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Kinematic criteria determining swing movement of world class dancesport athletes

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ABSTRACT
Purpose. The aim of the study was to identify the distinguishing characteristics of the swing movement of the world's top dancesport couples through kinematic variables.
Methods. The study involved six world-class and six intermediate dance couples. The couples were asked to execute three identical series of three natural turns of the figure in a Viennese Waltz, all being filmed as they danced to music. Six international experts evaluated all the trials of each couple from the point of view of the technical quality component based on the Absolute Judging System. A triaxial rotational angular velocity measurement (gyroscope) device was placed on the dorsal part of the pelvic girdle and on the posterior part of the thorax of each competitor.
Results. An analysis of covariance demonstrated that regardless of the sports level, the maximum hip girdle angular rotation velocity in the forward swing movement performed by men was significantly related to the judging score achieved ($F_{1,9} = 11.5$; $p < 0.05$; $\eta_p^2 = 0.45$).
Conclusions. The mean squares of the differences of the hip and thoracic spine angular rotation velocity signals were found to be a good criterion for evaluating the swing movement, which is related to the judges' evaluation. The descriptions of the performance of complex rotational movements obtained in this study can find their application in the analysis, teaching, and evaluation of dance couples. This is one of the first studies in the literature that deals in detail with swing movement in sports dance.
Key words: dancesport, kinematic, swing, technique, ballroom dancing

Introduction

Swing action in dancesport can be described as a specialised swinging movement that is used to achieve the desired characteristics of a particular standard style dance. Standard style is a special type of dance because a woman and a man perform all the movements while being in constant connection with each other's bodies. This type of movement is found in all standard style dances except the tango and is performed by both a woman and a man [1]. Each of the four dances – slow waltz, Viennese Waltz, foxtrot and quickstep – using this action has a different tempo of music and the characteristics of the swing movement action also depend on the dance being performed [2]. In the literature, the swing movement is defined as a movement that is necessary in dance in order to achieve an elegant and well-coordinated dance movement [3–5]. In physics, on the other hand, a swing motion is defined as a free oscillating motion around a fixed point (x). On the other hand, to better understand the standard style-specific swing movement, attempts have been

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made to conduct scientific studies to provide sound scientific data to comprehensible explain the pelvic-girth movement of the partners in individual figures [1]. Unfortunately, an insufficient number of studies that investigate the kinematic movement of the pelvic girth during dance has been published. However, the literature emphasises that a kinematic evaluation of the pelvic and joint centre movement technique of partners in standard style could yield very important practical applications [3, 7]. According to Yoshida et al. [8], kinematic evaluation of other standard dances is desirable for learning technique or as an additional tool to better evaluate dance couples in competitions. Kinematic evaluation of world-class dance sport athletes is presented in this study, which makes it unique. Hence, the aim of the study was to identify the distinguishing characteristics of the swing action of the world's top dancesport couples through kinematic variables.

Material and methods

Participants

The conducted study involved a total of twelve dancesport couples. The study did not include minors. Six pairs from the adult category of the top-level group were tested to obtain a movement pattern. All the athletes from this group are of the highest sport class (international class) and they were champions or vice-champions of their respective countries. It is noteworthy that the distinguishing element of the conducted research is the fact that within the top level-group, there were world champions, vice champions and finalists of the world championships. The other six couples participating in the study were Polish couples competing at the national level, which is characterised by an average sport level. Table 1 specifies the basic characteristics of the top-level and intermediate groups.

Accelerometric measurement of characteristic kinematic features in dance

The measurement involved determining the angular velocity component of the pelvic girdle (ω_{y1}) and thoracic spine (ω_{y2}) as they rotated around the transverse axis. 90 seconds was the measurement time for every trial and 200 Hz was the sampling rate. To measure the angular velocities of the thoracic spine and pelvic girdle segments of the athletes participating in the study, four three-component accelerometers with a digital recorder and gyroscope function were used (ZPP-3D/B, Zb. Staniak, Poland; length × width × depth: 8 × 4 × 2 cm, mass: 70 g with a frequency of 200 Hz) [9] and the data were downloaded wirelessly. Angular velocities were measured while the dance couples performed clockwise rotations, which are a basic figure from the Viennese Waltz called the 'natural turn' [11]. Three identical series of three complete natural turns along a straight line were performed by all couples in the top-level and intermediate level groups on the dance floor. The studied sport couples danced to music that is used during competitions at a tempo of 60 bars per minute, with each of the three iterations recorded by a camera at 30 fps. Six judges, holding an international WDSF Federation judges' licence, appraised all the dance pairs' rehearsals. In their evaluation, the judges took into account each of the three dance repetitions of the competitors using a technical quality criterion on a scale of 1 to 10, as defined by the Absolute Judging System, which is commonly used at the largest competitions (AJS). The evaluation of dance in this system is based on an absolute evaluation where the judges do not compare the performances of dance couples with each other. Considering that the first natural turn is accompanied by a preparatory movement and the last one by a stopping movement, it was decided that only each second natural turn of the tested couple should be considered in the analysis

Table 1. Mean (± *SD*) values of age, body weight, training experience and BMI of top-level and intermediate group athletes

Factors	Top-level group		Intermediate group	
	men (*n* = 6)	women (*n* = 6)	men (*n* = 6)	women (*n* = 6)
Age (years)	31 ± 3.6*	28 ± 3.9*	20 ± 2.4	19.7 ± 2.0
Body height (cm)	182 ± 3.8	170 ± 6.3	181.5 ± 3.4	170.8 ± 4.9
Body mass (kg)	71.3 ± 3.0	52.7 ± 4.0	72.7 ± 4.1	52.8 ± 5.7
BMI	21.6 ± 1.0	18.2 ± 0.4	22.1 ± 1.3	18.1 ± 1.3
Training experience (years)	22 ± 2.6*	19 ± 3.1	11.8 ± 1.5	12.7 ± 2.1

BMI – body mass index, different than in intermediate level group: * $p < 0.05$

of the kinematic characteristics of the dance and the judges' evaluation [2]. Two triaxial acceleration and triaxial rotation angular velocity sensors were positioned in foam stabilisation pads and then arranged on the dorsal part of the pelvic girdle (sacroiliac joint) and the thoracic (Th5) spine of the tested athletes. Stability pads with accelerometers were attached with rubber bands (Figure 1). Angular velocity of rotation around the transverse axis of the female thoracic spine was measured [3].

Figure 1. Method of placement of accelerometers with gyroscope

Statistical analysis

For the needs of the analysis, the following variables were determined: average difference of the squares of the angular velocity waveforms ω_{y1} and ω_{y1} (C) in the male and female athletes:

$$C = \frac{1}{T}\int_0^T \left[\omega_{y1}(t) - \omega_{y2}(t)\right]^2 dt,$$

where: t – time, T – time of execution of a swing movement.

The minimum, mean, maximum and standard deviation values of angular rotation velocities in relation to the transverse axis of the pelvic girdle (ω_{y1}) and angular rotation velocities in relation to the transverse axis of the thoracic spine (ω_{y2}) were also determined. As the study group was relatively small, it was decided to apply the non-parametric Mann–Whitney test to compare the obtained values of the relevant kinematic criteria to evaluate the technique of the athletes in the top and intermediate groups, and Glass' biserial correlation coefficient as an indicator of the effect size. An analysis of covariance was used to investigate the dependence of the judges' scores on the quantitative predictor of interest (accompanying variable) and group membership (champion, intermediate). The magnitude of the effect was assessed using the partial eta squared value (η_p^2). Spearman's rank correlation coefficient was used to compare the concordance of the mean trajectories of the angular velocities of the athletes in the two groups under investigation. The significance level was established at $\alpha = 0.05$. Statistica 13.0 was used to perform the statistical analysis.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the senate commission of research studies ethics of Józef Piłsudski University of Physical Education (approval No.: SKE 01-13/2022).

Informed consent

All participants gave their written consent online after receiving information on the study purpose, test procedures, and benefits. Furthermore, they were made aware of the possibility to withdraw their consent at any time for any reason.

Results

The judges scored the performances of the dance couples on a scale of 1 to 10 using the AJS system.

Table 2 presents the scores awarded to the top-level (champion) and intermediate level groups by the judges.

Swing action in forward movement of athletes

Table 3 presents the mean values of the studied kinematic variables during the execution of a swing action in the forward movement during the first three steps of the natural turn of men and women from the top-level and intermediate groups.

Table 2. Average scores awarded by judges for technical quality component

	Top-level group						Intermediate group					
Mean scores	9.79	9.43	9.33	9.49	8.79	8.19	3.43	3.17	2.45	3.04	3.18	2.77

Table 3. Mean (± *SD*) values of studied kinematic variables of forward swing movement

Factors	Top-level group		Intermediate group	
	males (n = 6)	females (n = 6)	males (n = 6)	females (n = 6)
Av. ω_{y1} [deg/s]	–1.43 ± 10.85	3.35 ± 10.90	4.27 ± 8.32	–0.03 ± 10.38
Min. ω_{y1} [deg/s]	–61.33 ± 22.91	–51.57 ± 13.11	–33.19 ± 17.40	–39.02 ± 15.78
Max. ω_{y1} [deg/s]	96.36 ± 37.20**	98.21 ± 13.84**	45.12 ± 14.05	47.21 ± 8.52
SD ω_{y1} [deg/s]	38.08 ± 9.20**	38.72 ± 5.45**	17.70 ± 5.09	20.70 ± 4.98
Av. ω_{y2} [deg/s]	–33.20 ± 12.75	–7.27 ± 18.72	–12.41 ± 20.91	–30.62 ± 28.91
SD ω_{y2} [deg/s]	–107.37 ± 16.60**	–86.47 ± 14.04	–53.93 ± 17.38	–71.72 ± 28.07
Min. ω_{y2} [deg/s]	63.99 ± 22.41	84.67 ± 20.50**	36.67 ± 11.99	17.21 ± 24.41
Max. ω_{y2} [deg/s]	49.85 ± 9.63**	48.21 ± 6.54**	24.62 ± 5.73	24.27 ± 6.24
C [deg^2/s^2]	3206.80 ± 2107.09	2079± 389	1254.07 ± 717.76	1885 ± 1265

Av. – average angular velocity, Min. – minimum angular velocity, Max. – maximum angular velocity, *SD* – standard deviation, C, ω_{y1} and ω_{y2} – mean sum of squares of signal differences between ω_{y1} and ω_{y2} for the average signal runs
different than in intermediate level group: ** p < 0.01, * p < 0.05

Table 4. Mean (± *SD*) values of the studied kinematic variables of the backward swing movement

Factors	Top-level group		Intermediate group	
	male (n = 6)	female (n = 6)	male (n = 6)	female (n = 6)
Av. ω_{y1} [deg/s]	–8.11 ± 15.22*	–0.71 ± 10.70	12.73 ± 14.64	4.70 ± 10.94
Min. ω_{y1} [deg/s]	–50.09 ± 13.11	–38.04 ± 15.81	–30.80 ± 29.11	–24.84 ± 14.70
Max. ω_{y1} [deg/s]	48.91 ± 26.98	51.17 ± 19.89	69.87 ± 42.09	35.73 ± 7.76
SD ω_{y1} [deg/s]	25.08 ± 6.78	25.48 ± 9.44*	23.13 ± 9.38	14.20 ± 3.48
Av. ω_{y2} [deg/s]	–48.64 ± 30.59**	–6.99 ± 20.05	–6.83 ± 12.77	–12.97 ± 17.26
SD ω_{y2} [deg/s]	–130.54 ± 17.20**	–82.08 ± 13.11**	–66.89 ± 29.00	–56.29 ± 13.49
Min. ω_{y2} [deg/s]	31.91 ± 50.61	46.38 ± 13.15	36.34 ± 8.96	21.78 ± 22.72
Max. ω_{y2} [deg/s]	44.33 ± 7.21*	38.96 ± 6.80**	28.25 ± 10.18	20.25 ± 6.31
C [deg^2/s^2]	3897.63 ± 1489**	2945.51 ± 173**	1475 ± 634	1180 ± 881.84

Av. – average angular velocity, Min. – minimum angular velocity, Max. – maximum angular velocity, *SD* – standard deviation, C, ω_{y1} and ω_{y2} – mean sum of squares of signal differences between ω_{y1} and ω_{y2} for the average signal runs
different than in intermediate level group: ** p < 0.01, * p < 0.05

Significant differences were found in the following values of the variables studied: for the angular velocities of rotation of the iliac rim (ω_{y1}), a significant difference was observed in their maximum deviations ($Z = 2.5$; $p < 0.001$; $R = 0.89$) and standard deviations ($Z = 2.8$; $p < 0.001$; $R = 1.0$) for the males. For the angular velocities of rotation of the thoracic segment (ω_{y2}), a significant difference was noted in their minimum values between the groups of males ($Z = –2.80$; $p < 0.001$; $R = 1.000$). As a result of the analysis of covariance, it was found that the maximum angular rotation velocities of the hip girdle in the forward swing movement performed by the males were strongly associated with the judging score obtained ($F_{1,9} = 11.5$; $p < 0.05$; $\eta_p^2 = 0.45$). The standard deviations of the angular rotation velocity of the hip girdle in the men's forward swing movement were also found to be strongly associated with the judging score ($F_{1,9} = 11.5$; $p < 0.001$; $\eta_p^2 = 0.58$). This indicates that the ability of the athletes in the top-level group to perform the swing movement is more developed in the upper body.

The mean changes in velocity of the iliac crest (ω_{y1}) of the study groups showed high similarity ($R = 0.65$). The correlation of the mean changes in velocity of the thoracic spine (ω_{y2}) of the studied groups was $R = 0.96$.

The differences in the mean velocity waveforms with respect to the transverse axis of the first part of the right rotation of the women from both groups were tested. Significant differences were found in the following values of the variables tested; the angular velocities of rotation of the iliac crest (ω_{y1}) and the angular velocity of rotation of the thoracic spine (ω_{y2}) showed significant differences in the maximum values achieved ($Z = –2.8$; $p < 0.001$; $R = 1.0$) and standard deviations ($Z = –2.80$; $p < 0.001$; $R = 1.0$).

Swing action in backward movement of athletes

Table 4 presents the mean values of the studied kinematic variables during the backward swing movement during the first three steps of the natural turn performed by men and women from the top-level and intermediate groups.

Differences in mean velocity waveforms relative to the transverse axis of the second part of the clockwise rotation of the men from both groups were examined. Among the kinematic variables, significant differences were found between the male groups in the mean angular velocities of rotation of the iliac crest (ω_{y1}) (Z = 2.00; $p < 0.05$; $R = 0.72$). In contrast, the mean and minimum velocities of the thoracic segment of the male spine (ω_y2) showed a significant difference between the two groups of athletes studied ($Z = 2.6$; $p < 0.001$; $R = 0.94$). The male groups differed significantly in the standard deviations of the angular rotation velocities ($Z = -2.32$; $p < 0.05$; $R = 0.83$) and in the mean differences of the squares of the angular rotation velocities of the ω_{y1} and ω_{y2} signals ($Z = -2.48$; $p < 0.001$; $R = 0.89$). The hip rim velocity (ω_{y1}) waveforms of the athletes' velocities tested from both groups showed a significant reciprocal correlation ($R = 0.5$). A similar correlation ($R = 0.9$) was observed for the athletes' thoracic spine rotation angular velocity (ω_{y2}).

The women's groups differed significantly in the mean squares of the difference in the angular velocity of rotation in the swing motion of the iliac crest (ω_{y1}) and the thoracic spine segment (ω_{y2}) in the backward motion ($Z = 2.64$; $p < 0.001$; $R = 0.94$).

The characteristics of the mean changes in the angular velocities of rotation of the iliac crest (ω_{y1}) of the female subjects showed a significant correlation (R = 0.59). Changes in thoracic spine velocity values (ω_{y2}) of the female subjects also showed a significant correlation ($R = 0.79$).

Comparison of the performance of the female and male forward swing movement

When comparing the performance of the swing movement during the forward movement of the female and male athletes, significant correlations were detected between the men and women in the intermediate and top-level groups. For the mean angular velocity waveforms of the rotation of the iliac crest (ω_{y1}) of the men and women in the top-level group, the correlation was $R = 0.75$. The intermediate group of athletes showed $R = 0.71$. The thoracic spine velocity waveforms (ω_{y2}) in the men and women correlate with each other in both the top-level group ($R = 0.99$) and the intermediate group ($R = 0.93$).

Significant differences in the top-level group were noted between men and women in the average (Z = –2.32; $p < 0.05$; $R = 0.83$) and minimum ($Z = -2.32$; $p < 0.001$ $R = 0.83$) thoracic spine rotation velocities (ω_{y2}).

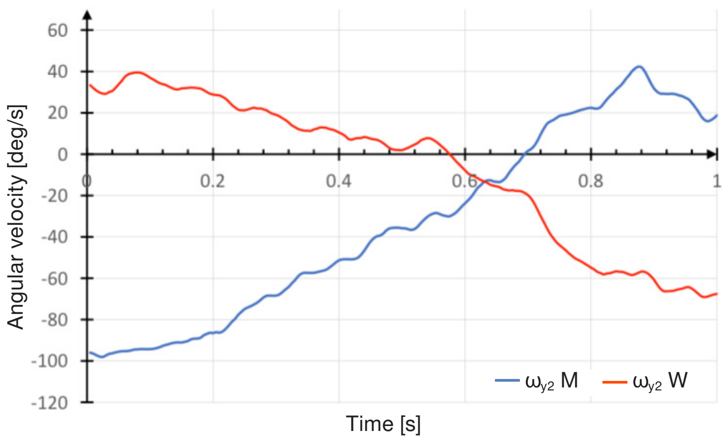
Comparison of execution of swing movement performed by men and women while moving backwards

Significant correlations were noted between the female and male athletes of both groups. A higher correlation in the measured angular velocities of rotation of the iliac crest (ω_{y1}) was noted in the women and men of the intermediate group. The relationship between the mean angular velocity of rotation of the thoracic spine of the men and women (ω_{y2}) among the athletes in the top-level group was $R = 0.977$, and among the athletes in the intermediate group, it was $R = 0.67$.

Comparison of the simultaneous execution of the swing movement (Swing) by women and men

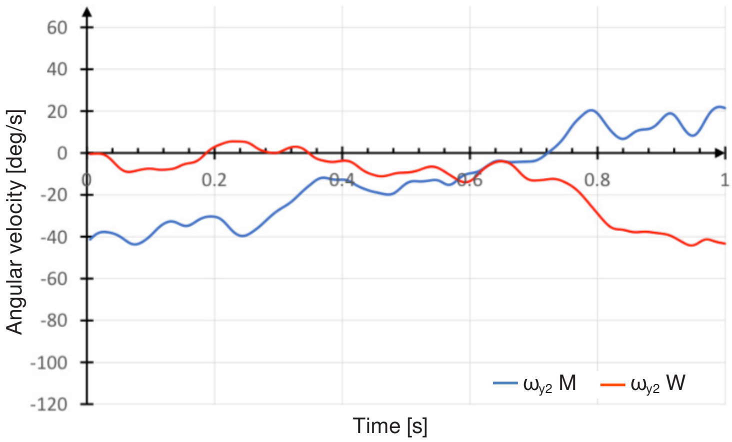
Figures 2 and 3 present the angular velocities of thoracic spine rotation in women (backward movement) and men (forward movement) from the top-level group and the intermediate group in the swing movement during the first three steps of a natural turn.

The mean changes in thoracic spine velocity (ω_{y2}) recorded for the men and women in the top-level group



ω_{y2} W – angular velocity of rotation about the transverse axis of the women thoracic spine
ω_{y2} M – angular velocity of rotation about the transverse axis of the men thoracic spine

Figure 2. Average angular velocity waveforms ω_{y2} during the forward (M) men and backward (W) women swing from the top-level group



ω_{y2} W – angular velocity of rotation relative to the transverse axis of the women thoracic spine
ω_{y2} M – angular velocity of rotation relative to the transverse axis of the men thoracic spine

Figure 3. Average angular velocity waveforms ω_{y2} during the execution of the forward (M) men and backward (W) women swing movements of the intermediate group

have a high Spearman correlation (R = –0.97). Among the athletes of the intermediate level group, the correlation of the same variable was R = –0.762.

Significant differences between the angular velocities of rotation of the iliac crest (ω_{y1}) of the men and women in the top-level group: in maximum (Z = 2.32; p < 0.05; R = 0.83), in average (Z = –2.32; p < 0.001; R = 0.83) and in minimum (ω_{y1}) (Z = 2.16; p < 0.05; R = 0.78) angular velocities of thoracic spine rotation. The curves of thoracic spine angular velocity (ω_{y1}) of women and men correlate with each other in both the top-level group (R = –0.96) and the intermediate dancers group (R = –0.91).

Statistically significant differences in the top-level group were noted between the men and women in the maximum velocities (Z = 2.48; p < 0.001; R = 0.89) and standard deviations (Z = –2.64; p < 0.001; R = 0.94) of the angular velocities of the hip rim rotation (ω_{y1}), in the minimum (Z = –2.48; p < 0.001; R = 0.889) and mean (Z = –2.16; p < 0.06; R = 0.78) angular velocities of thoracic spine rotation (ω_y2), and in the mean squares of signal differences (Z = 2.48; p < 0.001; R = 0.89).

Discussion

It has been pointed out that a clear and in-depth description of the assessment components is the basis for awarding an objective rating [10, 11], although recent global literature also indicates that the swing movement of the world's best couples in standard dances has not been studied in depth [8, 12, 13]. The men from the top-level group achieved higher maximum pelvic rotation angular velocities and minimum thoracic rotation angular velocities than the men from the intermediate group. The maximum angular rotation velocities of the pelvic girdle and standard deviations in the forward swing movement in the men were found to be strongly related to the judging score obtained. The same phenomenon was not found among the women. Between the two groups of women, however, significant differences were observed in the mean waveforms of the second part of the natural turn during their forward movement. In the performance of the swing movement, the same activity is expected from a female and a male [14, 15], however, the values of the kinematic variables indicate that the higher judges' scores were more strongly related to the two values obtained by the males only. The significant difference in standard deviation indicates a large difference in the amplitude of change in angular velocity, particularly in the thoracic spine rotations (ω_{y2}), of the athletes tested. This indicates that the ability to perform the swing movement of the athletes in the top-level group is more developed in the upper body [14, 16].

When comparing the swing movement of the men to the women, similarities were noted in the intermediate and top-level group in the hip girdle and thoracic spine movement. With a greater range of swing movement, the athletes in the top-level group obtained higher correlations in angular rotation velocities relative to the transverse axis than the athletes in the intermediate group. It can be seen that in the characteristics of the changes in the angular rotation velocity of the iliac crest when performing the forward swing movement, the women in the top-level group achieved higher velocities at an earlier stage of the movement than the men in the same group. It was also noted that the groups of athletes differed in the mean and minimum velocities achieved, as well as the standard deviations of the angular velocities of thoracic spine rotation (ω_{y2}) and the mean squared differences of the ω_{y1} and ω_{y2} signals. The athletes in the top-level group achieve significantly higher thoracic spine rotation velocities (ω_{y2}) than the men in the intermediate group. This indicates a stronger forward tilt for the men in the top-level group, which starts as early as the fourth step. In the men of the intermediate group, on the other hand, a noticeable acceleration of the thoracic spine (ω_{y2}) can only be seen in the sixth step. It is worth noting that the changes in angular rotation velocity in the men of the top-level group are smoother than in the men of the intermediate group. The mean velocity changes of the thoracic spine segment (ω_{y2}) between the men in the top-level and intermediate groups are similar (R = 0.91). However, a large difference in the amplitude of the velocity changes of the thoracic spine segment (ω_{y2}) is observed, indicating a more sublime upper body movement technique of the athletes in the top-level group. Based on the results of our own study and the literature data, it can be concluded that the upper body of top-level athletes is also closer to the intermediate athletes in the swing movement [12, 17]. It is interesting to note the observed significant difference of the pelvic girdle swing motion (ω_{y1}) in the standard deviations of the rotation angular velocity only in the intermediate group. Despite similar moments of increase in angular velocity of rotation, the swing movements of the top-level athletes and athletes in the intermediate group are not similar. The average course of angular velocities of rotation of the thoracic spine of the men (ω_{y2}) and women (ω_{y2}) in the athletes of the top-level group stands out with greater similarity (R = 0.98) compared to the athletes of the intermediate group (R = 0.67). This strongly indicates a more coordinated exchange of activity in the execution of the shuttle movement of the athletes in the top-level group and results in a better visual space in the pair. According to the literature, this effect is achieved by more experienced athletes [4, 5]. In the top-level group, significant differences were noted between the men and women in most kinematic variables. It is noteworthy that a significant high negative correlation between the mean waveforms of changes in thoracic spine rotation velocity (ω_{y2}) was noted in both groups in the first and second part of the clockwise rotation. A higher correlation was detected in the top-level group. At the same time, no negative correlation was noted in the swing movement of the iliac spine (ω_{y1}). This clearly indicates that men and women perform an inverted swing movement across the chest throughout the dance. If the male dancer performs a deviation, the female dancer performs a tilt. In addition, it can be seen that the higher speed in the top-level group is characterised by the movement of the person who starts their dance forward, which is in line with the principles of momentum exchange during the dance and the execution of the drive step [8, 20]. A dance performed in this way indicates good leadership in the couple and emphasises the fact that contact in the chest area in the couple is constantly maintained [21]. In the intermediate group, the trend of thoracic spine movement is similar, but it is performed with a much lower amplitude and should be a topic for a separate scope of study. The results obtained can provide a premise for the applied method of analysis of movement technique to also be used in other dance styles, such as Latin American dances.

Conclusions

A strong relationship was found between selected kinematic variables and judges' ratings in swing movement. The mean squares of the differences of the hip and thoracic spine angular rotation velocity signals were found to be a good criterion for evaluating the swing movement, which is related to the judges' evaluation. Most of the theoretical descriptions of the swing action technique are confirmed by the results of this study. However, it is worth mentioning that some of the theoretical explanations in the dance literature are very simplified and not supported scientifically. As a result of the measurements of kinematic variables in top-level couples, new phenomena were observed, so far unrecorded in the literature. The descriptions of the performance of complex rotational movements obtained in this study can find their application in the analysis, teaching, and evaluation of dance couples.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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