International Journal of Music and Performing Arts
June 2017, Vol. 5, No. 1, pp. 29-41
ISSN: 2374-2690 (Print) 2374-2704 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/ijmpa.v5n1a4
URL: https://doi.org/10.15640/ijmpa.v5n1a4

Biomechanical Characterization of Marimba Playing in Relation to the Strength of Sound

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Abstract

Musicians' body postures are directly related to the playing technique and the production of sound. This paper is the first to investigate the biomechanics of the marimba playing technique in twenty-two pre-professional musicians. Body postures were explored by three-dimensional motion capture and were related to the strength of sound. Bachelor students showed more leaning forward over the marimba keyboard than master students. Furthermore, females showed more arm flexion and less leaning forward than males. Larger upper limb motion was related to an increased strength of sound. This study provides fundamental data that can be used to develop pedagogical guidelines in marimba performance to improve body balance and sound production.

Keywords: Marimba, 3DMOCAP, body gesture, sound.

Introduction

Marimba is one of the most developed western percussion keyboard instruments in terms of its playing techniques, repertoire and musical education. During the past fifty years, the technical methods of playing (Stevens, 1979; Zeltsman, 2003; Ford, 2005) are developed in function of articulate execution of playing strokes on the marimba keyboard bars, sonority and musical interpretation (Ke, 2014, pp. 11-13).The modern 5 octaves classical marimba is a large instrument, which is around 2,5 meters long and 1 meter wide. The musician's body is like the engine and it moves constantly behind the marimba. The musician's mind thinks subconsciously where the body needs to be placed in order to create most efficient position. Therefore, the body posture is important for marimbists (Ke, 2014, p. 30).

The relation between musicians' body postures and musical performance is an interdisciplinary study subject in the research field of science and performing art (Godøy & Leman, 2010, pp. ix-xi).Body postures can be used as a communication tool, for instance communication with co-performers or the audience, but also they can reflect individual interpretations on expressive and emotional elements of the music, as well as relate to the performer's own experiences and behaviors (Dahl & Friberg, 2007).Expressive body postures could influence the observer's interest in marimba performance by affecting the musician-to-audience communication (Broughton & Stevens, 2009). Aside the influence to the listeners' auditory perception, one of the most obvious relations is the relation between body postures and sound production (Dahl & Friberg, 2007). Body postures in combination with the technical grip (the way of holding the marimba mallets in the hand) and the choice of mallet shafts and materials, have a direct influence on sound production (Albert, 2016).

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The physical movements and gestures of performers should not only be considered as part of the technical skills (Ke, 2014, p. 5), but surpass playing technique and can affect the performance in various ways. It is therefore not surprising that marimba education pays more and more attention to the importance of body postures. Albert (2016) developed a new playing method by incorporating various physical motions in function of producing better sonority on marimba. However, this method is developed by means of empirical evidence/ experience. The relationship between body gestures and sound production has not yet been explored by objective methods such as motion capture and biomechanical analysis.

Biomechanical analysis has been performed in various other art forms and instruments, where motion capture systems were used to examine physical movements in order to investigate the complexity of human body gesture. By using six Vicon M2 cameras, a method was designed for detailed investigation of the relationship between physical aspects of bowstring interaction and the physical action of the musician, as well as the use of the bow angles when playing the violin (Schoonderwaldt, 2009, p. iii). Another study usedmagnetic motion capturing to examine specific finger movements for piano (Rahman, 2011). A third study, on mapping body postures of pianists, used an unobtrusive, marker less method with the Kinect depth camera and two-dimensional (2D) motion tracking (Hadjakos, 2012).Meanwhile, similar methods have been experimented with in theater performance. One of the latest studies in theater performance used a three-dimensional motion capture system to examine body postures of theater performers to develop a biomechanical model for investigating non-standardized movements in theater performance (Jacobs, et al., 2016).

All abovementioned studies have one similar goal: exploring and investigating the importance of the human biomechanics in various art fields. Like discussed above, in the music field, a musician's body has important functions either related to the sound or as non-verbal communication tool. Therefore, examining the musicians' body motions related to the instrument can improve insights into playing techniques.

Consequently, the aim of this study is to provide an objective characterization of the kinematic movements of marimbists and to explore its relation to the sound production within the musical performance. This will allow us to understand, in depth, the marimba players' biomechanical characteristics affecting the sound. In the future, these insights can help to develop an intermediate method to enhance the marimba playing. We hypothesize that larger upper body postures might result in louder dynamics (strength of sound, dynamical range).Furthermore, the years of musical experience may influence the kinematics of movement and movement patterns may also differ between male and female musicians.

1. Methods

1.1 Study Design

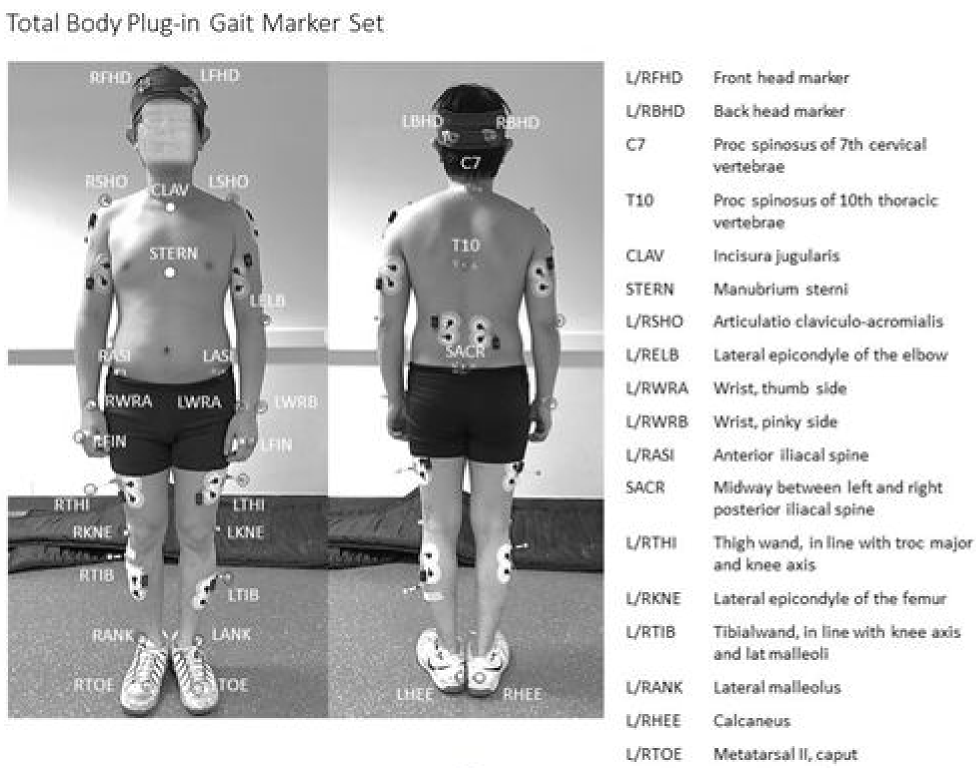
A cross-sectional study design was applied to investigate the key components of body motion during marimba playing that might affect the sound. Each musician performed on the Adams five octave (C2-C7) marimba instrument (A=442 Hz) and used Resta-Jay percussion Jean Geoffroy wooden shafts marimba mallets with different mallet head hardness (from left to right: semi medium soft, medium, medium, medium hard). One musical sample was particularly applied in this study: Marimba Concerto No.1, 3rd movement One Love by Chin Cheng Lin, that includes the large interval distance within a fast tempo and requires a great deal of physical motions. The duration of this musical fragment was approximately thirty seconds, and was performed three times. The music fragment was provided three weeks before the recording session. During the recording session, data were obtained on body motion and on sound.This study was performed according to the principles laid down in the Declaration of Helsinki; Recommendations guiding physicians in biomedical research involving human subjects. Adopted by the 18th World Medical Assembly, Helsinki, Finland, June 1964, amended by the 29th World Medical Assembly, Tokyo, Japan, October 1975, the 35th World Medical Assembly, Venice, Italy, October 1983, and the 41st World Medical Assembly, Hong Kong, September 1989. Ethical approval was obtained from the ethics committee of the University Hospital of Antwerp (reference number: B300201526557). Informed consent was obtained for all participants.

1.2 Setting

Recording sessions took place between 16th and 20th November 2015 at a multi-disciplinary, motion analysis laboratory, equipped with an automatic three-dimensional motion capture system (Vicon T10, 100 Hz, Vicon ® Oxford, UK, 100 fps, resolution 1 Megapixel (1120 x 896)).

Reflective markers were placed over the acromion, jugular notch of the sternum, xiphoid process of the sternum, C7, T10, spinailiaca anterior superior, sacral marker (midway between the posterior superior iliacal spines), thigh wand marker, lateral femoral epicondyles, tibial wand marker, lateral malleoli, calcanei and 2nd metatarsal heads according to the total body Plug-In Gait marker set-up (Figure 1, Davis, Ounpuu, Tyburski, & Gage, 1991; Kadaba, Ramakrishnan, & Wootten, 1990). After successful anatomical calibration, the subjects were instructed to play the music fragment while their movements were recorded by the 3D motion capture system.

Figure 1: Total Body Plug-in Gait Marker Set



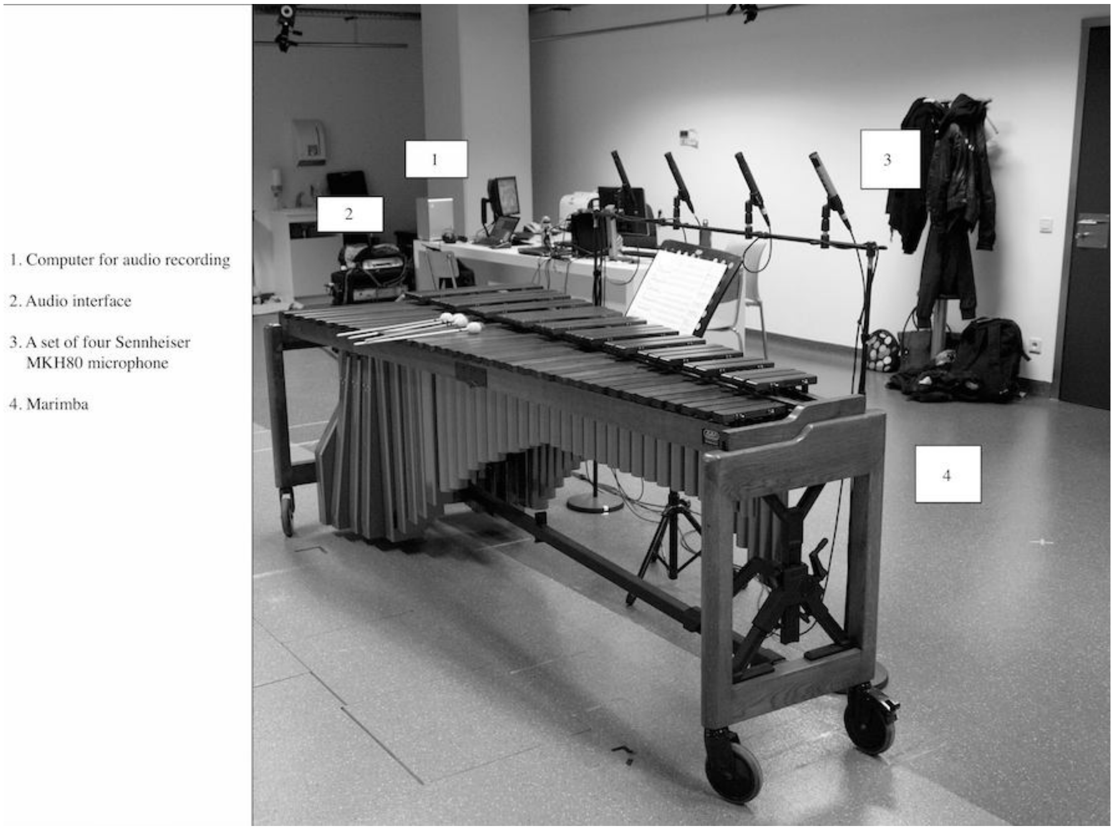
The audio recording of the experimental setup used four instead of two microphones and this allowed us to measure a balanced sound as the ambient noise of the lab was quite high. The noise floor (the background noise in a signal or the noise introduced by the system) of the recording was thus lowered sufficiently, to be able to get meaningful dynamic range measurements of the performances.

According to Willox (personal communication, August 19, 2016), the setup consisted of four Sennheiser MKH80 microphones, which had a low noise floor. The capsule patterns of the hypercardioid microphones were switchable and were used as microphone pick up characteristics. The primary sensitivity of the hypercardioid patterns was in the front of the microphones and was frequently used in situations where a lot of isolation is desired between sound sources. In this way, the better ambient noise rejection was available.

The four microphones were aimed to the instrument and the complete setup was measured to within 0.5 cm to be able to get repetitive results. In addition, the height of the setup was altered in function of the height of the instrument.

The four microphones were amplified by a Grace design M802 microphone preamp, which offered extremely low noise specifications and could have its gain set repeatedly to within 0.1 dB (it offers stepped gain switches). The m802 had a built-in AD converter to get the signal to the digital domain in the AES/EBU format. This was recorded on a standard PC with a Solid State Logic MX4 dual MADI interface and connected to a Solid State Logic Alpha-Link MADI SX (analogue and AES/EBU to MADI converter).

Figure 2: Set Up of the Audio Equipment and Marimba



1.3 Data Sources and Processing

To allow synchronization between motion and sound data, the first and last 10 seconds of the Marimba Concerto No. 1 were selected for analysis. Benefits are that these two fragments provide a wide range in use of the upper body motions and include large intervals in relation to the marimba.

Motion capture data from the individual cameras were reconstructed to a 3D image using the Vicon ® Nexus 1.8 software. After reconstruction and tracking of motion capture data, the raw marker coordinates were filtered using a second order zero phase-shift low-pass Butterworth filter (cut-off frequency 6 Hz). The conventional gait model (Baker, 2013) was used to obtain 3D kinematic data of the upper extremity joints (shoulder, elbow and wrist) from the 3D coordinates of the individual markers. Joint angular time profiles are expressed in Euler/Cardan rotations of the more distal relative to the more proximal segment. Following kinematic time profiles were selected for further analysis: ante flexion of the trunk, left and right shoulder flexion and extension, left and right elbow flexion and extension, left and right wrist flexion and extension and left and right wrist rotation.

The audio recording data were collected in Solid State Logic Sounds cape V7.2, and in four track 44.1kHz/24bit. A down mix (mixing process) was performed to two-track stereo for the measurements. For audio analysis, these fragments were edited and the smaller fragments were synchronized in exactly identical musical parts, to give results in the comparisons.

1.4 Outcome variables of interest

A custom written Matlab R2015a script was used to determine the variables of interest on each of the selected joint angular time profiles. For each joint angular time profile, five kinematic variables were selected to describe the mean posture, the extreme posture, the movement range; the movement speed and the smoothness of movement of one joint in a specified anatomical plane (see Figure 3). This resulted in a total set of 45 kinematic variables (Table 1). Mean and extreme posture is described by the mean value (Mj, in degrees) and peak value (Pj, in degrees) of the joint angular time profile.

Movement range, is characterized by the mean amplitude of movement (Aj, in degrees) during marimba playing of the selected joint in a specified anatomical plane. E.g. mean amplitude of shoulder flexion and extension was calculated by averaging the ranges of motion over the different flexion and extension movements that were performed during the 10 seconds of marimba playing that were considered. Movement speed is the mean angular velocity (Vj, first derivative of joint angular position) of the selected joint angular time profile. Smoothness of movement is calculated using the algorithms described by Kitazawa et al. (1993). These algorithms calculate the sum of the different vectors of Jerk values over the movement (the size and direction of the deviation from the average movement trajectory), with respect to the average movement time and distance. The Jerk index, Cj, was calculated as presented in formula 1.

$$\sqrt{\frac{1}{2}\sum_{i=1}^{n} j_i^2 \, \frac{t^5}{D}} \qquad (1)$$

Where J is the vector of the jerk values over the movement (calculated from the kinematic data, as described above), n the number of samples of the vector, i the vector index, t the movement time, and D the movement distance (Sjolander et al., 2008).

Figure 3: Selected Kinematic Variables

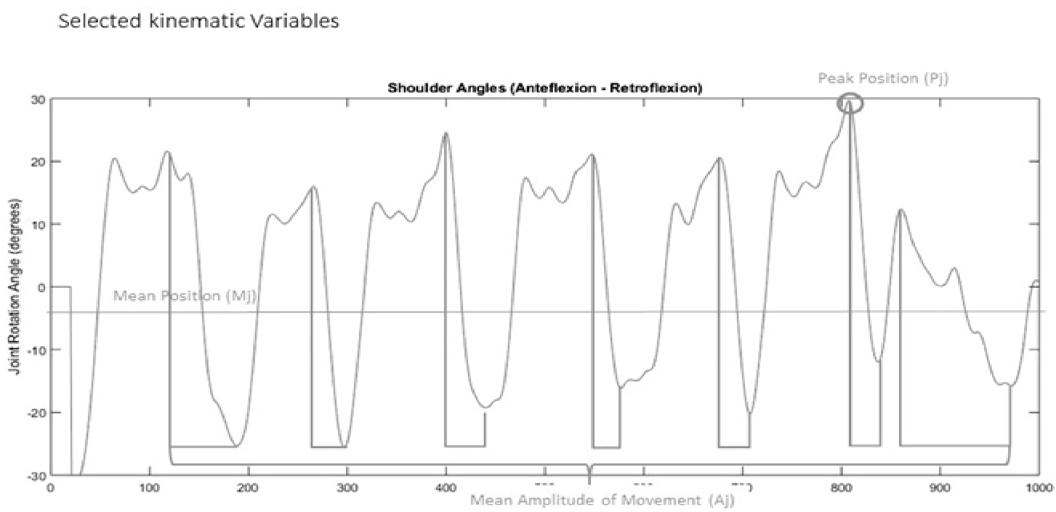


Table 1: Overview of the Selected Kinematic Parameters

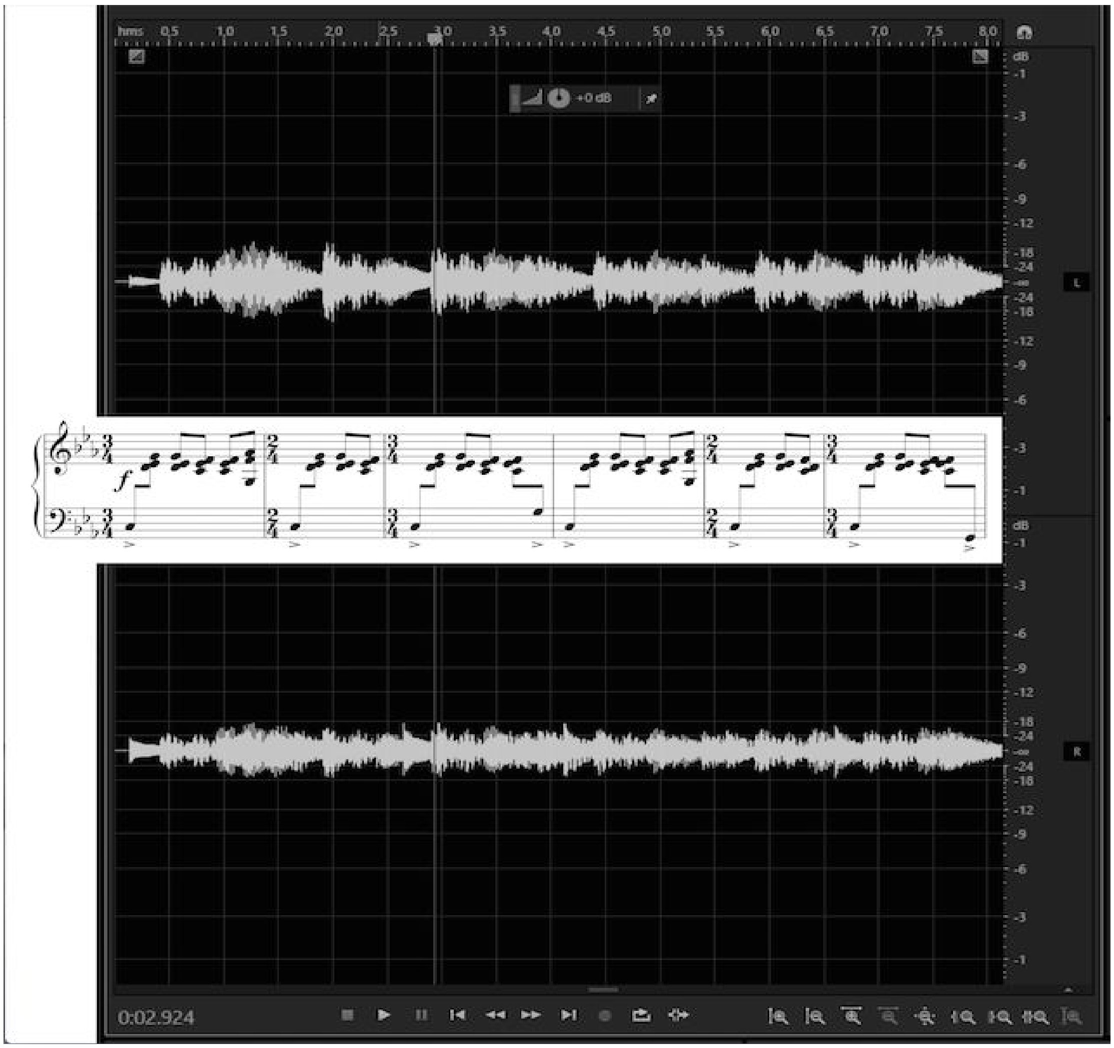
Variable	Description
M_LSF	mean left shoulder flexion
M_RSF	mean right shoulder flexion
M_LEF	mean left elbow flexion
M_REF	mean right elbow flexion
M_LWF	mean left wrist flexion
M_RWF	mean right wrist flexion
M_LWR	mean left wrist rotation
M_RWR	mean right wrist rotation
M_TL	mean trunk anteflexion
P_LSF	peak left shoulder flexion
P_RSF	peak right shoulder flexion
P_LEF	peak left elbow flexion
P_REF	peak right elbow flexion
P_LWF	peak left wrist flexion
P_RWF	peak right wrist flexion
P_LWR	peak left wrist rotation
P_RWR	peak right wrist rotation
P_TL	peak trunk anteflexion
A_LSF	amplitude of left shoulder flexion
A_RSF	amplitude of right shoulder flexion
A_LEF	amplitude of left elbow flexion
A_REF	amplitude of right elbow flexion
A_LWF	amplitude of left wrist flexion
A_RWF	amplitude of right wrist flexion
A_LWR	amplitude of left wrist rotation
A_RWR	amplitude of right wrist rotation
A_TL	amplitude of trunk anteflexion
V_LSF	velocity of left shoulder flexion
V_RSF	velocity of right shoulder flexion
V_LEF	velocity of left elbow flexion
V_REF	velocity of right elbow flexion
V_LWF	velocity of left wrist flexion
V_RWF	velocity of right wrist flexion
V_LWR	velocity of left wrist rotation
V_RWR	velocity of right wrist rotation
V_TL	velocity of trunk anteflexion
C_LSF	jerk index of left shoulder flexion
C_RSF	jerk index of right shoulder flexion
C_LEF	jerk index of left elbow flexion
C_REF	jerk index of right elbow flexion
C_LWF	jerk index of left wrist flexion
C_RWF	jerk index of right wrist flexion
C_LWR	jerk index of left wrist rotation
C_RWR	jerk index of right wrist rotation
C_TL	jerk index of trunk anteflexion

1.5Audio Data Analysis and Variables of Interest

The exported fragments were loaded into Adobe Audition CC. This software is widely available on both PC and Apple platforms. It also has qualitative audio analysis capabilities.

For each musical fragment, three different measurements were recorded and selected: 1) ITU-R BS.1770-3 Loudness LUFS, 2) maximum RMS amplitude, 3)Dynamic range in dB for the L and R channels, plus a mono sum (see Figure 4).

Figure 4: Exported audio data (on the left corner) includes ITU-R BS.1770-3 Loudness LUFS, 2) maximum RMS amplitude, 3) Dynamic range in dB, and example of the Music: Marimba Concerto No.1, 3rd movement. The demonstrated the correlation between music fragment and audio data for the beginning session.



According to Willox, ITU-R BS.1770-3 Loudness LUFS represented the current standard method to measure subjective loudness of musical signals in an objective/repetitive way. This corresponded to how the loudness was perceived subjectively, and was an up-to-date alternative A-weighted or C-weighted audio measurement. This measurement indicated the amount of sound each participant produced for a given short fragment.

Maximum RMS amplitude was chosen and this coincides more closely to how the maximum dynamic peaks in a music fragment are perceived, as opposed to true peak measurements. Dynamic range offers a good indication of how large the dynamic range could be produced by the musician. Considering not only very loud playing can yield high dynamic range, it is very possible some players cannot achieve great volume peaks, but can however get greater dynamic possibilities. This would mean that their body postures are larger, or they play more precisely.

1.6 Data Analysis and Statistics

Statistical analysis was performed using IBM/SPSS version 22 for Windows. The data were explored using box plots, in order to identify any extreme values. Mistakes (missing markers) were corrected or values were deleted if necessary. Missing data were treated as missing.

To reduce the large number of selected kinematic variables (N = 45) to a smaller set of factors describing body motion during marimba playing, a principal component analysis was performed (PCA). Assumptions regarding continuity of variables and linear relations between variables are not violated. In order to adhere to the principle of sampling adequacy, the set of 45 selected kinematic variables was divided into 4 sets of data. Set 1 contained mean position (Mj), peak position (Pj) and mean amplitude (Aj) of the right shoulder, elbow and wrist joint angular time profiles. Set 2 contained mean position (Mj), peak position (Pj) and mean amplitude (Aj) of the left shoulder, elbow and wrist joint. Set 3 contained mean speed (Vj) of all joint angular rotations. And set 4 contained all jerk indices (Cj) characterizing smoothness of movement. PCA was performed separately on each of the 4 datasets. Bartlett's test of sphericity indicated data were suitable for reduction. A 'varimax' (orthogonal) rotation was chosen for the PCA, to minimize the number of variables with high loadings on each factor. Newly composed variables of principal components were only represented if they explained a sufficient part of the variance (eigenvalue > 1). A scree plot was used to determine the optimal numbers of components for the further analysis. Only the factors left from the last steel slope of the scree plot were further included (Grover & Vriens, 2006).

Further statistical analysis was performed on the newly composed factors resulting from the PCA. In order to identify essential key elements of marimba playing, these factors were correlated with sound parameters. The Shapiro-Wilk test showed significant results for several of the newly composed factors (test statistic between 0.622 and 0.974; $p < 0.001$ to $p = 0.073$) as well as for loudness (test statistic 0.969, $p = 0.028$), violating assumptions of normality. Consequently, non-parametric Spearman Rank correlation coefficients were calculated with significance level at $p < 0.05$. Correlation coefficients will be interpreted as follows: from "0 to 0.19" a very weak relation is observed, from "0.2 to 0.39" the relation is weak, from "0.4 to 0.59" the relation is moderate, from "0.6 to 0.79" is strong and from "0.8 to 1.00" a very strong relation is observed. Furthermore, gender differences and differences in experience between bachelor and master students were investigated using the independent samples Mann-Whitney U test ($p < 0.05$).

2. Results

2.1Descriptive Participants Data

A total of twenty-two volunteering percussion and marimba students (sixteen male participants and six female participants) were recruited from two higher music universities: sixteen participants were from the LUCA Lemmens campus and six participants were from the Royal Conservatoire of Antwerp. The age was between 18 to 27 years old. Selection of the participants was based on the higher educational level (university level) and the music experience (from Bachelor 1 to Master 2 with a total of five or six years study experience) in marimba and percussion education.

Table 2: Descriptive Data of Gender, BMI, Grip and Degree

Gender		
	Male	16
	Female	6
BMI		
		22.5
Grip		
	Traditional	6
	Burton	12
	Independent	4
Degree		
	B1	3
	B2	1
	B3	6
	M1	7
	M2	5

From the total twenty-two subjects, twelve students were from the master study program in which five participants were situated in the year 5 and seven participants were in the year 4.

Ten students were from the bachelor study program in which six participants were in the year 3, one participant was in the year 2 and three participants were in the year 1. Three types of playing grips were used during this experiment. The participants chose the grips based on their personal experiences. Twelve participants (eight males and four females) handled the Burton grip; five participants (four males and one female) handled the traditional grip; and five participants (four males and one female) handled independent grip.

2.2 Outcome Data

A total number of 132 musical fragments were analyzed. In 28 of these fragments one or more kinematic variables were missing. Thus a set of 104 cases was included in the statistical analysis.

2.3 Principal Component Analysis

Four independent PCA were performed on the four predefined sets of data. Set 1 contained 15 kinematic variables describing the posture (Mj, Pj) and movements (Aj) of the shoulder, elbow and wrist joints of the right arm. PCA resulted in 3 newly composed factors together explaining 68% of the variance in the dataset. The first factor was characterized as **right arm flexion,** explained 27.3% of variance and showed high loadings on mean position Mj of shoulder flexion (negative), elbow flexion (positive) and wrist flexion (positive). The second factor was characterized as **right arm motion**. It explained 26.9% of variance and showed high loadings on mean amplitude Aj of shoulder flexion and extension, elbow flexion and extension, wrist flexion and extension and wrist rotation (all positive). The third factor was characterized as **trunk position**, explained 13.8% of variance and only showed high loadings on peak position Pj of trunk ante flexion (positive).

Set 2 also contained 15 kinematic variables describing the posture and movements of the shoulder, elbow and wrist joints of the left arm. Similarly, PCA resulted in 3 newly composed factors together explaining 59.5% of the variance in the dataset. The composition of factors was identical to the first set and thus they were attributed as **left arm flexion** (explaining 21.7% of variance), **left arm motion** (explaining 19.5% of variance) and trunk position (explaining 18.3% of variance).

Set 3 contained 9 kinematic variables describing mean speed of movement. PCA resulted in 2 newly composed factors explaining 57.2% of variance. Factor 1, **left arm speed**, explains 30.6% of variance. Mean speed Vj of the left shoulder, elbow and wrist show high loadings. Factor 2, **right arm speed**, explains 26.6% of variance. Mean speed Vj of the right shoulder, elbow and wrist show high loadings.

Set 4 contained jerk indices Cj for shoulder flexion and extension, elbow flexion and extension, wrist flexion and extension, and wrist rotation of the left arm and the right arm. PCA resulted in 2 newly composed factors whereby **smoothness of elbow and wrist** explained 32% of variance and **smoothness of shoulder movements** explained an additional 17% of variance.

2.4 Correlation Analysis

Table 3 shows results from the Spearman Rank Correlation Analysis. Several significant correlation coefficients are observed, ranging from weak to very strong. Only strong (0.5 – 0.79) and very strong (0.8 – 1.00) relations will be discussed.

First the correlations between the factors that describe upper limb movement during marimba playing were considered. A very strong negative correlation is found between right arm flexion and left arm motion (rho = -0.822, $p < 0.001$) while a strong correlation is observed between left arm flexion and left arm motion (rho = -0.503, $p < 0.001$). This indicates that when both arms are more in a flexed position, there is less range of motion in the left arm. A strong negative correlation is also found between shoulder smoothness and right arm flexion (rho = -0.748, $p < 0.001$) while left arm motion shows a strong positive correlation with shoulder smoothness (rho = 0.642, $p < 0.001$). This indicates that increased (left) arm motion is related to larger jerk indices.

Table 3: Spearman Rank Correlation Coefficients: **. Correlation Is Significant At the 0.01 Level; *. Correlation Is Significant At the 0.05 Level

Spearman's rho	R Arm flexion	L Arm Flexion	Right Arm Motion	Left Arm Motion	Right Arm Velocity	Left Arm Velo	Shoulder Smoothness	Elbow Wrist Smoothness	ITU-R BS.1770-3 Loudness LUFS (dBFs)	Max. RMS amplitude (dBFs)
L Arm Flexion										
R Arm Motion		-,503**								
LArm Motion	-,822**									
R Arm Velo										
LArmVelo	-,399**			,327**						
ShoulderSmoothness	-,748**			,642**		,371**				
Elbow Wrist Smoothness	-,286**	,239*	-,275**	,340**			,201*			
ITU-R BS.1770-3 Loudness LUFS (dBFs)	-,358**	**,569****	-,498**	,419**	-,223*		,257**	,358**		
Max. RMS amplitude (dBFs)	**-,623****	,205*	-,358**	**,515****	-,285**		**,516****	,275**	**,716****	
Dynamic Range (dB) mono	**-,711****	,212*	-,219*	**,759****	-,265**	,417**	**,566****	,309**	**,694****	**,744****

Moderate to strong correlations were also observed between factors of movement and sound parameters. Loudness showed a strong positive correlation with left arm flexion (rho = 0.569, p <0.001). RMS amplitude correlated strongly to right arm flexion (rho = - 0.623, p < 0.001) and left arm motion (rho = 0.515, p < 0.001). Similar strong correlations were observed between range of dynamics and right arm flexion (rho = - 0.711, p < 0.001) and left arm motion (rho = 0.759, p < 0.001). This shows that a less flexed position in the right arm and increased ranges of motion in the left arm affect the sound production.

2.5 Differences between Bachelor and Master Students

The Mann-Whitney U test only revealed some differences between bachelor and master students in peak trunk ante flexion (p = 0.009) whereby bachelor students show an increased forward leaning position compared to master students (60.5° versus 45°). Differences in loudness, maximum RMS amplitude or dynamic range were not significant.

2.6 Gender Differences

A Mann-Whitney U test was performed to investigate differences in kinematics of movement between males and females. Significant differences were found in peak trunk ante flexion (p = 0.003), trunk range of motion (p = 0.017), right arm flexion (p = 0.017) and left arm flexion (p = 0.037). Females show less forward leaning of the trunk, a large range of motion (ROM) in trunk movements and increased flexion in left and right arm. No effect of gender on sound parameters was found.

3. Discussion

In this study, the nature of body movements related to the playing technique of marimba was investigated. Firstly, we could identify the key elements of body motion that affect the sound production on the marimba. These key elements are related to arm position and amplitude of movement. A less flexed position in the (right) arm and larger ranges of motion in the left arm, are related to increased loudness and range of dynamics. Secondly, the years of experience, categorized as bachelor or master level, affected the playing technique. The results showed that the bachelor students showed more forward leaning over the marimba keyboard than the master students. Thirdly,females showed more arm flexion and a less forward leaning over the marimba keyboard as well as a larger ROM in trunk movements.

3.1 Relation between Movement and Sound

Range of dynamics showed strong correlations with motions of the left and right arm. These results confirm Albert's statement that the range of dynamics increased by the way how the range of wrist and elbow motions are used(2016, pp.132-134). In other words, louder dynamics may require larger ranges of motion. Average loudness showed a strong correlation with the position of the left arm (not the right arm). An explanation why this relation is only observed for the left arm might be that this arm is playing the bass line (left part of the instrument).The bass line is not only more powerful, but also the bars of the marimba's low register own a longer resonance. The marimba bars in the lower register are larger than the higher register and each bar has different length and width. This means the lower the note, the longer the vibration of the sound is required.

Furthermore, the musical composition may also influence the applied body movement. Marimba Concerto No.1 is constructed with larger interval distances in the bass section while the upper musical notes in the higher register stayed in the similar register. This required the performer to move the left limb in order to reach the bass register, while the right limb stayed in the similar position over the mid-high keyboard register. This explains why a less flexed position in the right limb and a larger range of motion in the left arm were detected.

3.2 Effects of Experience

Next to arm position and arm motion, the position of the trunk was identified as another key component of the marimba playing technique. According to the Albert marimba method (2016, p133), a suitable distance between the keyboard and the body also plays an important role in marimba playing. The ideal height of the keyboard corresponds one's height of the belt on the trousers and this offers an open body position of the upper trunk and upper limbs. A lower position of the keyboard might result not only in a poor tone production, but also in a more static body position whereby one is only playing with the forearms. A correct body position may produce a better sonority on the marimba. Compared to bachelor students, the master students demonstrated a less forward leaning upper trunk position and this might relate to better body movements and technical control. The students in the early stage of learning might still search and adjust the ideal distance to the marimba while the master student already found their ideal playing position.

3.3 Effects of Gender

This study shows that the gender influences the body postures. Females showed less forward leaning of the trunk over the marimba keyboard, which is more related to the natural body movement while males showed more forward leaning body postures. Like discussed above, a less forward leaning upper trunk position offers better technical control and sound production on marimba. Therefore, males should pay more attention on trunk position because, if one does not use the body movements properly in marimba performance, this could influence their performances and cause musculoskeletal injuries (MSI) such as finger tendons, wrists and arm muscles and back pain (Albert, 2016, p. 134).The difference between males and females is an important parameter to consider in future research and may be considered as a part of marimba education.

3.4 Study Limitations

This study did not include equal numbers of male and female participants, which might influence the comparison between males and females.

Different technical grips, previous education and cultural background might influence the sound production and body movement. In these twenty-two volunteering participants, nine students focused only on marimba in the master study program, five students preferred the keyboard-percussion instruments and eight students were overall trained in percussion. Their personal interests and career choices might influence the time of marimba study and therefore the fluency of the performance and the execution of the music (more or less mistake notes). Moreover, different level of previous experience might also influence the musical interpretation and personal own playing characteristics (Dahl &Friberg, 2007). Nevertheless, in our study, we choose not to control for these variables.

The participants might have the psychological stress or be nervous for the performance with this unnatural setting and experiment. In comparison with the actual reality, the duration of a concert program is normally around one hour or ninety minutes; the solo concert exam is around forty-five minutes to one hour and an actual concert performance is for open public. The participants stated that they might became nervous or stressed for the first time because of seeing their professor in the room, performing for other researchers or randomized playing of the musical fragments. However, the participants could gain back the concentration after playing two or three times musical fragments during the measurement. In addition, the degree of stress was less presented during the experiment because the performance of the experiment was not for open public.

Although the results showed a close relation between the upper body parts and marimba playing, Albert (2016, p.133) also addressed that the students mainly focused on the upper limbs but were stiffer in the lower limbs. Similar observation discovered that professional marimbaists moved with more flexibility in their lower limbs (Colton, 2013, p. 113). Lower limbs were not investigated in this study.

4. Conclusion

This study provides biomechanical data identifying key elements of marimba playing technique in relation to sound which are motion of the arms and trunk position. The range of dynamic is related to the range of motion of the upper limbs. Marimba master students, as well as female marimbaists, showed less leaning forward over the marimba keyboard. The results from this study provide valuable input for future work on methods to improve the playing technique. Furthermore, it provides a conceptual framework to investigate whether playing technique interventions also affect the sound in the preferred way.

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