Acta of Bioengineering and Biomechanics
Vol. 24, No. 2, 2022

Original paper
DOI: 10.37190/ABB-02047-2022-02

Kinematic evaluation of contrary body movement in sport ballroom dancing

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Purpose: The aim of the study was to analyse the contrary body movement in Viennese waltz performed by dancesport athletes and to determine its relationship on scores awarded by the adjudicators. *Methods*: Six high-level and six intermediate dance couples took part in the study. Each couple performed three identical series of three natural turns figure in the Viennese waltz. All of them were recorded on camera while performing to music. All the trials of each couple were evaluated by 6 international adjudicators as to the technical quality component from the Absolute Judging System. A device for measuring triaxial rotational angular velocities was mounted on the dorsal part of the pelvic girdle and on the back of the chest of each athlete. *Results*: An analysis of covariance revealed that the mean squares of the difference in angular rotation velocity of the pelvic girdle and thoracic spine of the tested dancers were strongly associated with scores given by the adjudicators ($F_{1,9} = 11.5$, $p = 0.0240$, $\eta_p^2 = 0.449$) independently of the assignment to the given group. *Conclusions*: The analysis and comparison of top level and intermediate athletes showed that the suggested method of measurement, presentation and analysis of the profile motion of pelvic girdle and chest motion may become a good tool for a general evaluation of the movement technique as well as a quick and effective qualitative and quantitative biomechanical assessment of selected components of movement technique in dancesport.

Key words: *dancesport, kinematic, dance, technique, ballroom dancing*

1. Introduction

Given the continuous development of the World Federation of DanceSport and its desire to include dancesport among the Olympic disciplines, the improvement of the judging system used to determine the winners in competitions has recently become one of its most important objectives [7], [12], [18]. The World DanceSport Federation does its best to continuously improve its judging methods and systems in attempt at making them more transparent, clearer, and also strives at eliminating any possible ambiguity in the process [8], [20], [31]. The new assessment system and method developed on the basis of the system used in skating appears to be objective. However, the available literature sources indicate that the dance definitions and assessment components and subcomponents included encompassed by it, as well as their scale, require a much more detailed description [19]. Contrary, rolling and swinging movements are the main components of the body action assessment subcomponent, and are considered by experts to be the three fundamental motions that are particularly taken into account in the judging process [13]. The current state of knowledge related to dancesport does not provide answers to questions as to the strict kinematic description of the movement of the best sports dancers in standard style [17], [36]. Kinematic evaluation of selected movements during the dance performed by top-level class competitors using accelerometers may prove its usefulness in teaching dance couples the technique of movement, as well as in quantitative technical evaluation of their dance [3], [10]. Hypothetically, the kinematic description of the best couples could contribute to developing a movement pattern of

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Received: February 28th, 2022
Accepted for publication: May 17th, 2022

a champion and, in the long run, help the adjudicators in an effective and objectified assessment of dance couples. The present study is the first one which proposes a quantitative approach to the description of dance technique. In qualitative terms, the importance of contrary movements has already been hinted at many times by other researchers. Literature sources dedicated to movement technique suggest that in standard dances contrary body movements are considered to be one of the most important movements performed during the dance [15], [24]. The current state of knowledge suggests that the relationship between the technical performance of individual dance actions and the judges' assessment has not yet been investigated. For this reason, the aim of the study was to analyse the contrary body movement in Viennese waltz performed by dance sport couples and to determine its relationship on the marks given by the adjudicators.

2. Materials and methods

2.1. Participants

A total of twelve sport dance couples participated in the study. All respondents were informed about the purpose and method of the study and the possibility of resigning without having to provide reasons at any stage of the study and gave their written consent to participate in the project. The ethical approval for this study was given by the local ethical committee at Józef Piłsudski Academy of Physical Education (SKE 01-13/2022). In order to obtain the movement pattern, six couples from the adult category from the championship group were examined. All competitors in this group hold the highest sport class (international class) and are champions or vice champions of their countries (Lithuania, Poland, Russia, Romania). The surveyed competitors represent the world's top level in standard style. The remaining six polish couples participating in the study were intermediate level who compete at a national level. This group is characterised by an intermediate sport level. All the participants had lack of injury in the last six months. In Table 1, the basic characteristics of the top-level and intermediate groups are shown.

2.2. Accelerometric measurement of kinematic characteristics in natural turn in Viennese waltz

Four three-component accelerometers with a digital recorder were used to measure the angular velocities of the thoracic spine section and the pelvic girdle section of the tested dancers. (ZPP-3D/BC; JBA Zb. Staniak) [29]. Measurements were carried out of the velocity vector component of the angular motion of the pelvic girdle (ω_{x1}) and thoracic spine (ω_{x2}) around the vertical axis. The measuring device was placed on the subjects bya person trained by the producer of the equipment. Calibration of the equipment has been done according to the manufacturer's instructions. The measurement time was 90 seconds for each trial. The sampling rate was 200 Hz. The angular velocities were measured while the dance couples performed a clockwise turn after ten minutes warm up. This is a basic figure from the Viennese waltz called the "natural turn" [27]. All couples in the top-level and intermediate groups performed identical three series of full three natural turns along a straight line in the gymnasium. The sport couples danced to the rhythm of music at a tempo of 60 bars per minute. In addition, each of the three repetitions was recorded with a camera in 4K quality, 30 fps. All the dance couples' rehearsals were assessed by six adjudicators, holding an international judging licence of the WDSF federation. The judges evaluated each of the three competitors' dance repetitions according to the criterion of technical quality on a scale from 1

Table 1. Average values (±SD) of age, body mass, training experience and BMI of competitors from the top-level group and intermediate group

	Top Level Group		Intermediate group	
	Males (n = 6)	Females (n = 6)	Males (n = 6)	Females (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

Different than in intermediate level group: * – $p < 0.05$.

to 10 in accordance with the Absolute Judging System (AJS). Given the fact that the first natural turn is combined with a preparatory movement and the last one with a halting movement, it was decided that only each second natural turn of the tested couple should be taken into account in an analysis of kinematic characteristics of the dance and the judges' assessment. The scheme of the test and the positioning of the judges are shown in Fig. 1.

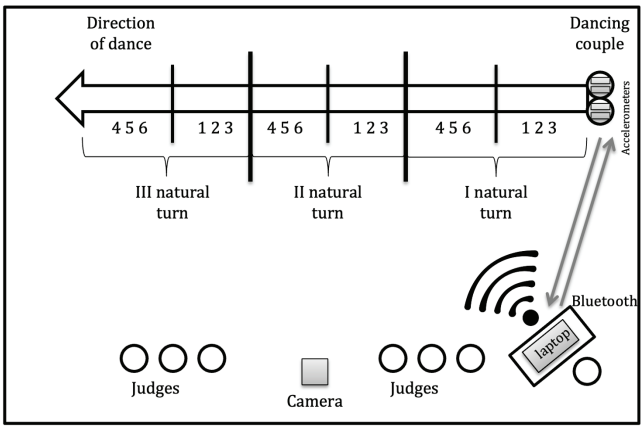

Fig. 1. Schematic of accelerometric measurement of the natural turn kinematic characteristics of the Viennese waltz

2.3. Arrangement of recorders

The triaxial acceleration and triaxial rotation angular velocity recorders were placed in foam stabilisation pads and arranged on the dorsal part of the pelvic girdle (sacroiliac joint) and on the thoracic region (Th5) of the spine of the studied dancers by experienced and trained researcher. Stabilisation pads with accelerometers were fixed with the use of an elastic band (Fig. 2). Equipment calibration was performed after the mounting of the equipment on the tested subjects.

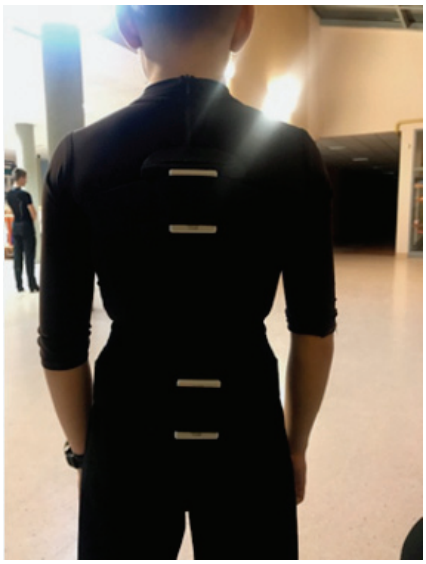

Fig. 2. Mounting of accelerometers on the thoracic spine and dorsal part of the pelvic girdle [own study]

2.4. Statistical analysis

The following variables were distinguished to carry out the analysis: mean difference of squares of angular velocity waveforms ω_{x1} and ω_{x1} (C) in women and men:

$$C = \frac{1}{T}\int_0^T [\omega_{x1}(t) - \omega_{x2}(t)]^2 dt \,,$$

where t – time, T – time of execution of a contrary movement as well as minimum, mean, maximum and standard deviation values of angular rotation velocities in relation to the vertical axis of the pelvic girdle (ω_{x1}) and angular rotation velocities in relation to the vertical axis of the thoracic spine (ω_{x2}). Given the small size of the study group, a decision was made to use the non-parametric Mann–Whitney test to compare the achieved values of the kinematic criteria for assessing the technique of dancers from the top-level and intermediate groups and, as an indicator of the effect size, Glass's biserial correlation coefficient. The dependence of judges' scores on the quantitative predictor studied (accompanying variable) and group membership (champion, intermediate levels) was examined by performing an analysis of covariance (ANCOVA). Selected variables describing dance kinematics were used as accompanying variable. The volume of the effect was appraised using the partial value of eta square (η_p^2). The concordance of the mean courses of angular velocities of dancers from both studied groups was compared using Spearman's rank correlation coefficient. The concordance of the marks awarded by the adjudicators was checked using the Friedman test and Kendall's concordance coefficient. The significance level was set at $\alpha = 0.05$. The statistical analysis was performed using Statistica 13.0.

3. Results

3.1. Scores given by adjudicators

In Table 2, the average scores given by the judges for each couple from both groups are collected.

Table 2. Judges' average scores for the technical quality component from three repetitions for each pair in the top-level (CH) and intermediate (IL) groups

	CH group						IL group					
Mean assessment	9.83	9.46	9.46	9.14	8.79	8.19	3.43	3.17	2.63	3.04	3.18	2.85

The judges agreed that champion level dance couples differed from those in the intermediate level with regards to the technical quality component. The Kendall concordance coefficient of the ratings for both groups combined was K = 0.992 (p = 0.0006). High concordance of the ratings given by the judges was shown in both the top-level group (K = 0.981, p = 0.0117) and the intermediate group (K = 0.975, p = 0.0121).

The champion level group was shown to differ significantly from the intermediate level group in mean ω_{x2} (Z = 2.00, p = 0.0411, R = 0.722) and maximum angular rotation velocities of the thoracic spine segment ω_{x2} (Z = 2.16, p = 0.0260, R = 0.778). It should be emphasised that significant differences have been ascertained between the male groups in the mean sums of squares of the differences in pelvic rotation angular velocity (ω_{x1}) and thoracic spine rotation angular velocity ω_{x2} signals (Z = 2.48, p = 0.0087, R = 0.889). An analysis of covariance revealed that the mean squares of the signal difference were strongly associated with the judging score obtained ($F_{1.9}$ = 11.5, p = 0.0240, η_p^2 = 0.449). In Figures 2 and 3, examples of the mean angular velocity waveforms ω_{x1} and ω_{x2} during the execution of the contrary movement of men from the champion and intermediate level group in the forward step are shown.

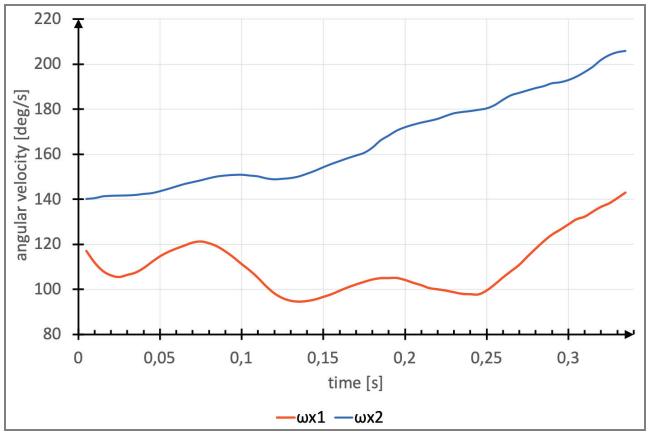

Fig. 3. Mean courses of angular velocity ω_{x1} and ω_{x2} during the execution of contrary movement of men from the championship level group in the forward step: ω_{x1} – angular rotation velocity in relation to the vertical axis of the pelvic girdle, ω_{x2} – angular rotation velocity in relation to the vertical axis of the thoracic spine

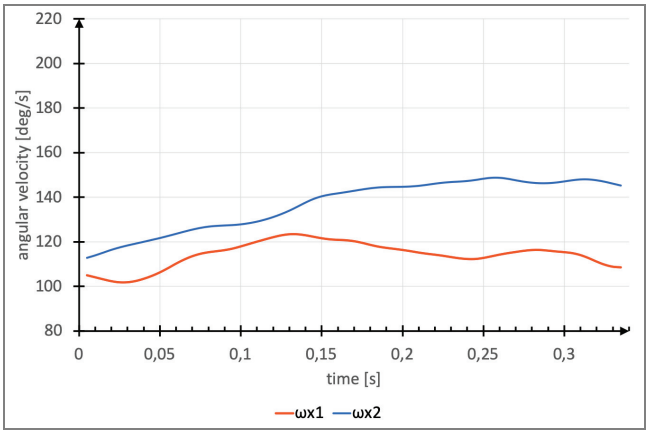

Fig. 4. Mean courses of angular velocity ω_{x1} and ω_{x2} during the performance of contrary movement by men from the intermediate group in step forwards: ω_{x1} – angular rotation velocity in relation to the vertical axis of the pelvic girdle, ω_{x2} – angular rotation velocity in relation to the vertical axis of the thoracic spine

The characteristics of mean changes in ω_{x2} signal velocity in men from the champion and intermediate level groups points to a high correlation (R = 0.939). However, it was found that the maximum angular rotation velocity of the thoracic spine of men in the champion group is reached at the final step. The difference in achieved angular rotation velocity between the first and last signal is higher.

A negative, statistically significant correlation (R = –0.457) was recorded between the courses of angular velocities ω_{x1} in men from both groups: top-level and intermediate dancers. This indicates different technical performance of the contrary movement by the groups of men (Figs. 2 and 3).

3.2. Contrary body movement of women in forward step

Significant differences between groups were observed for the mean sums of squares of the differences in courses (ω_{x1} and ω_{x2}) (Z = 2.48, p = 0.0087, R = 0.889).

It has also been proven that mean squares of the difference of courses of ω_{x1} and ω_{x2} in contrary movement obtained by women from the top-level group are strongly correlated with the awarded score by the judges ($F_{1,9} = 11.5$, $p = 0.0079$, $\eta_p^2 = 0.562$). However, no significant differences were found for the other analysed variables. In Figures 4 and 5, examples of mean values of the angular rotation velocity components (ω_{x1} and ω_{x2}) in the first step of natural turn of women in the champion level group (M) and the intermediate group (S) are presented.

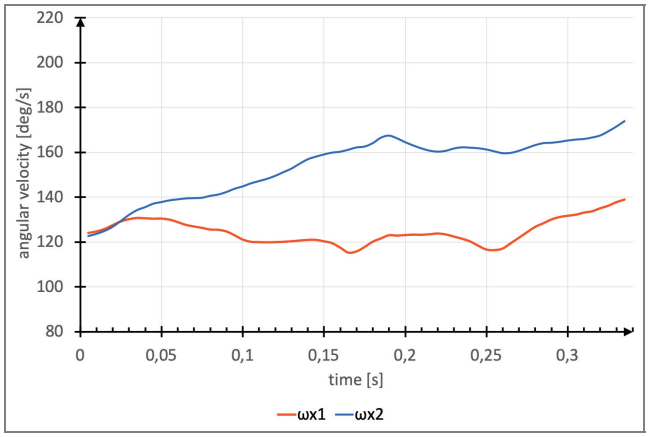

Fig. 5. Illustrative mean courses of angular velocity ω_{x1} and ω_{x2} during contrary movement of women from the top-level group in step forwards: ω_{x1} –angular rotation velocity in relation to the vertical axis of the pelvic girdle, ω_{x2} – angular rotation velocity in relation to the vertical axis of the thoracic spine

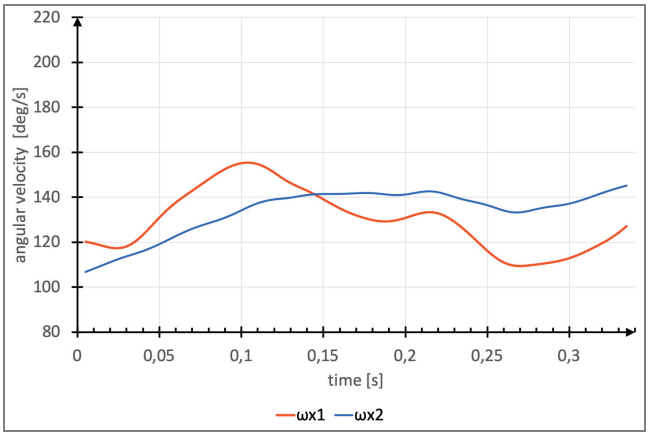

Fig. 6. Illustrative mean courses of angular velocity ω_{x1} and ω_{x2} during contrary movement of women from the intermediate group in step forwards: ω_{x1} – angular rotation velocity in relation to the vertical axis of the pelvic girdle, ω_{x2} – angular rotation velocity in relation to the vertical axis of the thoracic spine

The mean courses of angular velocity ω_{x2} in women from the top-level and intermediate groups were found to show significant similarity and correlate strongly with each other ($R = 0.751$), and the maximum velocity ω_{x2} in women from the top-level group is higher than in women from the intermediate group. The curves of angular velocity ω_{x1} in women from the top-level and intermediate groups are different and correlate negatively ($R = –0.321$) – at times when ω_{x1} reaches higher values for the top-level group, lower values occur for the intermediate group.

3.3. Contrary body movement in backward step in men

Significant differences were ascertained in the minimum velocities of the ω_{x1} signal ($Z = 2.32$; $p = 0.0152$; $R = 0.833$) and the minimum velocities of the ω_{x2} signal ($Z = 2.00$; $p = 0.0411$; $R = 0.722$). The mean angular velocity waveforms ω_{x1} and ω_{x2} in the intermediate group indicated a high statistically significant similarity ($R = 0.707$). Such a significant relationship was not observed among men from the top-level group. The correlation between the studied signals of ω_{x1} and ω_{x2} of men from both groups is low: ($R = 0.287$) for the angular velocity of the pelvic girdle (ω_{x1}) and ($R = 0.291$) for the angular velocity of the thoracic spine (ω_{x2}).

3.4. Contrary body movement of women in backward step

Significant differences were demonstrated for the minimum ($Z = 2.64$, $p = 0.0043$, $R = 0.944$) and mean values of the ω_{x1} signal ($Z = 2.64$, $p = 0.0043$, $R = 0.944$). The mean velocity waveforms of the ω_{x1} and ω_{x2} signals of women in the top-level group exhibited substantial similarity ($R = 0.538$). No other significant relationships were identified between these waveforms in women in the top-level and intermediate groups.

3.5. Comparison of contrary body movement performed by women and men in forward step

A significant correlation was observed between mean angular velocities of the pelvic girdle in men and women (ω_{x1}) from the top-level and intermediate groups. In the top-level group of dancers, the correlation between the waveforms was $R = 0.780$, and in ath-

letes of the intermediate group it equalled to $R = 0.491$. Spearman's correlation between the mean courses of angular velocities of the male and female thoracic spine (ω_{x2}) in dancers from the top-level group was $R = 0.903$. Among the intermediate group dancers, a lower correlation was ascertained ($R = 0.532$). The concordances in the angular velocity waveforms of female and male dancers in the top-level group were found to be higher than in the intermediate level couples, which suggests that male and female dancers in the top-level group perform forward contrary body movements more concordantly than male and female dancers in the intermediate group. No significant differences were observed between women and men in forward movement in both groups.

3.6. Comparison of contrary body movement performed by women and men in backward step

Among the male and female dancers in the championship group, significant differences have been ascertained in the angular rotation velocity of the thoracic spine (ω_{x2}) ($R = 0.581$). On the other hand, no significant similarity was discovered between female and male dancers in the angular rotation velocities of the pelvic girdle (ω_{x1}) in backward step. As regards courses of angular rotation velocities of the thoracic spine (ω_{x2}), no significant differences have been ascertained between men and women in the intermediate group, however, a significant negative correlation was observed between the courses of pelvic rotation velocities (ω_{x1}), which amounted to $R = –0.407$. Angular rotation velocity in relation to the vertical axis of the pelvic girdle of men and women in the intermediate group is characterized by significant differences of mean values ω_{x1} ($Z = 2.16$, $p = 0.0260$, $R = 0.778$) and maximum ones ω_{x1} ($Z = 2.00$, $p = 0.0411$, $R = 0.722$). It was found that, with respect to the vertical axis of the thoracic spine (ω_{x2}), dancers from the intermediate group differed significantly in the achieved mean values ($Z = 2.32$, $p = 0.0152$, $R = 0.833$), minimum ones ($Z = 2.48$, $p = 0.0087$, $R = 0.839$) and maximum ones ($Z = 2.48$, $p = 0.0087$, $R = 0.889$) with respect to angular rotation velocities ω_{x2}. Among female and male dancers in the top-level group, significant differences were ascertained only in the minimum rotation speeds in relation to the axis of the thoracic spine (ω_{x2}) ($Z = 2.00$, $p = 0.0411$, $R = 0.833$). No significant differences have been ascertained in the remaining criteria of the master group. This suggests that women and men in the top-level group perform the contrary body movement in the backward step in a more consistent way than women and men in the intermediate group.

4. Discussion

This paper is one of the first investigations where dance sport technique is scientifically examined. Technical preparation is expressed in the form of mastered specialised movement skills and is fundamental in any sport [11]. Soraka and Sapezinskiene [28] and Xiaoxi [32], emphasise that the economy and effectiveness of a dance technique result from the interaction of many factors. Literature indicates that when considering a particular movement technique, it is necessary to refer to a hypothetical movement pattern [23]. The literature source were found to point out that the aim in the process of long-term training should be to bring the athlete's technique closer to the model of a champion [9]. Therefore, in this study, a kinematic analysis was carried out of angular velocities of selected body points in semi-finalists and finalists of the world championships, taking their movement as a model. The choice of the tested group of top-level group dancers can be considered the most reasonable.

4.1. Contrary body movement of men and women made in forward step

According to literature sources that describe the movement technique in standard dances, contrary body movement is considered one of the most important motions performed during a dance [6], [25]. Competitors in the top-level group received higher scores from judges with respect to the technical quality component. The value of these scores can be confirmed by the obtained results of kinematic variables. Men from the top-level group achieved statistically higher mean and maximum angular rotation velocities of the thoracic spine segment (ω_{x2}) than males dancing in the intermediate group. The correct execution of the contrary movement by dancers from the top-level group is also proven by the significant difference in the mean sum of squares of the differences in signals between the angular rotation velocity of the pelvic girdle (ω_{x1}) and the angular velocity of the thoracic spine segment (ω_{x2}). The contrary body movement of men and women of the top-level group was found to be performed more accurately in contrast to their counter-

parts of the intermediate group. This phenomenon implies that the way the contrary body movement is performed in a dance, especially through the thoracic spine section (ω_{x2}), is an element that has a direct influence on the judges' higher scores. This was also confirmed by the analysis of covariance. The results of our own study confirm the theory of contrary body movement technique given by Sietas et al. [27].

The mean curves of angular rotation velocity of the thoracic spine (ω_{x2}) of men from the top-level and intermediate groups are highly correlated ($R = 0.939$). The high correlation indicates a high similarity of the movement performed by men from both groups. However, the maximum velocity of angular rotation of the thoracic spine (ω_{x2}) is reached by the men of the champion group in the final part of the first step, and the difference in angular rotation velocity between the first and last part of this step is greater. Concurrently, it was also noted that the courses of the angular velocity of the pelvic girdle (ω_{x1}) in men from the champion and intermediate groups showed a significant negative correlation ($R = –0.457$). This indicates that the dancers' pelvic girdle movement is not uniform or even reversed, and that the moment of reaching the maximum angular rotation velocity in relation to the vertical axis is different. Dancers in the top-level group are characterised by a higher degree of motor coordination. This is evident during the performance of a combination of the contrary body movement and the simultaneous transfer of the body weight from the left leg to the right leg when performing the first step in a natural turn. In dancers from the intermediate group, the angular rotation velocities of the thoracic spine (ω_{x2}) were found to be higher, but their movement was characterised by relatively small velocity differences in relation to the angular rotation velocities of the pelvic girdle (ω_{x1}). When analysing the courses of angular rotation velocity of the thoracic segment (ω_{x2}) in groups of women from the champion and intermediate groups, a high correlation ($R = 0.751$) was found between these courses. Despite the similar performance of the contrary movement by women from the champion and intermediate groups, it was noted that the maximum angular velocities of the thoracic segment of the spine of dancers from the champion group were significantly higher than those of women from the intermediate group. An interesting finding was the observed negative significant correlation of the courses of angular velocities of the pelvic girdle (ω_{x1}) in women from the champion and intermediate groups ($R = –0.321$). This phenomenon certainly indicates a completely different performance of the analysed movement and a lower level of technique in women from the intermediate group. The hip movement of the more experienced dancers seems calmer and more coordinated with the movement of the partner.

The measured courses of the angular rotation velocity with respect to the vertical axis of the thoracic spine (ω_{x2}) of women from the championship group prove that these velocities are greater than the velocity of pelvic angular rotation along the vertical axis. This allows the presumption that the contrary movement is performed to a greater extent by the upper body, which is in accordance with the theoretical description of the movement technique from the literature sources [15]. Regarding intermediate dancers, however, a clear deviation from this principle may be observed. During the dance, they reached higher angular velocities in the rotation of the pelvic girdle (ω_{x1}) in relation to the angular rotation velocities of the thoracic spine segment (ω_{x2}). Particularly substantial increases in angular velocity of the pelvic girdle (ω_{x1}) of dancers from the intermediate group were observed in the first part of the performed step. These phenomena may have a significant influence on the ergonomics of the dance movement and the lower scores awarded by the judges for the component of movement technique quality.

Shioya [23] attempted to describe this phenomenon in a theoretical way. A similar approach was presented by Chang [4] and Moore [15]. The aforementioned works base their rationale only on coaching experience and are not studies in which the subjects had acquired a high sport level. The high similarity of the achieved movements among men and women from both groups may be proven by the significant Spearman's correlation observed between the mean course of angular velocities of the pelvic girdle (ω_{x1}) of men and women from both groups. In dancers of the top-level (champion) group, the correlation coefficient was $R = 0.780$, while in dancers of the intermediate group it equalled to $R = 0.491$. The higher correlation coefficient in dancers of the champion group indicates a similar execution of the contrary movement with similar angular speeds of rotation. An interesting phenomenon recorded for the dancers of the intermediate group was that there were moments in which the hip girdle rotation was performed to the left, especially in the initial part of the step. This is probably one of the reasons for the lower correlation coefficient between men and women in this group. A high similarity was observed of the course of angular rotation velocities of the thoracic spine segment (ω_{x2}) of men and women from the champion group while analysing kinematic variables of contrary movements in dancers from both groups. This fact may be con-

firmed by a high correlation (R = 0.903). A lower, but also statistically significant correlation (R = 0.532) was observed in the group of women and men in the intermediate group of dancers. It seems that dancing in pairs does not affect the kinematic parameters achieved by the dancers. In this type of dancing, women and men do not differ significantly in their groups in forward contrary movements. This theory is supported by the results obtained by other authors [2], [22].

4.2. Contrary body movement of women and men performed in backward step

As previously mentioned, in order for a dance couple to successfully execute a natural turn in a Viennese waltz, the contrary movement should be performed in the first and fourth step of the figure during the natural turn. According to guidelines provided by literature, in the backward movement the contrary movement in the dancer's body should be initiated by rotation of the hip girdle and then continued by the upper body [16], [27], [30]. According to Sietas et al. [27], it is expected that in the first step backwards, the angular velocity of the pelvic girdle should be higher than the angular rotation velocity of the thoracic spine. When analysing the measured angular velocities in men moving backwards in the fourth step, it was noted that the angular rotation velocity of the pelvic girdle (ω_{x1}) of athletes in the intermediate group decreases in particular at the end of the fourth step. During the analysis, it was noticed that the angular rotation velocities of the thoracic spine (ω_{x2}) are higher than those of the pelvic girdle. This is not in line with the principle set out in literature [14], [15], [27]. Higher angular velocities of the pelvic girdle can be observed in men of the championship group (ω_{x1}) in the backward motion than the velocity of the thoracic spine, which supports the correct description of the execution of the contrary movement of the body in the backward motion in available literature [21], [27]. The velocity changes in the contrary motion of the pelvic girdle (ω_{x2}) and thoracic spine (ω_{x2}) are similar in male dancers of the intermediate group. This may be proven by the correlation (R = 0.707). A decrease in angular velocity in the final part of the step points to the incorrect execution of the contrary movement. For the champion group, no statistically significant correlation was observed. However, higher velocities achieved by the pelvic girdle (ω_{x1}) of male dancers in relation to velocity of the thoracic spine section confirm the principle of the correct execution of contrary movement described in literature [15], [23], [27]. Statistically significant differences in the minimum pelvic girdle velocities (ω_{x1}) and mean angular velocities ω_{x1} have been ascertained in the performance of the backward contrary movement of women from the top-level and intermediate groups. It can be seen that in female dancers of the top-level group, the angular rotation velocities of the pelvic girdle (ω_{x1}) are higher than the angular rotation velocity of the thoracic spine (ω_{x2}) throughout the first step backwards, similarly to the male dancers of the same group. The performance characteristics of the backward contrary movement of women from the top-level group are as described by dance experts [15], [26], [34]. Furthermore, female dancers in the intermediate group were found to have higher hip rotation speeds (ω_{x1}) at the beginning of the first step, however, in its middle part the rotation speed (ω_{x1}) tends to fall drastically. It seems that a slight decrease in the angular velocity of the thoracic spine segment (ω_{x2}) in the contrary movement in female dancers of the intermediate group is probably the reason for the lower fluency of the dance. The characteristics of mean waveforms of velocity changes of the ω_{x1} and ω_{x2} signals for top-level dancers were found to have a significant similarity (R = 0.538). No other significant correlations were found between top-level and intermediate women. The rotation of the thoracic spine in relation to the vertical axis ω_{x2} in the backward movement of men from both groups is characterised by a significant correlation (R = 0.581). The literature sources do not provide distinguishing between the way in which male and female dancers perform the contrary movement [8]. When assessing the technical quality component, the judges expect the same technical performance from both the male and female dancer [5], [18]. It is, therefore, interesting to note that no significant correlation was observed between the angular velocities of the pelvic girdle (ω_{x1}) during the backward motion of men and women from the top-level group in the waveform characteristics of this signal. It may not be ruled out that this phenomenon could be caused by the greater backward deviation from the vertical axis of the dancers in the top-level group in the starting position or by high-heeled footwear [1]. Meanwhile, the upper body movement of men and women from the intermediate group during backward motion was not found to differ significantly. It turns out that the components of the change in the ω_{x1} signal waveform of the dancers in the intermediate group have a negative correlation (R = –0.407). This probably indicates that the rotation of the pelvic girdle by the dancers could be executed

in a rather chaotic way. One of the most difficult elements in the standard style is to coordinate the movement of two people moving in constant contact [33], [36]. Considering the dance movement of contestants having less sport experience, this problem becomes clearly evident. This may also be further proven by the significant differences ascertained in kinematic variables between men and women in particular groups. Male dancers in the intermediate group differed significantly from women in the same group with respect to the average signal runs obtained ω_{x1}. The angular rotation velocities of the thoracic segment (ω_{x2}) of the achieved mean, minimum and maximum courses were significantly different among dancers in this group. In the top level group, male dancers were found to differ significantly from women only with respect to the minimum angular rotation velocity of the thoracic spine (ω_{x2}). No significant differences were ascertained for the remaining parameters in this group. The above indicates that female and male dancers from the top-level group perform the contrary movement of the body in backward motion more consistently than women and men from the intermediate group.

4.3. Practical implications

The present study may be, therefore, considered as the first empirical analysis dedicated to the actual movements performed by several championship sports couples. It is recommended that while learning the contrary movement during the training cycle, special attention be paid to the correct execution of this movement, taking the above mentioned facts into account.

4.4. Limitations

The limitations of the study mainly concern the accuracy of the measurement of the angular velocity components. There is a possibility that the accelerometers may have moved to some extent. The relatively small size of the study groups allows only large effects to be detected. On the other hand, athletes belonging to the world elite cannot constitute a large group.

5. Conclusions

The study shows that the scores awarded by judges for the quality of movement technique are considerably consistent. The adjudicators of the highest category were unanimous in their assessment of dance couples from the champion and intermediate groups. The group of champion dancers differs from the group of intermediate dancers in terms of criteria of the technical quality component expressed quantitatively and qualitatively by courses of the angular velocity of performed contrary movements. In contrary body movement during backward motion, signal components were found to be similar for males and females in thoracic spine motion. In the top-level group, the similarities are greater than in the intermediate group. It was found that the mean squares of the differences in angular rotation velocity signals of the pelvic girdle and thoracic spine are a useful criterion for adjudicators to use while evaluating contrary body movements. The applied measurement method enables a quantitative description of complex rotational movements and differentiation of movements performed by the pelvic girdle and the thoracic spine of sport dancers. The descriptions of complex rotational movements obtained in this study can be used in the analysis, teaching and evaluation of dance couples.

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