the second finger is relatively free and controlled by this finger's additional muscle called extensor indicis. The most independent fingers are the little one and the thumb, both of which have their own muscles which increase their moveability and strength.[50]

Each of the skeletal muscles consists of multiple bundles of so-called of muscle fascicles, made up of muscle fibers. Their length is reduced during contractions, which makes movement possible. Muscle contractions and increase in muscle tension are initiated and controlled by impulses sent from the central nervous system, which submits these muscles to our conscious control.[51] This tissue is well vascularised; the total length of its vessels amounts to c. 40–50 thousand kilometres.[52] Contraction is followed by relaxation. During the former, most of the blood flows out of the muscle along with the toxic metabolites; in the relaxation phase, blood flows in, supplying the muscle with necessary nutrients and oxygen. Any disturbances in this process, such as too long and too frequent contractions, and rare relaxation, cause hypoxia and deposition of toxins.[53] Muscle relaxation after pressing the key is therefore important for the effective work of our playing apparatus.

Achieving the desired results in piano playing obviously calls for systematic practice. However, we must remember that our body's functioning depends on the principles of physiology and its endurance is limited. Our staying power is, to a large extent, an individual quality. We should be aware, though, that each organism needs mental and physical rest. Despite our amazing powers of regeneration, once the number of hours spent at the piano exceeds the threshold of endurance, we risk strain, fatigue, and pain. Such symptoms are quite common in pianists, and if they persist, this may lead to injury.

instrumentach muzycznych (1962), 94.

50 Deahl, Wristen, *Adaptive Strategies…*, 51.

51 Marecki, *Anatomia funkcjonalna…*, 39.

52 Marecki, *Anatomia funkcjonalna…*, 42.

53 Sielużycki, *Wybrane wiadomości…*, 101.

What, then, is muscle fatigue? It is a process resulting in most cases from insufficient supply of oxygen and nutrients to the muscles, and from the accumulation of toxic metabolites. This happens when contractions are too long or too fast (i.e. when muscle work is too intense, too long, incorrect or strenuous), when the amount of blood flowing into the muscle is too small to nourish the tissues, and intense work leads to the accumulation of harmful substances which cannot be removed with blood at the appropriate pace. This state manifests itself, first and foremost, in the muscle's diminished ability to relax and rest, which in turn reduces the efficacy of the contraction that follows.[54] This leads to muscle fatigue, whose symptoms may include a subjective sense of increased muscular tension, reduced strength, pain, weakness, and trembling, which in turn contributes to poor coordination and lack of precision. Muscular tissues can regenerate, and therefore fatigue is reversible; however, the longer it lasts, the more time we will need to return to a state of equilibrium. In case of evident fatigue or enfeeblement, we should interrupt our muscular effort and give the body time to recuperate. One of the most important though frequently neglected preventive and curative factors is sleep. Its role can hardly be overestimated. It is thanks to sleep that our organism effectively detoxifies itself and regenerates. Research has shown, too, that massage is one of the best methods of fatigue prevention and of curing pain or inflammation. Other methods include compression clothing stabilising the limbs and torso as well as therapy, for instance placing body parts in cold water, cryotherapy, and stimulating the body alternately with cold and hot water.[55]

In the context of the affinity between excessive muscular effort and the risk of injury, we should mention the 2010 test study concerning the use of force while playing the piano, conducted by Professor Hartmut Riehle and Henriette Gärtner.[56] The researchers used specialised equip-

[54] Ortmann, *The Physiological Mechanics…*, 56–57.

[55] L. Bosquet et al., 'An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review with Meta-Analysis', *Frontiers in Physiology* (2018), 403, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5932411/?fbclid=IwAR1aOtKWc-9IoNK2hi-7xCPBtL-YQkzDmYcHgBWyfbuVTxas6Qczl_cg8eo, accessed 22 May 2020.

[56] Information from direct contact with the researcher who performed the tests; materials in the author's private archive.

ment to examine fifteen pianists (eight women and seven men) divided into two groups: concert pianists and promising beginners. These are the conclusions that can be drawn from these tests:

- Students used more force than concert pianists. The higher index of force application and slower decrease of force reflected their muscle tension, which eased more slowly after pressing the key. This increased the risk of muscle strain, which may lead to injury.
- The repeatability of the same model of force distribution was greater among concert pianists than among students, which may suggest that the former controlled their technique better and their finger action was more even. We may conclude that, apart from inborn abilities, these qualities may be related to experience and performance practice.
- On the basis of the data concerning force use and the number of nervous impulses generated in order to activate muscle contraction, the muscle work efficiency index was calculated. It was higher in concert pianists, which proves that a similar musical effect is possible to achieve with smaller effort.
- The fingers' bending force was slightly higher in men than women, which made it easier for the former to obtain the desired sound intensity. The concert pianists excelled the students also in this respect; this may be related both to natural predispositions and acquired experience.

Conclusions

Good piano technique consists in the choice of purposeful, suitably selected movements, which allow pianists to attain the desired effect while at the same time saving their energy and muscular effort. This decreases the risk of fatigue and strain, both of which may lead to injury. In order to obtain the given sound effect, we need to understand which factors have positive and which – negative impact on its production. This entails the suitable choice of movements while playing. Movements can be differentiated by their span, type, and force. The ability to select adequate types of movement calls, in turn, for the knowledge of the origins of movement, its various kinds, the mutual relations between mass, force, and acceleration. Laws of physics thus combine

in piano playing with elements of human physiology. It is therefore prerequisite that we should become acquainted with the structure and functioning of our bodies. Understanding the causes, foundations and sources should be our starting point in the pursuit of the pianist's aims. The type of movement, its span and speed, determines the generated force. Force is influenced by both the weight applied and the degree to which we depend on controlled muscle contractions. As a consequence, it is possible to produce sounds highly diversified in terms of intensity, sound colour, and articulation. The awareness of the effects of the different types of movement makes it possible to select them consciously and, by controlling them, to attain the desired type of sound in terms of both quality and quantity. For this purpose, it will be useful to be aware of the intentionality of movements originating in different parts of the limb: arm playing, forearm playing, from-the-wrist, and finger playing technique. The position of the fingers during piano playing and the presence or absence of the element of swing also have a major impact on sound quality.

Teaching piano technique involves at the same time work on the sound and on the final effect. A high technical level will facilitate achieving the desired sound. Technique is a visible and definable tool for the presentation of the timeless and immeasurable beauty of music.

Bibliography

References

Bosquet, L., et al., 'An Evidence-Based Approach for Choosing Post-exercise Recovery Techniques to Reduce Markers of Muscle Damage, Soreness, Fatigue, and Inflammation: A Systematic Review with Meta-Analysis', *Frontiers in Physiology*, 403 (2018), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5932411 /?fbclid=IwAR1aOtK-Wc-9IoNK2hi-7xCPBtLYQkzDmYcHgBWyfbuVTxas6Qczl_cg8e0, accessed 22 May 2020.

Chopin, F. *'Esquisses pour une méthode de piano'. Textes réunis et présentés par..,* Eigeldinger, J.-J., ed. (Flammarion: Paris, 1993).

Deahl, L., Wristen, B., *Adaptive Strategies for Small-Handed Pianists* (Oxford University Press: New York, 2017).

Földes, A., Keys to the Keyboard: A Book for Pianists (Oxford University Press: Oxford, 1968).

Gieseking, W., Leimer, K., *Piano Technique Consisting of Two Complete Books: The Shortest Way to Pianistic Perfection and Rhytmics, Dynamics, Pedal and Other Problems of Piano Playing* (Dover Publications, Inc.: New York, 1972), http://waltercosand.com/CosandScores/Composers%20E-K/Gieseking,%20Walter/Gieseking%20&%20Leimer%20-%20Piano%20Technique.pdf, accessed 2 February 2020.

Kowalska, M., ABC *historii muzyki* (Musica Iagiellonica: Kraków, 2001).

Li, M., et al., 'Assessing Injury Risk in Pianists', MTNA *e*-JOURNAL 2015, https://www.eldertech.missouri.edu/wp-content/uploads/2016/06/Assissing-Injury-Risk-in-Pianists.pdf, accessed 18 April 2020.

Ortmann, O., *The Physiological Mechanics of Piano Technique* (K. Paul: Trench, Trubner & Co., Ltd, E. P. Dutton & Co., Inc.: London, 1929), http://archive.org/details/in.ernet.dli.2015.89583/page/n7/mode/2up, accessed 12 April 2020.

Marecki, B., *Anatomia funkcjonalna w zakresie studiów Wychowania Fizycznego i Fizjoterapii* (4th edn, Akademia Wychowania Fizycznego im. E. Piaseckiego w Poznaniu: Poznań, 2004).

Matthay, T., *The Act of Touch in All Its Diversity. An Analysis and Synthesis of Pianoforte Tone Production* (Bosworth & Co. Ltd.: London, 1903), https://archive.org/details/actoftouchinallio09163mbp/mode/2up, accessed 21 May 2020.

Sandor, G., *On Piano Playing: Motion, Sound, and Expression* (Schirmer: New York, 1981).

Sielużycki, C., *Wybrane wiadomości z anatomii i fizjologii do użytku nauczycieli i uczniów szkół muzycznych*, 4, *Ręka, jako główny narząd ruchu w grze na instrumentach muzycznych* (Centralny Ośrodek Pedagogiczny Szkolnictwa Artystycznego: Warszawa, 1962).

Sielużycki, C., *Ręka pianisty: Fizjologiczne podstawy techniki* (PWM: Warszawa, 1982).

Wristen, B., *Overuse Injuries and Piano Technique: A Biomechanical Approach. A Dissertation in Fine Arts* (Texas Tech University: Lubbock, 1998), https://ttu-ir.tdl.org/handle/2346/10941?show=full, accessed 6 February 2020.