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The Impact of Piano Styles on Muscle Force in Pianist Students

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Abstract: The study of the consequences of different sonata styles (baroque, classical and romantic piano repertoire) on pianists' upper limbs represents a research topic for both the musical and medical fields. Twenty piano students were examined using a MicroFet2 dynamometer after playing three sonatas (Scarlatti K. 1 Sonata as a representative of the baroque style, Haydn Sonata no. 60 for the classical style and Chopin second Sonata for the romantic style). The phase sequence was randomised for each subject: firstly, continuous interpretation of 10 bars of a sonata was conducted 10 times, with the metronome tempo set by the investigator; secondly, the subject interpreted 10 bars of a different sonata continuously, standardised by tempo, which was carried out 10 times; finally, the continuous interpretation of 10 bars of the remaining third sonata, standardised by tempo, was carried out 10 times. After each performance of the 10 bars, the elbow extensor's isometric muscle force was measured. Significant differences were found between the elbow extensor's isometric muscle force assessed after playing Scarlatti's sonata and Haydn's sonata ($p = 0.005$ for left arm, $p = 0.03$ for right arm), between Scarlatti's sonata and Chopin's sonata ($p < 0.0001$ for both left and right arms) and between Haydn's sonata and Chopin's sonata ($p = 0.01$ for left arm, $p < 0.0001$ for right arm). In healthy piano students, the dynamometric assessment of elbow extensors' isometric muscle force after playing three different sonatas (baroque, classical and romantic) showed that the lowest values were recorded after playing the baroque style. Our results showed bilateral symmetry in the elbow extensor's isometric muscle force for all three piano styles. The testing of arm muscles, besides that of the fingers, should be considered as a regular evaluation for future professional pianists with regard to the prevention of musculoskeletal complaints.

Keywords: elbow extension muscles; force; pianist; style of music; dynamometric measurement

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Citation: Toma, I.; Amaricai, E.; Onofrei, R.R.; Popean, M. The Impact of Piano Styles on Muscle Force in Pianist Students. *Symmetry* **2022**, *14*, 1927. https://doi.org/10.3390/sym14091927

Academic Editors: Grzegorz Miękisiak, Lukasz Kubaszewski, Tomasz Szmuda and John H. Graham

Received: 28 June 2022
Accepted: 14 September 2022
Published: 15 September 2022

1. Introduction

The study of the consequences of different sonata styles (baroque, classical and romantic piano repertoire) on pianists' upper limbs represents a research topic for both the musical and medical fields. Thus, the assessment of muscle strength can provide data regarding the differences between dominant and non-dominant upper extremities, as well as the musculoskeletal involvement in different pianistic acts. Fast, accurate and deft hand movements are fundamental to reaching the best performances in music. Researchers have drawn attention to the neuroplasticity of early and thoroughly trained hands in terms of structural adaptations [1,2]. On the keyboard, the fingers have two prevailing maximal repetitive speed predictors: the fingertip hit speed and the strength of elbow extensor muscles. The two speed indicators prove their prognostic value. The pianist's anatomy and history of piano training are features that should also be taken into account [1]. It has been suggested that the non-synchronous character of the repetitive fast movement of multiarticular muscles is also involved [2]. The study of Furuya S. (2009) demonstrated a clear skill-level difference in the coordination of upper-arm muscular activity in relation to the production of elbow extension muscular torque [3].

The baroque repertoire for keyboard instruments of compositors, such as J.S. Bach and Domenico Scarlatti [4], require the pianist to press the keys in a calm and moderate way within a narrow gamut of movements [5–7]. Classicism witnessed a greater innovation in the development of musical instruments and in musical compositions [8]. Starting with Beethoven and romanticism, composing for the piano displayed a higher level of orchestrated texture, dense with ample cords and dynamic variation, requiring the pianist to act temperamentally [9]. The pianist must simultaneously organise the performer's expression tools of baroque language (in terms of tempo, accents, phrasing and architecture) and the plethora of ideas and balance of formal means used to express the classics' emotions. The artist needs to exert control over the means of the romanticists' description, thus requiring additional strain [10]. The pianist's muscle strength determines the speed of their finger movement (amplitude and key attack angle) [11,12]. A melody played on a piano presents a unique opportunity to analyse the motor aptitudes required by the deft, natural and multiarticular movements [13].

Many composers train the involved skeletal muscles differently [14]. Neuhaus H. stated that stylistic eras and the individual style of a composer imply totally distinct piano interpretation issues in terms of form, content and pianistic technique [15]. Breikaupt R. declared that piano sound intensity correlates to the force applied to the keyboard [16]. The pianist translates the emotion intensity printed in the music scores by involving the muscles [17]. Moreover, the technical piano passages that are extremely difficult to play determine a definite stress on the hand muscles [18]. Romantic piano repertoire is an instance of intense muscle demand based on the mechanical development of the instrument [19].

Piano techniques relate to music styles based on the studying methods assumed by the pianist [20]. The eventual result of the time invested in reaching peak performance in piano interpretation can be easily evaluated by observing the effects on the upper extremity muscles. Piano players are at risk of developing upper-limb musculoskeletal complaints due to repetitive movements and playing techniques; the last two features can determine an increased force on the wrists, fingers and elbows [21].

Various factors impact the required motoric charge necessary for a piano performance: the pianist's age and gender are a couple of these factors. The more accurate a work needs to be, the more difficult it becomes; the response time can vary for the same person, or among various persons [22]. The differences in physiological reactions to different environmental and occupational circumstances result from the disparity of forces [23]. This is why the comparison of muscle forces should be based on the research results of specific tasks carried out by individuals belonging to a definite group [24–26].

The present research started from the hypothesis that musical stylistic factors of distinct sonatas (baroque, classical and romantic) have different load effects on the pianist's elbow extensor strength. To our knowledge there is no study that has investigated the relationship between arm muscle strength and musical style in pianists. The aim of our study was to assess and compare the isometric muscle force of elbow extensors after playing each of the three particular piano sonatas, namely Scarlatti K. 1 Sonata as a representative of the baroque style, Haydn Sonata no. 60 for the classical style and Chopin second Sonata for the romantic style.

2. Materials and Methods

2.1. Participants

The participants included in the study were piano students at the piano or general music department. The students were healthy subjects, with no musculoskeletal injuries or neurological disorders. Each student filled in a form of personal written consent to take part in the experiment and to have the results used only for scientific purpose. The study was carried out in accordance with the Declaration of Helsinki and was approved by the Institutional Ethics Committee (no 06/2022).

2.2. Protocol

After an initial meeting with twenty-three students, three withdrew due to personal reasons (busy schedules due to participation in concerts and contests). Twenty students agreed to take part in the study and represented the final number of participants as no one further withdrew. The students were instructed about the daily activities involved in the experiment, mentioning the necessary absence of drugs, alcohol, energisers or other stimulators or inhibitors of the central nervous system.

Each subject performed the experiment individually. The testing procedure was explained to the participants by one investigator. They were made aware that they should signal out, at any moment, pain expressions. Pain complaints not signalled out by a subject could be a factor leading to withdrawal. After the experiment description, a questionnaire regarding demographic data and daily habits (diet, coffee, energisers, black tea or alcohol intakes, as well as physical activity levels) was conducted with the subjects. They were allowed 10 min to fill in the questionnaire.

Five minutes for pianistic warm up was granted, even though the muscle tone was already activated due to the students' performing in regular concert activity. With the intent of excluding the possibility that the order chosen by the investigator would bias the results, the sequence of phases was randomised for each subject. The first phase was the continuous interpretation of 10 bars of a sonata, 10 times, with the metronome tempo set by the investigator. Afterwards, the subject interpreted 10 bars of a different sonata continuously, standardised by tempo, which was carried out 10 times. The last phase was the continuous interpretation of 10 bars of the remaining third sonata, standardised by tempo, which was carried out 10 times. After each performance of the 10 bars, the elbow extensor's isometric muscle force was measured by an examiner (one of the study investigators who was only involved in muscle testing). The subjects were asked if any pain or any sensation prior to the experiment were perceived.

As the experiment was run individually, each student required around one hour. Consequently, meetings were scheduled over several days, starting from 12 a.m. to 6 p.m. The students had to play three distinct sonatas on a wall piano. Each student received about 10 bars of each sonata (Scarlatti, Haydn and Chopin sonatas) two weeks before the experiment. During this period, the subjects studied the music excerpts to be able to play them coherently and within the required tempo limits at the time of the experiment. The music material was chosen as advised by doctoral committee professors, i.e., containing the comprehensive technical expression as close as possible to the represented style (bars 14 to 23 in Scarlatti Sonata K. 1; bars 54 to 64 in Haydn Sonata no. 60, first movement; and bars 138 to 152 in Chopin Sonata no. 2, first movement). The musical materials were chosen to be identical in terms of tempo, intensity and duration of pianistic interpretation.

The metronome ticked as long as the interpreters played the musical fragments. This was considered necessary to preserve the same tempo factor, excluding differences in interpretation speed of the three fragments. The tempo constants were determined as follows: quarter = 100 for Scarlatti's sonata, quarter = 90 for Haydn's sonata and half note = 70 for Chopin's sonata. The composers' instructions for the interpretation of the excerpts (as indicated on the music sheet) were observed by the interpreters (i.e., in terms of loudness, finger mode of articulation and emotional expression): the only exception was the examiner's indication for the interpreters to not use the pedal at their free will in Scarlatti's sonata.

2.3. Isometric Muscle Force Assessment

The isometric muscle force was measured using a MicroFet 2 dynamometer (Hoggan Health Industries, Draper, MA, USA). The device is recognised worldwide for muscle force assessment [27]. A possible alteration factor of the results could have been an inadequate understanding of the examiner regarding the basis of anatomy and kinesiology [28,29]. Such a variable was counteracted by the fact that the examiner (E.A.) was a primary physician in physical medicine and rehabilitation.

Measurements were run for both the dominant and non-dominant hand, with the subject seated on a chair, with their shoulder in flexion, and their elbow in a flexion of 90° (Figure 1) [27]. The assessment of isometric muscle force lasted for 5–6 s and was repeated three times. The three measurements were run for each position, interspaced for 1 min; the mean value was then computed. The testing order of arms varied so to avoid muscle fatigue and the possibility of motor memory patterns of the muscles (related to the muscle learning effect). The muscle force was measured in Newton (N).

Figure 1. The testing position.

One of the factors that could have altered the results was the distraction of the subjects during the test [30]. The examiner reassured and motivated the subjects to yield maximum muscle force and to keep focused. The sequence of arm assessment was alternated for each sonata, right–left and left–right. The examiner recorded the results immediately after running the measurement. As only one examiner was involved in the data collection, these were not under scrutiny, which is a situation suggested by some researchers.

2.4. Statistical Analysis

The data are presented as mean and standard deviation. Repeated-measures ANOVA tests were performed in order to compare the isometric muscle force in the three situations (after playing baroque, classical and romantic piano sonatas) for each arm. Paired t-tests were applied to analyse the differences between the right and left elbow extensor's isometric muscle force. A p-value < 0.05 was considered significant. Statistical analysis was performed with MedCalc Statistical Software version 19.2.1 (MedCalc Software Ltd., Ostend, Belgium).

3. Results

Eleven subjects were women (55%) and nine were men (45%). Eighteen subjects were Romanian and two were Hungarian. No language barrier affected cooperation and motivation of the Hungarian students; they are bilingual and enrolled in a Romanian study program.

Subjects were aged between 19 and 25 years (mean age 21.85 ± 2.23 years). All subjects had a normal weight (mean weight 65.40 ± 15.96 kg) and a mean height of 169.55 ± 9.40 cm (Table 1). The professional status of all subjects, except one, was that of a full-time student; one student was employed as a piano teacher. Fruits and vegetables were in the subjects' diets in variable proportion: 40% of them consumed them daily; 50% several times/week; and 10% several times/month. Regular intake of coffee, black tea or energisers was present for 40% of the subjects; and there was no intake of drugs or pure alcohol above 14 g [31] for the previous 5 days. The sleeping time was about 8 h for 65% of the subjects; 15% of the subjects slept 6–7 h per night; and 20% slept 5–6 h per night. Medication was absent in 90% of the subjects; two subjects were on antiallergenic pills, if needed. Regarding the subjects' physical activity status, 50% of the subjects were involved in light exercise at least 4 h/week; 25% trained on a regular basis, at least 2–3 h/week; and the rest of the subjects were physically inactive. All the subjects were right-handed.

Table 1. Participants characteristics.

Parameters	
Age, years (mean ± SD)	21.85 ± 2.23
Height, cm (mean ± SD)	169.55 ± 9.40
Weight, kg (mean ± SD)	65.40 ± 15.96
Sex	
Male, n (%)	9 (45)
Female, n (%)	11 (55)

Scarlatti's sonata resulted in an average elbow extensor muscle isometric force value of 68.34 ± 17.84 N in the left arm and of 72.70 ± 22.87 N in the right arm. The musical excerpt of Haydn's sonata resulted in average values of 77.79 ± 21.57 N in the left arm and 80.79 ± 18.01 N in the right arm. The ten bars of Chopin's sonata resulted in average values 85.79 ± 24.53 N in the left arm and 94.53 ± 21.77 N in the right arm (Table 2). No significant differences were found between arms for any of the musical excerpts.

Table 2. The elbow extensor's isometric muscle force.

	Baroque Sonata (Scarlatti)	Classical Sonata (Haydn)	Romantic Sonata (Chopin)	p *
Left	68.34 ± 17.84	77.79 ± 21.57	85.79 ± 24.53	<0.0001
Right	72.70 ± 22.87	80.79 ± 18.01	94.53 ± 21.77	<0.0001

Data represents the muscle force (N), presented as mean ± standard deviation; * repeated-measures ANOVA.

The repeated-measures ANOVA showed a significant effect of the different sonatas' playing types on the elbow extensor's isometric muscle force in both arms ($F_{2,38} = 21.95$, $p < 0.001$ in the left arm, $\eta^2 = 0.536$, and $F_{2,38} = 27.97$, $p < 0.001$, $\eta^2 = 0.595$ in the right arm). The multiple comparisons showed significant differences between the elbow extensor's isometric muscle force assessed after playing Scarlatti's sonata and Haydn's sonata ($p = 0.005$), between Scarlatti's sonata and Chopin's sonata ($p < 0.0001$) and between Haydn's sonata and Chopin's sonata ($p = 0.01$) for the left arm. In the right arm, significant differences were found between Scarlatti's sonata and Haydn's sonata ($p = 0.03$), between Scarlatti's sonata and Chopin's sonata ($p < 0.0001$) and between Haydn's sonata and Chopin's sonata ($p < 0.001$).

There was a significant interaction between the effect of different sonatas' playing type on the elbow extensor's isometric muscle force and gender, but only in the left arm ($F_{2,36}$ = 10.39, p < 0.001, η^2 = 0.366 for the left arm; $F_{2,36}$ = 1.84, p = 0.17 for the right arm). In Figure 2, the differences between the elbow extensor's isometric muscle forces are represented based on gender.

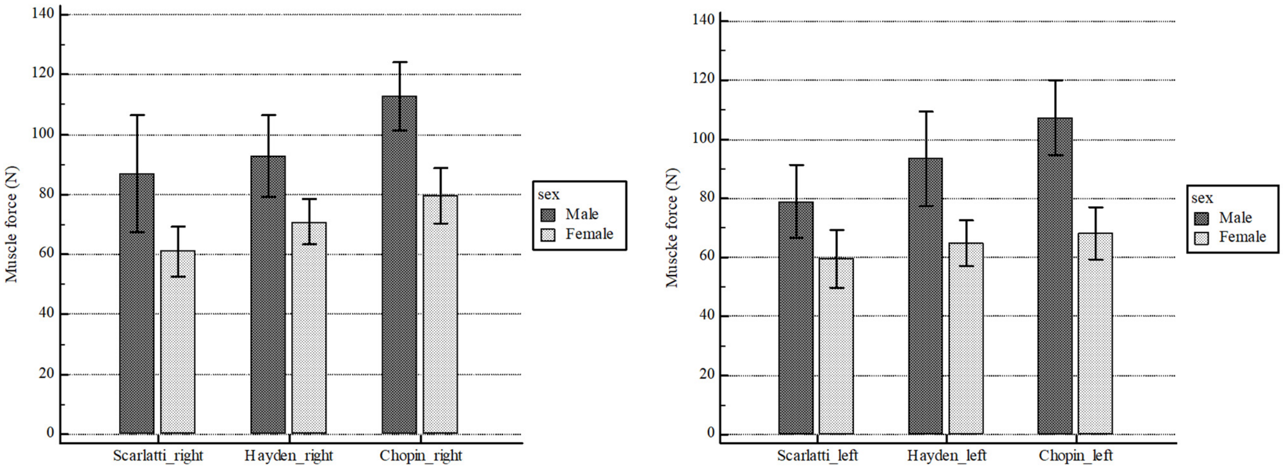

Figure 2. The effect of different sonatas playing types and gender on elbow extensor's isometric muscle force.

4. Discussion

The current research may have future innovative potential considering several factors, i.e., the start hypothesis was never tested, and neither were the muscular effects on young students playing three different sonatas.

In our study, we used an assessment of pianists' elbow extensor's isometric muscle force after interpreting particular piano sonatas, namely Scarlatti K. 1 Sonata as a representative of the baroque style, Haydn Sonata no. 60 for the classical style and Chopin second Sonata for the romantic style. Our research question started from the data recorded by Furuya S. et al. (2015) [1], who identified that the maximum muscular forces for extension and flexion were not significant predictors at any loudness level at piano, including mezzo-piano and mezzo-forte, except for the elbow extension muscular force. They stated that strength training of the elbow extensor muscles may be an effective method for performers and teachers to achieve faster playing.

The current research showed that the maximal values of the isometric muscle force were recorded when the pianists played the romantic sonata. One of the causes for this can be found in the interpretation *ff* (extra loud) of the analysed selection, as when the piano keys are pressed by both hands, a 100–200 N average force is needed for piano-forte, and 300–500 N is needed for ff [1]. A possible explanation for this could be the ample movement above the keyboard for chords of more than four sounds, and the ampler spans needed by each hand, which activate the right arm muscles more intensely.

Our results showed bilateral symmetry in the elbow extensor's isometric muscle force. No statistically significant differences were found between the right and left arm. Although all subjects have a dominant right arm (i.e., the arm where muscle force is more developed due to the requirements of playing an instrument), they tend to develop their arms similarly in terms of arm muscle strength over time.

Our research brings additional information related to the importance of musical repertoire on the load of elbow extensors, as we have assessed the isometric muscle force after playing three different piano sonatas. The study of Furuya S. et al. (2015) [1] on 24 pianists, including both winners of international piano competitions and amateur players, showed a positive relationship between the maximum rate of repetitive piano keystrokes and elbow extensor forces (left side: partial regression coefficient = 0.024,

$p = 0.00019$; right side: partial regression coefficient = 0.009, $p = 0.177$), and the maximum rate of single-finger tapping, respectively (left side: partial regression coefficient = 0.498, $p = 0.00014$; right side: partial regression coefficient = 0.517, $p = 0.005$).

Turner C. et al. (2021) [32] examined two elite pianists' motor behaviours during a complex music performance (the first six measures of Chopin's Revolutionary Etude Op. 10, No. 12) to quantify pianists' joint activity in the trunk, shoulders, elbows and wrists. They noticed that both pianists displayed compensatory movements suitable for their own anthropometry and interpretations of the musical demands. However, the study did not assess the elbow extensor's muscle strength as we did in our research.

The assessment of muscle strength has future indications for the prevention and identification of possible motor functional failure, related to the improvement of physical performance or to the diagnosis of the affected areas. This evaluation can also be run for pianists known to be at risk of or suffering from musculoskeletal pathologies.

As isometric muscle force is influenced by a particular musical style, the results can be of interest for professional pianists who interpret a prevalent genre. For example, it could be presumed that a pianist who plays mainly the romantic's repertoire is more predisposed to develop musculoskeletal disorders than a pianist who plays mainly a baroque repertoire.

The present study may have impact on present music education and pedagogy in musical schools.

Our results could be of interest for subjects with problems implying underdeveloped arms. Underdevelopment specifically means hypokinetic arms, on a scale starting with the most severe cases up to physiologically developed arms, but below the standard of musical interpretation.

Further studies can be run, starting from our experiment. The research is easily reproducible, not requiring for costly equipment or invasive methods. New prospects of predictability could be opened by testing groups of professional pianists, or by using historical music instruments. For future research, an initial assessment correlated with a control group, if possible, is recommended.

The assessment of muscle force in experienced pianists can provide data of interest for all musicians.

As old age is associated with musculoskeletal atrophy and muscle weakness, testing could be run on a group of pianists with years of concert expertise. A similar assessment in terms of age was run on subjects aged 75 ± 11.2 years [23].

Future research may analyse the correlations not only between musical style and muscle force, but also between music instrument and muscle force.

This research can conducted using historical music instruments by interpreting Scarlatti's sonata on a harpsichord, Haydn's sonata on a fortepiano and Chopin's sonata on a Pleyel piano. At the beginning of the 19th century, each key was 6 mm tall (root) and 23 g in weight, while pianos keys in the 20th century are 10.5 mm tall and weigh 50–60 g. If the 18th century piano technique continues to be used and the mechanical actions of various pianos are ignored, the pianist's musculoskeletal system is at risk of being unable to meet all the requirements [23].

The small sample size is a limitation of our study; this was due to the small number of piano students enrolled. The lack of the initial assessment also represents a limitation of our study. Future studies are needed to more accurately assess the relationship between music style and upper-limb muscle strength.

5. Conclusions

In healthy piano students, the dynamometric assessment of isometric muscle force of elbow extensors after playing three different sonatas showed that the lowest values were recorded after the baroque style. Our results showed bilateral symmetry in the elbow extensor's isometric muscle force for all three piano styles.

The testing of arm muscles, besides that of the fingers, should be considered as a regular evaluation for future professional pianists, with regard to the prevention of musculoskeletal complaints.

Author Contributions: Conceptualisation, I.T. and M.P.; methodology, I.T., M.P., E.A. and R.R.O.; software, I.T., E.A. and M.P.; validation, I.T., M.P., E.A. and R.R.O.; formal analysis, I.T. and M.P.; investigation, I.T.; data curation, I.T. and M.P.; writing—original draft preparation, I.T., M.P., E.A. and R.R.O.; writing—review and editing, I.T., M.P., E.A. and R.R.O.; visualisation, I.T., M.P., E.A. and R.R.O.; supervision, M.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethics Committee) of "Victor Babes" University of Medicine and Pharmacy Timisoara, Romania (no 06/2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflict of interest.

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