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Reliability of Lower Limb Kinematics during the Arm-Throw Wrestling Technique

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ABSTRACT. The purpose of this article was to study the reliability of kinematic parameters during the arm-throw wrestling technique. Two experienced wrestlers (age: 18.5 ± 0.7 years, body mass: 73.5 ± 0.7 kg, height: 174 ± 1.4 cm) voluntarily served as subjects. Their arm-throw technique was recorded by an optoelectronic system (Vicon MX) with six infrared video cameras operated at 100 Hz. Each wrestler performed five trials using the arm-throw technique against a wrestling dummy with a 30-kg mass and 1.6-meter height. The results showed that the pelvic, hip, knee, and ankle kinematics showed high to very high reliability during the performance of an arm-throw technique.

Keywords: arm throw, wrestling, reliability

INTRODUCTION

Wrestling performance strongly depends on the wrestler's ability to disturb an opponent's balance by applying rotational forces, using a case-sensitive optimal technique. This optimal technique is a very difficult task (Petrov, 1986) and involves several simple or more complex movements of the wrestler's body and limbs that have to be fully coordinated and take full advantage of the athlete's physical capacities and mental skills (Wang, Liou, & Liou, 2000).

Modern wrestling biomechanics use state of the art equipment and advanced techniques in order to record, to analyze, to quantify, to describe, and to explain the mechanisms underlying a successful technique or the technical errors that lead to a diminished performance. Such information about the relationship among several mechanical factors and performance is critical for the coach who has to decide upon the optimal strategy to develop a young wrestler's technique or to improve his senior athlete's technical performance in those small details that could make the difference and lead to success (Mason & Portus, 2005).

A very popular technique, the arm-throw wrestling technique, requires higher levels of neuromuscular-coordination ability than muscle force. According to Tunnemann (2016), throwing techniques are performed by all three wrestling styles (Greco-Roman, Freestyle, and Women Freestyle) in all body-weight categories and significantly contribute to scoring. However, there is no quantitative evidence in terms of the frequency or other objective measure regarding the execution of arm-throw techniques in any wrestling style.

In the arm-throw technique, the wrestler's body and segments have to move in a continuous and coordinated manner to make one act as a lever and to take full advantage of an opponent's momentum to lead the opponent in a throwing path on the wrestling mat (Wang et al., 2000). Because of the complexity of this technique, younger wrestlers find some difficulty in understanding the exact mechanism that is activated and in applying it properly in competitive conditions during their training. Current scientific literature involves a lot of qualitative information about the mechanics of arm throw in wrestling but there is a lack of quantitative data regarding the segment/joint kinematics. The use of such quantitative information could facilitate the training process, enhance its outcomes and improve the young wrestler's performance (Kazarian, 2010).

According to Tunnemann (2010), an integrated approach for the development of a technique in young wrestlers should incorporate all possible information about the kinematics and the kinetics of every simple movement involved in a given technique. However, such information has to be derived by accurate and reliable biomechanical data, recorded by valid measurement equipment and advanced biomechanical methods (Mason & Portus, 2005). Fortunately, modern biomechanical systems are more than valid and capable of analyzing

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even the most complex wrestling technique. The reliability of the exported data, however, is not solely an issue of the system and the method used.

Biomechanical measurements like every measurement are subjected to various sorts of errors, which cause the measured value to differ from the true value. The reliability of biomechanical data relates the magnitude of the error involved in the actual measurement (measurement error) to the inherent data variability in an ideal (free from errors) or true measurement within or between subjects. High reliability means that measurement errors are small in relation to the true differences between performance trials of a single subject or between a single trial performed by several subjects, so that subjects can be relatively well described and distinguished by the quantified variable that is measured (Bartlett & Frost, 2008). Conversely, low reliability means that measurement errors tend to be large in comparison to the true differences between trials or subjects, and differences between data from measurements of different trials or subjects might be due to error rather than to a real difference in their true (error-free) values (Bartlett & Frost, 2008). Because of its importance, reliability has been extensively studied in the literature, and several methods and indices have been used to test it. A popular reliability parameter is the intraclass correlation coefficient (ICC; Koch, 1982). The intraclass correlation coefficient in biomechanical measurements is commonly used to quantify the degree to which movement-data arrays from different trials or subjects resemble each other in terms of a quantitative trait.

ICC takes values between 0 and 1, with a value of 1 corresponding to zero measurement error and a perfect match, while a value of 0 means that all the variability in measurements is due to measurement error.

Despite its importance, the reliability of biomechanical parameters used in quantifying wrestling techniques has not been studied yet. In fact, only two reliability studies concerning wrestling-movement parameters have been found in the literature and none of them involved biomechanical parameters critical for wrestling performance.

Recently, López-González and Miarka (2013) studied the reliability of a new time-motion analysis (TMA) model based on technical–tactical interactions in the three Olympic wrestling styles: freestyle (FS), female wrestling (FW), and Greco-Roman (GR). They used a semi-quantitative method involving two raters to analyze two video-recorded combats per style downloaded from FILA's World Senior Championships '11 WebTV site, using 11 categories as indicators for classification and to determine the duration of the wrestlers' actions in both activity and rest time. The reliability of the TMA model was estimated by Cohen's kappa and the intraclass correlation coefficient (ICC) for the categorical and duration data, respectively. The results showed that their TMA model could be considered a reliable tool when being used by different raters (Lopez-Gonzalez & Miarka, 2013).

Wright, Isaacson, Malecek, and Steffen (2015) studied the reliability of a sport-specific conditioning test for wrestling that will incorporate the physiological demands of a match. Sixteen collegiate wrestlers performed the new sandbag test using a bag filled with sand that was repeatedly thrown over a course of seven 1-minute rounds. Average time per throw (T/T) was determined in each round. Test-retest reliability for the sandbag test was found to be almost perfect (intraclass correlation coefficient, $r = .96$) using the T/T (Wright et al., 2015).

The purpose of this article was to study the reliability of kinematic parameters used for the quantification of the movements of the lower body segments (lower limbs and pelvis) during the knee-drop arm-throw wrestling technique.

METHODS

Participants

Two experienced wrestlers voluntarily served as subjects. They had a mean age of 18.5 ± 0.7 years, a mean body mass of 73.5 ± 0.7 kg, a mean body height of 174 ± 1.4 cm, and similar training age (about 10 years).

Instruments and Procedures

All measurements were performed in the Biomechanics Laboratory of the Department of Physical Education and Sport Science of Democritus University of Thrace in Komotini within the project entitled "Integrated Young Wrestlers Development" that aimed in developing an interactive wrestling training manual for the development of young wrestlers that incorporated three major modules: *physical testing and training; technical training;* and *tactical training.*

The knee-drop arm-throw technique was recorded by an optoelectronic system (Vicon MX) with six infrared video cameras operated at 100 Hz. All cameras were connected to a synchronization unit (MXnet) and then to a computer. Space calibration was performed prior to the recording by a specific wand that was moved by the tester in all directions for a short time period. The NEXUS (Vicon, Oxford, UK) and MatLab (Mathworks, Natick, MA, USA) software were used for both the recording and the processing of the kinematic data sequences. Prior to each recording, reflective markers were placed in specific anatomical landmarks (see Figure 1). By these markers, the body was modeled in theoretically rigid segments that were defined as follows: head (four markers in a circular arrangement), torso (7th cervical, 10th thoracic vertebrae, clavicle, sternum, and right back), right and left upper limb (shoulder, upper arm, elbow, forearm, medial and lateral wrist, and 2nd metatarsal head), pelvis (four markers in anterior and posterior iliac spines), and left and right lower limbs (thigh, knee, tibia, ankle, toe, and heel). In this article, only the data describing the movement of the lower body segments were used in further processing and analysis.

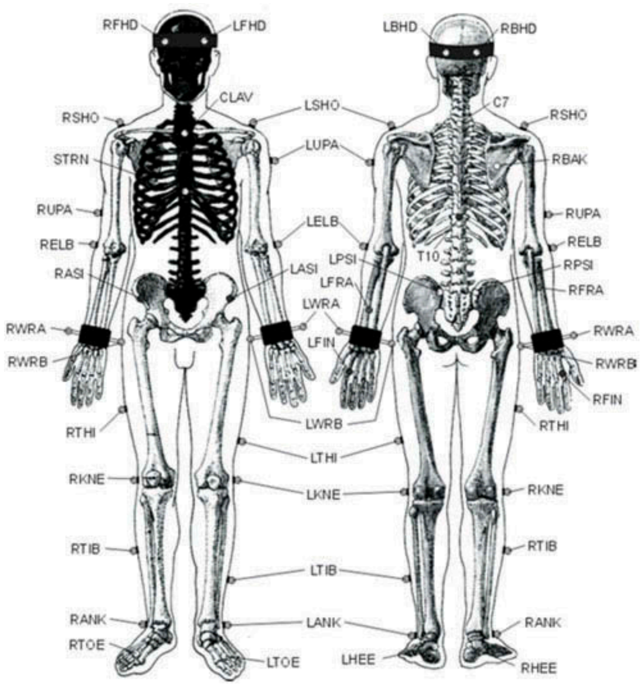

FIGURE 1 Full body-marker placement protocol.

Data processing involved the reconstruction of the three-dimensional coordinates of the markers, the calculation of the segment's anatomical reference systems, the smoothing of the raw data using fourth-order Butterworth digital filters with a cutoff frequency of 6 Hz, and the calculation of the anatomical angles in each lower limb joint (hip, knee, and ankle) and the pelvis, for each 1% interval of the total arm-throw duration. The output of the analysis was the waveforms of the following angular movements: (a) in the anterior-posterior plane of movement: anterior/posterior pelvic tilt, hip flexion/extension, knee flexion/extension, ankle dorsal/plantar flexion; (b) in the frontal plane of movement: right/left pelvic tilt and hip adduction/abduction; (c) in the transverse plane of movement: right/left pelvic rotation and hip internal/external rotation. Figure 2 shows typical values of these waveforms for each segment and joint (pelvis, hip, knee, and ankle).

Each wrestler performed a number of trials using the arm-throw technique against a wrestling dummy with a 30-kg mass and 1.6-meter height. The arm-throw technique in each trial started from the same starting position for both the wrestler and the dummy, which was assured by marking the boundaries of the dummy's base and the wrestler's feet on the ground with adhesive tape. Furthermore, the wrestler had to perform the arm throw at approximately his "preferred" time, which was the mean time for the execution of five arm throws that he was asked to perform two hours before the actual measurement, during his familiarization period. During the actual measurement, the wrestler was asked to perform successive arm throws until he succeeded five valid trials. A valid trial was performed within +/- 5% of his "preferred" execution time.

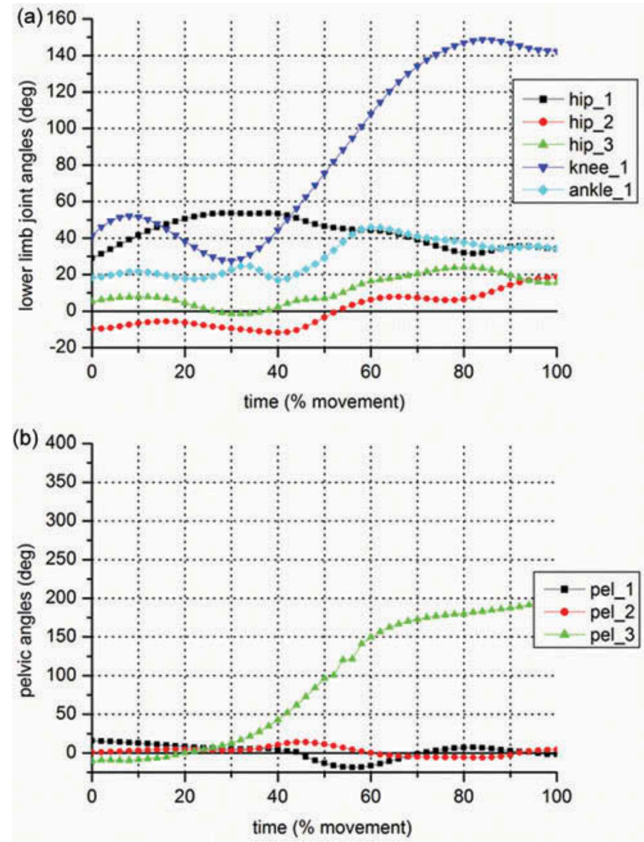

FIGURE 2 Typical kinematic waveforms of all joint angles (a) of the lower limbs and (b) of the pelvis during a single arm-throw performance (hip_1: hip flexion/extention, hip_2: hip adduction/abduction, hip_3: hip internal/external rotation, pel_1: pelvic anterior/posterior tilt, pel_2: pelvic right/left tilt, pel_3: pelvic right/left rotation).

Statistical Analysis

The intraclass correlation coefficient (ICC) was used to quantify the reliability of each kinematic waveform. The ICC in the current research was calculated through a two-way analysis of variance (ANOVA) according to the following formula (Baumgartner, 1989):

$$ICC = \frac{MS_s - MS_i}{MS_s}, \tag{1}$$

where, *ICC* is the intraclass correlation coefficient between the five trials, MS_s is the mean square difference between the trials, and MS_i is the mean square difference of the interaction between the trials and the time intervals of each waveform (100).

Next, the least number of trials needed to obtain an ICC greater than or equal to .80 was estimated using the Spearman-Brown prophecy formula (Baumgartner, 1989):

$$r_{ICC} = \frac{K \cdot (ICC_1)}{1 + [(K-1) \cdot (ICC_1)]} \Rightarrow K = \frac{r_{ICC} \cdot (1 - ICC_1)}{ICC_1 \cdot (1 - r_{ICC})}, \quad (2)$$

where ICC_1 is the ICC that was estimated for a single trial, K is the least number of trials, and r_{ICC} is the desired ICC value (.80).

RESULTS

For each trial, an average kinematic waveform was calculated from the respective waveforms of the two wrestlers in the respective trial. The five average kinematic waveforms of the right hip-joint movements in the three dimensions (flexion/extension, adduction/abduction, and internal/external rotation) during the arm throw in the five trials are shown in Figure 3. As can be seen, the hip internal/external rotation and hip adduction/abduction patterns showed great similarities during the different trials, while the hip flexion/extension patterns were more dissimilar. This was also the case for the movements of the left hip.

The five average kinematic waveforms of the right knee- and ankle-joint movements in the sagittal plane (flexion/extension and dorsal/plantar flexion) during the arm throw in the five trials are shown in Figure 4. As can be seen, both joints showed very similar waveforms in the different trials. Moreover, this was also presented in the left knee and ankle movements.

The five average kinematic waveforms of the pelvis movements in the three dimensions (anterior/posterior pelvic tilt, right/left pelvic tilt, and right/left pelvic rotation) during the arm throw in the five trials are shown in Figure 5. As it can be seen, all movement patterns showed great similarities during the different trials.

The reliability of each kinematic waveform was quantified by the intraclass correlation coefficient. The ICCs for all kinematic waveforms of the pelvis and the lower limb joints in all planes of motion are shown in Table 1. In the same table, one can see that up to four trials are needed in order to obtain reliable data for some kinematic parameters, although just a single trial can be enough in the case of some others (see Table 1).

DISCUSSION

The current article studied the reliability of kinematic parameters that are usually recorded during a biomechanical analysis for the quantification of the movements of the

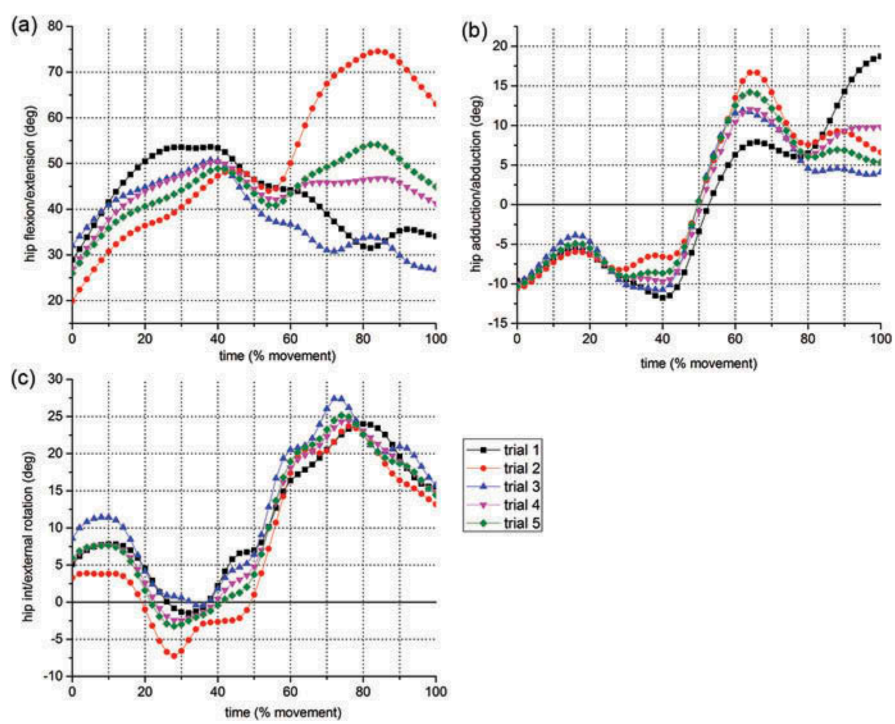

FIGURE 3 Average kinematic waveforms of the hip-joint movements during the arm throw in five performed trials: (a) flexion/extension, (b) adduction/abduction, and (c) internal/external rotation.

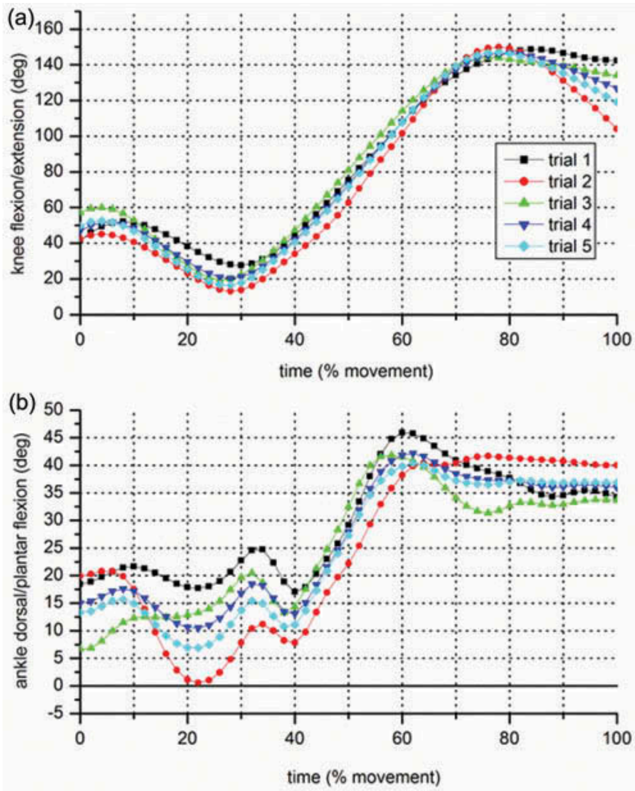

FIGURE 4 Average kinematic waveforms of the knee- and ankle-joint movements in the sagittal plane during the arm throw in five performed trials: (a) flexion/extension and (b) dorsal/plantar flexion.

lower body segments (lower limbs and pelvis) during a popular wrestling technique, the arm-throw wrestling technique.

The results showed that, for the knee and ankle movements in the sagittal plane (knee flexion/extension angle and ankle dorsal/plantar flexion angle), the reliability coefficients (ICC) were excellent and one trial was more than enough in order to record representative data (see Table 1). This was in agreement with the reliability of knee and ankle movements in other sports, such as running (Giannakou, Aggeloussis, & Arampatzis, 2011).

Concerning the hip joint, an excellent reliability was found for its movements on the frontal (hip abduction/adduction angle) and transverse planes (hip internal/external rotation angle), while, in the sagittal plane, hip flexion/extension angle was attributed with less but still more than accepted reliability (see Table 1). In any case, two trials are needed to record fully reliable data concerning the hip movements in real three-dimensional space. This finding is also in accordance with the findings of previous research about running (Karamanidis, Arampatzis, & Bruggemann, 2003).

On the other hand, pelvic movements showed less reliability than the lower limb joint movements (see Table 1). More specifically, pelvis right/left rotation angle showed the greatest reliability among them, while pelvis anterior/posterior tilt angle and pelvis right/left tilt angle showed the lowest reliability among all the examined kinematic parameters. As a result, up to four trials were needed to reliably record kinematic data about the pelvic movements when

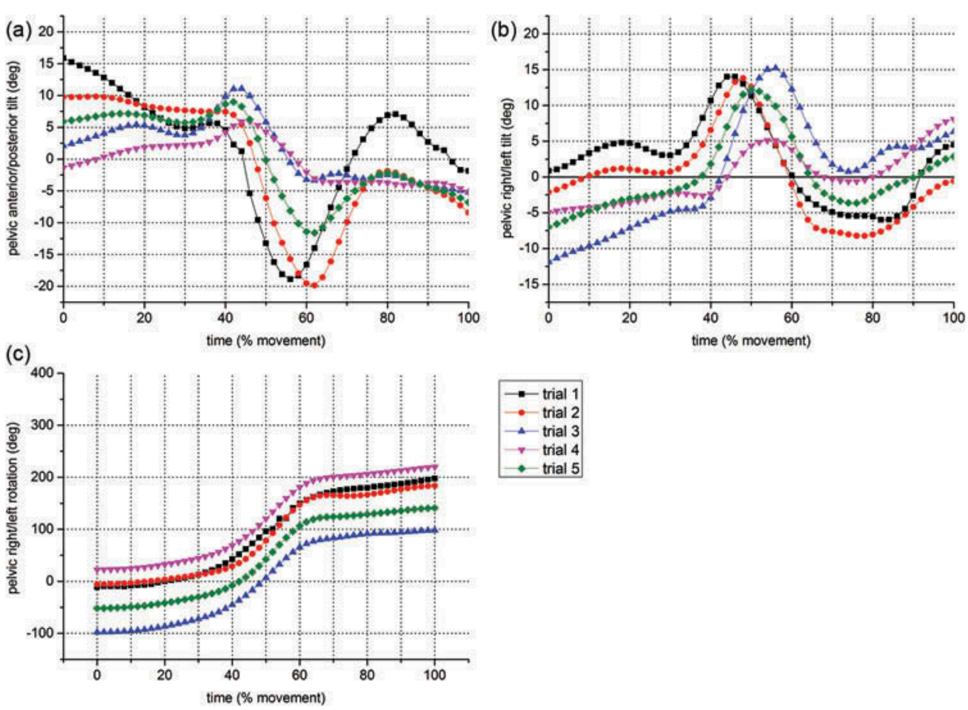

FIGURE 5 Average kinematic waveforms of the pelvic movements during the arm throw in five performed trials: (a) anterior/posterior pelvic tilt, (b) right/left pelvic tilt, and (c) right/left pelvic rotation.

TABLE 1 Intraclass Correlation Coefficients (ICC) and Least Number of Trials (*K*) to Ensure an ICC = .80 for the Kinematic Waveforms of the Pelvis and the Right and Left Lower Limb Joints in all Planes of Motion

	ICC (single)		*K*	
Segment/Joint Angle	*Right*	*Left*	*Right*	*Left*
Pelvis anterior/posterior tilt angle	.864 (.560)		4	
Pelvis right/left tilt angle	.793 (.534)		4	
Pelvis right/left rotation angle	.917 (.749)		2	
Hip flexion/extension angle	.876 (.674)	.911 (.673)	2	2
Hip abduction/adduction angle	.984 (.925)	.899 (.911)	1	1
Hip internal/external rotation angle	.990 (.951)	.980 (.915)	1	1
Knee flexion/extension angle	.997 (.986)	.989 (.949)	1	1
Ankle dorsal/plantar flexion angle	.976 (.891)	.979 (.903)	1	1

Note. The ICC within parentheses is for cases in which only a single trial is performed.

performing a wrestling arm throw. This might be explained by the fact that, although hip, knee, and angle movements are joint movements, pelvic movements are recorded as segment movements. Consequently, pelvic angles in each plane are recorded as the angle that a pelvis axis (e.g., the sagittal axis) has in relation with the respective axis (sagittal) of the global space of the movement. As so, pelvic angles are more sensitive to measurement errors in relation with the lower limb joint movements (hip, knee, and ankle) that are recorded by the angles between a segment and its next segment throughout the motion. However, even in this case, the problem can be solved by recording more trials for each athlete, an easy task for most current motion analysis system.

In a previous article (Barbas et al. 2012), the important issue of the variability of each separated segment or joint movement involved in the performance of the total arm-throw movement has been discussed. In that article, it was found that some of the discrete movements that the athlete's segments and joints performed were characterized by high reproducibility (reliability) and were considered as the continuum of "standard movements" that form the typical (standard) biokinematic profile of the arm-throw technique. On the contrary, some other joint movements showed greater instability (lower reliability) and were considered as "variable movements" that constitute a temporal biokinematic profile that is opponent dependent and, thus, is continuously altered in successive performances (Barbas et al., 2012).

This article's data seemed to support such a speculation and one can distribute examined parameters on the two biokinematic profiles based on their reliability coefficients. In this direction, pelvis right/left rotation angle, hip flexion/extension angle, hip abduction/adduction angle, hip internal/external rotation angle, knee flexion/extension angle, and ankle dorsal/plantar flexion angle could be considered the "standard biokinematic profile" of the arm-throw wrestling technique. On the other hand, pelvis anterior/posterior tilt angle and pelvis right/left tilt angle could be considered as the temporal biokinematic profile of the arm-throw technique. However, more research is needed towards the study or reliability of the above kinematic parameters in real competitive environments against an active opponent before valid conclusion could be drawn about this issue.

In addition, it has been shown (Bartlett & Frost, 2008) that the reliability of any examined parameter or method also depends on the spreading of its true values around the population mean. Because of this, it is suggested that the current research's design should be applied in other wrestling samples with several characteristics (age, gender, experience level, background, etc.) as well as in other wrestling styles in order to establish a reliable general kinematic evaluation protocol for all wrestling categories and styles.

In conclusion, the pelvic, hip, knee, and ankle kinematics showed high to very high reliability during the performance of an arm-throw technique. This means that these specific parameters could be used for the quantification of the athlete's lower body movements, in addition to any qualitative analysis that a coach may apply during training towards the more faster and injury-free development of the optimal arm-throw wrestling technique.

REFERENCES

Barbas, I., Aggelousis, N., Podlivaev, B., Shakhmuradov, Y., Mizraei, B., Tunnemann, H., & Kazarian, S. (2012). Biomechanical protocol to assist the training of the arm-throw wrestling technique. *International Journal of Wrestling Science*, *2*(2), 93–97.

Bartlett, J. W., & Frost, C. (2008). Reliability, repeatability and reproducibility: Analysis of measurement errors in continuous variables. *Ultrasound and Gynecology*, *31*, 466–475.

Baumgartner, T. A. (1989). Norm-referenced measurement: Reliability. In M. J. Safrit & T. M. Woods (Eds.), *Measurement concepts in physical education and exercise science* (pp. 45–72). Champaign, IL: Human Kinetics.

Giannakou, E., Aggeloussis, N., & Arampatzis, A. (2011). Reproducibility of gastrocnemius medialis muscle architecture during treadmill running. *Journal of Electromyography and Kinesiology*, *21*, 1081–1086.

Karamanidis, K., Arampatzis, A., & Bruggemann, G. P. (2003). Symmetry and reproducibility of kinematic parameters during various running techniques. *Medicine and Science in Sports and Exercise*, *35*, 1009–1016.

Kazarian, S. (2010). Some main teaching methods of the sport wrestling. *Advanced School for Coaches handouts*. Tokyo, Japan.

Koch, G. G. (1982). Intraclass correlation coefficient. In S. Kotz & N. L. Johnson (Eds.), *Encyclopedia of statistical sciences* (Vol. 4, pp. 2113–2117). New York, NY: John Wiley & Sons.

López-González, D. E., & Miarka, B. (2013). Reliability of a new time-motion analysis model based on technical–tactical interaction for wrestling competition. *International Journal of Wrestling Science*, *3*(1), 21–34.

Mason, B. R., & Portus, M. (2005). Essay biomechanical support in sport. *The Lancet*, *366*, S25–S26.

Petrov, R. (1986). *Freestyle and Greco-Roman wrestling*. Lausanne, CH: International Amateur Wrestling Federation–FILA.

Tunnemann, H. (2010). Training and science in wrestling. In Russian Wrestling Federation (Eds.), *Proceedings of the 2010 FILA Conference* (pp. 38–40). Moscow, RU:International Amateur Wrestling Federation–FILA.

Tunnemann, H. (2016). Scoring analysis of the 2015 World Wrestling Championships. *International Journal of Wrestling Science*, *6*, 39–52.

Wang, G., Liou, H., & Liou, P. (2000). Biomechanical analysis of hold-throw technique in elite wrestler. In Y. Hong, D. Johns, & R. Sanders (Eds.), *Proceedings of 18th International Symposium on Biomechanics in Sports* (pp. 312–313). Hong Kong, China: International Scociety of Biomechanics and Sports.

Wright, G. A., Isaacson, M. I., Malecek, D. J., & Steffen, J. P. (2015). Development and assessment of reliability for a sandbag throw conditioning test for wrestlers. *Journal of Strength and Conditioning Research*, *29*(2), 451–457.