The level of body balance in standing position and handstand in seniors athletes practicing artistic gymnastics

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Purpose: The aim of the study was to compare the values of selected stability indices registered in the trials in standing with eyes open and without visual control, and in handstand in athletes practicing artistic gymnastics at the highest level of advancement. Methods: The study included 20 athletes practicing artistic gymnastics. The research tool was posturograph CQ-Stab 2P. The results obtained in individual trials were compared using Friedman repeated measures analysis of variance by ranks and then subjected to Dunn post-hoc test with Bonferroni adjustment. Results: Statistically significant differences in the values of stability indices recorded in individual samples were found. Exceptions are the results obtained in the trials with eyes open and without visual control with regard to the size of the surface area delineated by the COP (p = 0.173) and the frequency of corrective reactions (p = 0.464), as well as the length of the statokinesiogram path in the mediolateral direction (p = 0.342), mean velocity of COP movement in the mediolateral direction (p = 0.246), maximal amplitude of the COP in the mediolateral direction (p = 0.342) and number of COP displacements in the mediolateral direction (p = 0.246). Conclusions: In seniors, disabling visual control during free standing as well as adopting a handstand position result in deterioration of the stability indices, which is a resultant of the COP displacement in both directions as well as in the anteroposterior direction. Lack of differences in the values of stability indices in the mediolateral direction suggest that in a free standing position, seniors practicing artistic gymnastics control the movement of the center of foot pressure in the mediolateral direction and eye control is not important for the stability of the body in the frontal plane.

Key words: standing position, handstand, stabilometry

1. Introduction

The ability to maintain balance is an important component of coordination affecting the quality of movements in technical and aesthetic disciplines, to which artistic gymnastics belongs. It enables the gymnasts to reduce the risk of sports injury and failures during sports competitions which require performing difficult and dangerous motor tasks repeatedly. Loss of balance or even slight body “imbalance” during static and dynamic exercises affects decisions of the judges’ committees on the reduction of the score, and thus the final evaluation of the competitor [5].

Scientific studies clearly indicate that properly programmed training can be effective for postural and neuromuscular control improvements [28]. Krištofič et al. [16] observed that even a low volume specific balance program performed in addition to regular training sessions may lead to postural stability enhancement. Review of the available scientific literature enables to conclude that in standing position, which is natural for a man, gymnasts obtain similar or significantly better postural control indices in relation to non-exercisers and athletes representing other disciplines. Garcia et al. [8] observed significantly better postural stability indices in 5-to-7-year-old gymnasts with visual control than in their non-exercising peers. In the same studies, both with the eyes open and without visual control, no significant differences were found in the group of older athletes (group of 9–11-year-olds). Kochanowicz et al. [15] divided the gym-
The test inclusion criteria were: competitive artistic gymnastics for at least 10 years, no complaints resulting from injuries to the musculoskeletal system, the ability to keep handstand for 30 seconds [1], dominating right hand and leg (determined on the basis of the Waterloo Handedness and Footedness Questionaire – Revised) [21], written informed consent to participate in the study.

The study was approved by the Bioethics Committee at the Regional Medical Chamber in Krakow, Poland (Approval Ref. No. 42/KBL/OIL/2017).

The tests were carried out the day before the start of the athletes in multi-discipline gymnastic event, as part of the Polish Championships in Sports Gymnastics (Warsaw, Poland, May 2017). The championships were held in accordance with the rules of the International Gymnastic Federation [5]. In order to exclude the impact of sports training fatigue on the results, the

2. Materials and methods

The study included 20 seniors athletes practicing artistic gymnastics in Polish gymnastic clubs (average age: $\bar{x} = 21.10 \pm 3.8$ years). The average training period of the tested athletes was $\bar{x} = 15.25 \pm 3.60$ years. The obtained data show that the average body weight of the studied athletes was $\bar{x} = 68.71 \pm 6.08$ kg and the average body height was $\bar{x} = 173.80 \pm 5.73$ cm.

Selection of the research groups was purposive. The inclusion criteria were: competitive artistic gymnastics for at least 10 years, no complaints resulting from injuries to the musculoskeletal system, the ability to keep handstand for 30 seconds [1], dominating right hand and leg (determined on the basis of the Waterloo Handedness and Footedness Questionaire – Revised) [21], written informed consent to participate in the study.

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The consistency of the values with the normal distribution was verified by means of the Shapiro–Wilk test. The results obtained in individual trials were compared using Friedman repeated measures analysis of variance by ranks and then subjected to Dunn post-hoc test with Bonferroni adjustment. Results were considered statistically significant if the probability level of the test was lower than the predetermined level \( \alpha = 0.05 \). The IBM SPSS Statistics application (version 24) was used to process the test results.

tests were conducted before the training, on a day off from starts. They were preceded by a 15-minute warm-up, after which each of the gymnasts performed two trials of handstand on the mattress.

In order to preserve the integrity of the research process, all the tests were carried out in the morning, using the same measuring instruments, operated by the authors. The measurements were carried out in the gym, in conditions which ensure the isolation of acoustic stimuli that could interfere with postural reflexes during the study. Athletes were wearing gymnastic costumes without shoes. All procedures were carried out in full compliance with the Declaration of Helsinki. All participants received detailed information concerning the aim and method used in the study.

The research tool was two-platform posturograph (manufactured by CQ Electronic System). The test consisted of three 30-second trials. The first attempt was the measurement of the body stability in a relaxed standing position. The platforms were levelled, their surfaces aligned in a single plane. After entering the platform, the subject stood still trying to keep his eyes on the fixation point which was placed 1 meter away. The stance width of the lower limbs and the feet angle were natural, unforced. Subsequently, the second test was conducted, while the subject had his eyes closed (i.e., had no visual control over the positioning of his body). The third trial was carried out in handstand. Before measuring the body stability in this position, the plates of the platform were placed at a distance relevant to the examined person for the sake of protection.

The motion signal, as generated by the point of application of the resultant pressure force exerted by the feet directly onto the platform plates, duly registered in the computer memory, was then used to calculate the values of the stability indicators. The names of the displacement directions of the center of foot/hand pressure (COP) were referred to the Cartesian coordinate system, as made up by the pairs of perpendicular axes. The \( X \) axis was the axis of the abscissae, and the \( Y \) axis – of the ordinate, whereas the point \( O \) (coordinates \( 0.0 \)), i.e., the origin of the system of coordinates was the so-called “geometric center of gravity of the COP trajectory”.

The following indicators of stability were analyzed:

- \( \alpha \) – sway area delimited by the COP point (i.e., the surface area of an irregularly shaped polygon, demarcated by a boundary line connecting up the extreme points of the statokinesiogram) [\( \text{mm}^2 \]);
- \( \text{SP} \) – statokinesiogram path length [\( \text{mm} \)];
- \( \text{SPAP} \) – statokinesiogram path length on the \( Y \) axis (i.e., the trajectory followed by the COP in the anteroposterior direction (AP) during a 30-second measurement) [\( \text{mm} \)];
- \( \text{SPML} \) – statokinesiogram path length on the \( X \) axis (i.e., the trajectory followed by the COP in the mediolateral direction (ML) during a 30-second measurement) [\( \text{mm} \)];
- \( \text{MV} \) – mean velocity of COP movement [\( \text{mm/s} \)];
- \( \text{MVAP} \) – mean velocity of COP movement on the \( Y \) axis (anteroposterior direction) [\( \text{mm/s} \)];
- \( \text{MVML} \) – mean velocity of COP movement on the \( X \) axis (mediolateral direction) [\( \text{mm/s} \)];
- \( \text{MaxAP} \) – range of anteroposterior stability: maximal displacement of the COP from the origin on the \( Y \) axis (i.e., maximal amplitude of the COP in the anteroposterior direction) [\( \text{mm} \)];
- \( \text{MaxML} \) – range of mediolateral stability: maximal displacement of the COP from the origin on the \( X \) axis (i.e., maximal amplitude of the COP in the mediolateral direction) [\( \text{mm} \)];
- \( \text{MF} \) – mean frequency of COP displacement (i.e., the ratio of the total statokinesiogram’s path length [on both axes] to the circumference of the circle the radius of which is equal to the average COP displacement, calculated per 1 second) [\( \text{Hz} \)];
- \( \text{LWAP} \) – number of COP displacements along the \( Y \) axis (i.e., number of COP displacements in the anteroposterior direction, within the range: over 0.2 mm – below – 0.2 mm, relative to the center of the coordinate system);
- \( \text{LWLML} \) – number of COP displacements along the \( X \) axis (i.e., number of COP displacements in the mediolateral direction, within the range: over 0.2 mm – below – 0.2 mm, relative to the center of the coordinate system).

Examples of the path length for the COP are comprised in Figs. 1–3.

The following indicators of stability were analyzed:

- \( \text{SA} \) – sway area delimited by the COP point (i.e., the surface area of an irregularly shaped polygon, de-
Fig. 1. Diagram showing the sample of the path length for the COP during the test in standing position with eyes open.

Fig. 2. Diagram showing the sample of the path length for the COP during the test in standing position with eyes closed.
3. Results

The data presented in Table 1 indicate a statistically significant variation in the values of stability indices recorded in individual samples. A more detailed analysis with the post-hoc test revealed that the exceptions were the results obtained in the trials with eyes open and without visual control with regard to the size of the surface area delineated by the COP \((p = 0.173)\) and the frequency of corrective reactions \((p = 0.464)\), as well as the length of the statokinesiogram path.

In the mediolateral direction \((p = 0.342)\), mean velocity of COP movement in the mediolateral direction \((p = 0.246)\), maximal amplitude of the COP in the mediolateral direction \((p = 0.342)\) and number of COP displacements in the mediolateral direction \((p = 0.246)\).

4. Discussion

Own research showed statistically significant differences in the values of such indices as: statokinesiogram path length, statokinesiogram path length in the anteroposterior direction, mean velocity of COP movement, mean velocity of COP movement in the anteroposterior direction, number of COP displacements in the anteroposterior direction – recorded during the trials in standing with open and closed eyes. These results indicate the important role of eye control in the process of maintaining stability under static equilibrium conditions. It can be assumed that this is the effect of the need to use information from the visual receptors during the performance of physical tasks in gymnastic training, in order to better orientate in space, especially when performing complex evolutions and elements containing the flight phase. Visual inspection helps to perform the correct landing, which ends with adoption of a stable posture on both lower limbs. Lee et al. [17] reached similar conclusions analyzing the results of research on the postural stability of trampolinists performing forward somersaults. According to the authors, vision improves precision of control. In turn, Davlin et al. [6] based on the analysis of stability indices in female gymnasts, concluded that gymnasts were more stable at landing under conditions that allowed vision during either the entire somersault or the last half of the somersault.

In the Luis and Tremblay [18] study participated
the experienced female acrobats performed back tucksomersaults under four experimental conditions: full-vision, vision at angular head velocity below 350 deg/s, vision at angular head velocity above 350 deg/s, and no-vision. The authors stated that presence of visual feedback during all phases of an aerial skill is beneficial for landing stability. Asseman et al. [2], Garcia et al. [8], Kochanowicz et al. [15] and Kristofič et al. [16] arrived at similar conclusions. The results of our research and reports of other authors indicate that visual information improves the balance reactions, which certainly translates into athletic perform-

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Standing position with eyes open (EO)</th>
<th>Standing position with eyes closed (EC)</th>
<th>Handstand (hand)</th>
<th>$\chi^2$</th>
<th>$p$</th>
<th>$W$</th>
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<tr>
<td>SA [mm$^2$]</td>
<td>$149.95 \pm 118.87$ $111.50$</td>
<td>$229.40 \pm 165.64$ $186.00$</td>
<td>$2621.55 \pm 1159.18$</td>
<td>$2390.50$</td>
<td>$33.60$</td>
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<td>SA-EO vs. SA-EC ($p = 0.173$); SA-EO vs. SA-hand ($p &lt; 0.001*$); SA-EC vs. SA-hand ($p &lt; 0.001*$)</td>
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<td>SP [mm]</td>
<td>$219.80 \pm 43.71$ $198.00$</td>
<td>$319.70 \pm 115.19$ $289.00$</td>
<td>$1518.20 \pm 352.85$</td>
<td>$1472.00$</td>
<td>$38.10$</td>
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<td>SP-EO vs. SP-EC ($p = 0.013*$); SP-EO vs. SP-hand ($p &lt; 0.001*$); SP-EC vs. SP-hand ($p = 0.003*$)</td>
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<td>SPAP [mm]</td>
<td>$138.15 \pm 37.38$ $124.00$</td>
<td>$241.45 \pm 114.74$ $190.00$</td>
<td>$1270.55 \pm 353.09$</td>
<td>$1211.00$</td>
<td>$40.00$</td>
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<td>MV [mm/s]</td>
<td>$7.33 \pm 1.46$ $6.60$</td>
<td>$10.65 \pm 3.84$ $9.60$</td>
<td>$50.61 \pm 11.76$</td>
<td>$49.05$</td>
<td>$38.10$</td>
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<td>Post-hoc</td>
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<tr>
<td>MVAP [mm/s]</td>
<td>$4.61 \pm 1.25$ $4.10$</td>
<td>$8.05 \pm 3.83$ $6.30$</td>
<td>$42.36 \pm 11.77$</td>
<td>$40.35$</td>
<td>$40.00$</td>
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<td>MVML [mm/s]</td>
<td>$4.70 \pm 0.77$ $4.50$</td>
<td>$5.26 \pm 0.97$ $5.20$</td>
<td>$19.55 \pm 5.16$</td>
<td>$18.70$</td>
<td>$33.44$</td>
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<td>MaxAP [mm]</td>
<td>$5.51 \pm 2.96$ $4.30$</td>
<td>$9.72 \pm 6.84$ $7.70$</td>
<td>$23.29 \pm 6.09$</td>
<td>$22.35$</td>
<td>$30.70$</td>
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<td>MaxML [mm]</td>
<td>$2.89 \pm 1.38$ $2.3$</td>
<td>$3.42 \pm 1.19$ $3.50$</td>
<td>$10.32 \pm 5.00$</td>
<td>$9.25$</td>
<td>$26.80$</td>
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<td>Post-hoc</td>
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<tr>
<td>MF [Hz]</td>
<td>$0.69 \pm 0.26$ $0.72$</td>
<td>$0.76 \pm 0.27$ $0.78$</td>
<td>$1.22 \pm 0.25$</td>
<td>$1.20$</td>
<td>$23.70$</td>
<td>$&lt;0.001* $</td>
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<tr>
<td>LWAP</td>
<td>$12.55 \pm 6.00$ $11.50$</td>
<td>$23.85 \pm 10.33$ $24.00$</td>
<td>$63.70 \pm 18.47$</td>
<td>$65.50$</td>
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<td>LWML</td>
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<td>LWML-EO vs. LWML-EC ($p = 0.246$); LWML-EO vs. LWML-hand ($p &lt; 0.001*$); LWML-EC vs. LWML-hand ($p &lt; 0.001*$)</td>
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**Table 1. Comparison of the values of stability indices obtained in standing position with eyes open, standing position with eyes closed and handstand.**

**Abbreviations:** SA – sway area delimited by the COP point; SP – statokinesiogram path length; SPAP – statokinesiogram path length in the anteroposterior direction; SPML – statokinesiogram path length in the mediolateral direction; MV – mean velocity of COP movement; MVAP – mean velocity of COP movement in the anteroposterior direction; MVML – mean velocity of COP movement in the mediolateral direction; MaxAP – maximal displacement of the COP from the origin; MaxML – maximal displacement of the COP from the origin in the anteroposterior direction; Me – Median; $\chi^2$ – value of the Friedman’s test statistic; $p$ – probability value; $W$ – Kendall’s tau.

* $\alpha = 0.05$. 

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5. Conclusions

In practicing artistic gymnastics disabling visual control during free standing, as well as adopting a handstand position, results in deterioration of the stability indices which is a resultant of the COP displacement in both directions, as well as in the anteroposterior direction.

Lack of differences in the values of stability indices in the mediolateral direction suggest that in a free standing position, seniors practicing artistic gymnastics control the movement of the center of foot pressure in the mediolateral direction and eye control is not important for the stability of the body in the frontal plane.

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