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POSTURAL CONTROL IN FEMALE RHYTHMIC GYMNASTS IN SELECTED BALANCE EXERCISES: A STUDY OF TWO CASES

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Abstract

Introduction. The aim of the study was to determine the differences in the quality of postural control between two female rhythmic gymnasts with different training experience during the performance of balance exercises. In rhythmic gymnastics, the same balance exercises are performed by novice and elite gymnasts. Balance exercises involving standing on the toes of one leg with the free leg raised in different positions are considered to be extreme forms of exercise in terms of the postural balance abilities required. In coaching practice, it is important to have tools which facilitate the objective assessment of the process of maintaining balance in such exercises. ***Material and methods.*** The study involved two female rhythmic gymnasts: a younger one (age = 8 years and training experience = 4 years) and an older one (age = 21 years and training experience = 14 years). The athletes performed three balance exercises standing on a Kistler platform: the split with hand support (lateral balance), the ring with hand support, and the back split without hand support (balance on the whole foot). The parameters describing the quality of postural control used in the current analysis were the range and velocity of COP displacements in the anterior-posterior and medial-lateral directions. ***Results.*** Postural control in the balance exercises in the younger rhythmic gymnast was characterised by almost two times greater COP displacements in the anterior-posterior direction and more rapid than that of the older gymnast. COP displacements in the medial-lateral direction in all the exercises described did not differentiate the subjects. In the back split without hand support, the older athlete showed greater variability of postural control with smaller COP displacement and velocity than the younger gymnast. ***Conclusion.*** Gymnastics training should include exercises strengthening the muscles acting on the ankle and hip joints, which could improve the stability of these joints during the performance of difficult balance exercises. Improving the stabilising function of these muscles helps to minimise anterior-posterior movements in these joints.

Key words: single-leg stance, COP trajectory, training experience

Introduction

In rhythmic gymnastics, postural control is trained daily. The determinants of effective training in this sports discipline were investigated by Bobo-Arce and Mendez-Rial [1], according to whom an important component of this process is the development of postural control abilities during the performance of single-leg exercises, which may be carried out on the whole foot or on the toes (in relevé). Most exercises in rhythmic gymnastics require an above-average ability to maintain balance while standing on a very small support surface; what causes additional difficulty is that the gymnast is required to keep the free leg in different demanding positions and move the apparatus [2]. Since the beginning of their sport training, which starts at the age of 5-6 years and takes from 2 to 3 hours a day, rhythmic gymnasts learn how to perform gymnastics exercises, most of which require improving the ability to maintain a vertical position of the body [3, 4]. Balance exercises in which gymnasts stand on the toes of one leg with the other leg raised in a split and held with the hand in the head area, which are characteristic for rhythmic gymnastics, can be considered an extreme form of postural balance tasks. This position of the raised leg causes additional lateral movements in the hip joint of the supporting leg, which are significantly limited in double-leg positions [5].

In rhythmic gymnastics, the greatest technical value is attributed to balances which are performed in relevé [2]. The condition for maintaining balance on such a small support area is minimising the movements of all body segments in such a way that the vertical projection of the centre of mass (COM) falls within the surface of the sole of the foot of the supporting leg (which is a general prerequisite for maintaining a vertical position) [6]. The gymnast must block all degrees of freedom in the musculoskeletal system in order to maintain balance on such a small support surface. In these positions, stabilisation of the ankle joint, which is regulated by the m. gastrocnemius, is particularly important [7, 8].

Many balance exercises are performed in routines with apparatuses both by gymnasts starting their sporting careers and elite gymnasts. Gautier et al. [9] have found that gymnastics training activates specific adaptive abilities, which may manifest themselves in better postural control in difficult vertical positions of the body [10, 11].

One parameter describing the quality of postural control is the range of centre of pressure (COP) displacement. The values of this parameter in the anterior-posterior and medial-lateral

directions are indicative of the magnitude of postural sway in the frontal and sagittal planes. Lower values of COP displacement ranges are evidence of better postural control during the execution of a given balance position [12, 13]. COP displacement velocity, on the other hand, reflects the efficiency of the nervous system in regulating the reaction of the musculoskeletal system to momentary imbalances. Lower average velocity of COP displacement indicates better postural control [14].

We believe that in coaching practice, it is important to have tools that make it possible to objectively assess the process of maintaining balance in balance exercises. Therefore, the aim of this study was to determine the difference in the quality of postural control between two female rhythmic gymnasts with significantly different training experience. The investigation of possible differences between the two athletes could have implications for training, especially at its the initial stage, as it could help avoid excessive strain on the muscles and joints of the young gymnast's supporting leg during the performance of balance exercises.

Material and methods

Subjects

The study involved two rhythmic gymnasts: a younger gymnast (age = 8 years, height = 1.35 m, weight = 29 kg, and BMI = 16) with 4 years of training experience (gymnast A), who had the so-called third class (that is the fifth top class) in the sport discipline in the Polish system, and an older one (age = 21 years, height = 1.67 m, weight = 61.5 kg, and BMI = 22) with 14 years of training experience (gymnast B), who had the national championship class (second top class).

The older athlete consented to take part in the research whereas in the case of the younger athlete, consent was given by the parents. The non-invasive postural balance study was approved by the Research Ethics Committee of the University School of Physical Education in Wroclaw.

Measurement procedure

The tests were carried out in the Laboratory of Biomechanical Analysis (ISO Quality Certificate No. 1374-b/3/2009, PN-EN ISO9001:2009). The research apparatus was the Kistler 9286AA platform (600 × 400 mm), which was mounted on the floor. In order for the measurement to take place on a similar surface as the one on which gymnasts practise, the measuring platform was covered with a piece of carpet used in gymnastics training. The athletes stood of the force plate and performed the following three balance exercises, which are shown in Figure 1: (a) the split with hand support (lateral balance), (b) the ring with hand support, and (c) the back split without support (balance on the whole foot).

Both athletes performed three repetitions of the each balance exercise in the same order.

We determined the displacement of the point of application of the resultant ground reaction force as a function of time

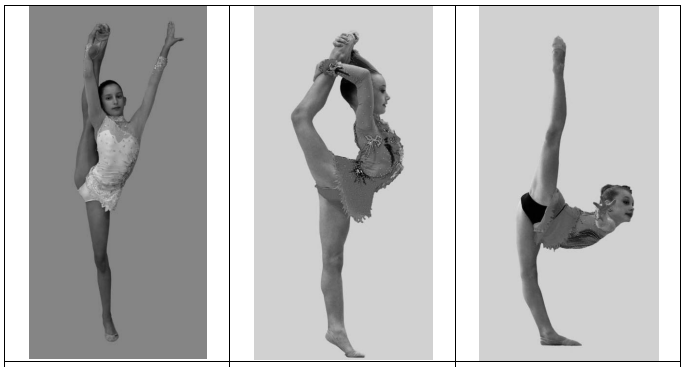

Figure 1. Balance exercises performed by the gymnasts

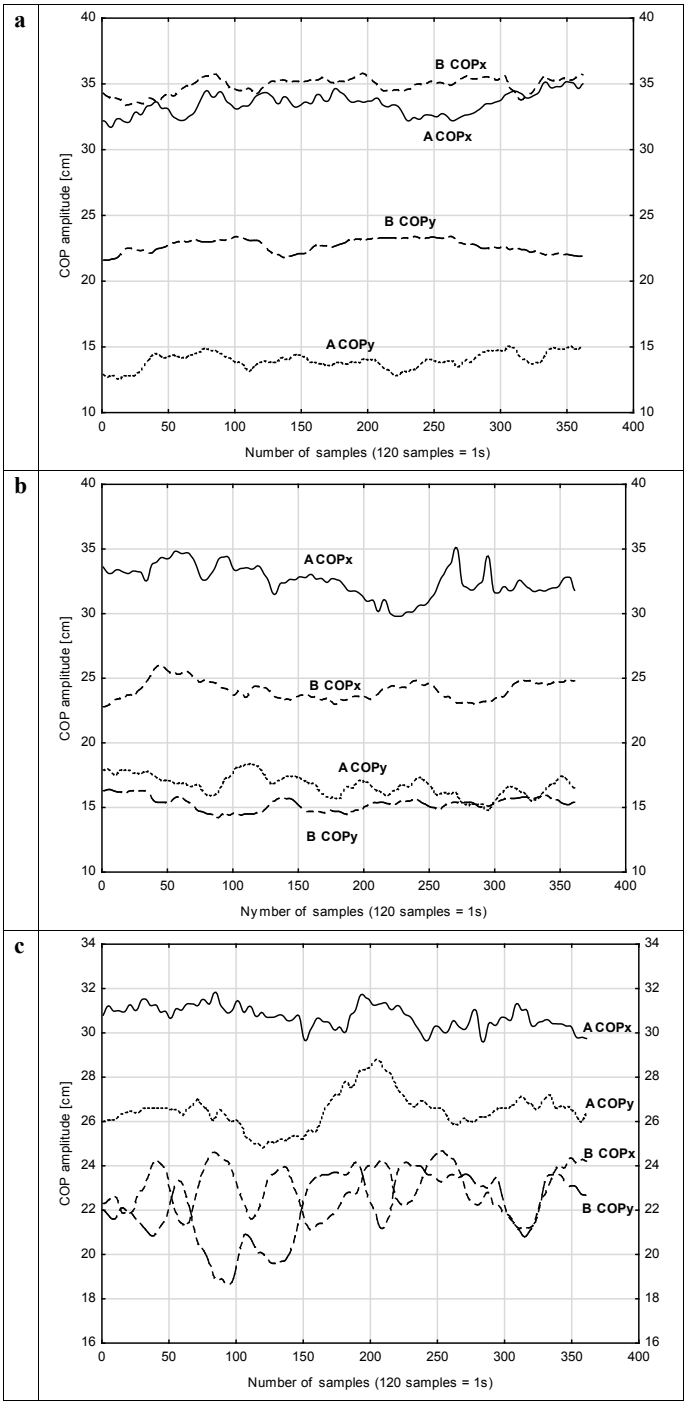

Figure 2. COP displacement path in the medial-lateral (COP_X) and anterior-posterior (COP_Y) directions in the best trial (a – side split with hand support, b – ring with hand support, c – back split without hand support; A – younger gymnast, B – older gymnast)

measured with a sampling frequency of 120 Hz (Fig. 2). A 3-second segment of the recording of the COP trajectories was used in the calculations. The 3-second recording started from the moment a given balance position was stabilised.

On the basis of the COP trajectory, the following postural balance parameters were calculated:

- COP_X [cm] – COP amplitude in the medial-lateral direction;
- COP_Y [cm] – COP amplitude in the anterior-posterior direction;
- V COP [cm/s] – mean COP displacement velocity.

The COP displacement recorded during the measurement was used to calculate the mean value of COP displacements in two directions of motion and the average COP velocity from 360 samples (120 Hz x 3 s).

Results

The values of the postural balance parameters for the two athletes in particular balance positions are presented in Table 1.

Table 1. Mean values of postural control parameters in the best trials for the three balance positions in the two female rhythmic gymnasts (coefficients of variation [%] are given in brackets)

	Gymnast	
	Younger (A)	**Older (B)**
Split with hand support (a)		
COP_X [cm]	3.23 ± 0.64 (20%)	3.47 ± 0.94 (27%)
COP_Y [cm]	2.52 ± 0.53 (21%)	2.65 ± 0.28 (11%)
V COP [cm/s]	18.77 ± 0.62 (3%)	10.94 ± 0.25 (2%)
Ring with hand support (b)		
COP_X [cm]	4.45 ± 2.04 (46%)	4.01 ± 0.92 (23%)
COP_Y [cm]	3.65 ± 0.54 (15%)	2.00 ± 0.18 (9%)
V COP [cm/s]	20.38 ± 2.19 (11%)	10.53 ± 0.17 (2%)
Back split without hand support (c)		
COP_X [cm]	4.14 ± 1.22 (29%)	4.60 ± 0.56 (12%)
COP_Y [cm]	11.31 ± 0.94 (8%)	4.85 ± 0.77 (16%)
V COP [cm/s]	21.51 ± 1.24 (6%)	16.46 ± 1.79 (11%)

In the split with hand support lateral balance position (Fig. 1a, Tab. 1), the two athletes had very similar values of the amplitude of COP displacement, both in the medial-lateral (COP_X) and anterior-posterior (COP_Y) directions. In this exercise, the only difference between the two gymnasts was the value of the COP velocity parameter; the younger one (A) had a significantly higher COP displacement velocity than the older one (B). The coefficients of variation of these three parameters in lateral balance were similar in both subjects; only in the case of anterior-posterior COP amplitude did the results of the younger gymnast show almost twice as much variability than those of the older one.

In the second exercise, that is the ring with hand support (Fig. 1b, Tab. 1), the gymnasts performed similarly only in terms of the magnitude of the COP amplitude in the medial-lateral direction (COP_X). The amplitude value was similar, but the coefficient of variation was found to be twice as high in the younger gymnast as in the older one. Similar differences were observed for the amplitude of COP displacement in the anterior-posterior direction. The coefficient of variation of the COP_Y amplitude was also significantly higher for the younger gymnast compared to the older one. The younger gymnast had twice as high COP displacement velocity as the older one, and the coefficient of variation of this parameter was more than 5 times higher for the former athlete.

The results for the third exercise (Fig. 1c, Tab. 1) were somewhat different than those for the two previous ones. Although the amplitude of COP displacement in the medial-lateral direction did not differ significantly between subjects, the coefficient of variation in the younger one was more than two times higher than in the older one. In the case of the amplitude of COP displacement in the anterior-posterior direction, the mean value of this parameter was twice as high in the younger subject compared to the older one. On the other hand, the coefficient of variation was twice as high in the older gymnast as in the younger gymnast (Tab. 1). Similar results were recorded for the velocity of COP displacement. The older gymnast shifted the COP more slowly than the younger one, but with significantly greater variability (Fig. 2, Tab. 1).

Discussion

What differentiated the two gymnasts except for their training experience and age was their weight, height, and BMI index. One of the reasons why persons with higher body weight are considered to have smaller amplitudes of COP displacements is their higher moment of body inertia compared to that of persons with lower body weight [10]. Such conclusions, however, have been drawn in research involving overweight and obese persons and not rhythmic gymnasts, who, as a rule, are very thin. Nascimento et al. [15], who compared postural control in single-leg stance in persons with obesity and normal weight and a height of 1.68 m, found that body weight did not have an impact on the quality of postural control in this stance in persons of very similar height. Although Ku et al. [16] demonstrated that in young adults, BMI had a significant effect on postural control in overweight and obese persons, both in single- and double-leg stances, they did not find such a difference in the case of subjects with underweight or normal weight. Błaszczyk et al. [10] presented the results of posturographic tests evaluating the surface area, range, and length of the COP path in overweight and obese subjects and found that the values were smaller in overweight and obese persons than in the control group; thus, the former stood in a more stable way than those with normal weight and BMI.

To summarise, based the results of the studies mentioned above, it can be concluded that body weight and BMI are important factors in the quality of postural control and that persons with higher weight and BMI have more stability than those with lower weight and BMI, but these results refer to people with high body weight and BMI in relation to normal values. The rhythmic gymnasts who participated in the current study, however, are a different case. According to WHO standards, the younger athlete qualified as underweight with a BMI of 16, and the older athlete had normal body weight with a BMI of 22. The results of ballet dancers and the control group in Błaszczyk et al.'s study showed that the specific postural control training used in ballet was the reason for higher postural sway in this group compared to non-dancers of similar height and age [10].

COP displacement in the medial-lateral direction (COP_X) in all three balance exercises did not clearly differentiate the two gymnasts, which would indicate that the lateral movements of the foot in the ankle joint and those in the hip joint of the supporting leg were performed in a similar range by the gymnasts, regardless of their level of expertise. Coaching practice shows

that minimising lateral movements in these two joints is crucial for maintaining any balance position involving standing on one leg, both performed in relevé and on the whole foot. According to Rutkowska-Kucharska et al. [13], balance exercises in relevé should be limited in children, because the activity required from the m. gastrocnemius when performing this exercise considerably exceeds its natural maximum activity during standing on the toes of one lower leg at this age. The current analysis showed that, regardless of training experience, the stability of maintaining a stable sing-leg standing position required controlling the lateral movements of the body.

The magnitude of the range of COP displacement in the anterior-posterior direction did not differentiate the gymnasts in the lateral balance position (the easiest position in their view), but in the other two positions, gymnast A had almost twice as large a value of this parameter as gymnast B. Lateral balances in the relevé position (Fig. 1a) are basic rhythmic gymnastics exercises, which even the youngest gymnasts perform many times during each training. This is a probable reason why there was no difference between athletes A and B in the magnitude of COP displacement in the two movement directions (Tab. 1). The relatively high coefficient of variation of this parameter, especially in the younger athlete, may be seen as evidence that she was more unstable when performing the postural control task in this position, which was not found for the older athlete.

In the ring with hand support exercise (Fig. 1b), there was a significant difference between the gymnasts in the magnitude of COP range in the anterior-posterior direction (COP_Y), and the younger one had almost twice as great a range of COP displacement in this direction as the older one. The coefficient of variation was also higher in the younger athlete than in the older one, which indicates greater anterior-posterior postural sway during this exercise in athlete A than in athlete B. This exercise is also performed by most gymnasts regardless of their level of expertise, but – as the trunk is bent in the sagittal plane, inclined forwards, and arched backwards – it requires specific stabilisation of the supporting leg and adequate positioning of the hip joint of this leg to counterbalance the unnatural position of the trunk and of the free leg, which is kept in a vertical position behind the head. The older athlete, who had more expertise, was better able to cope with this task, having an almost twice as small COP displacement range in the foot of the supporting leg in the anterior-posterior direction as the younger gymnast. A similar regularity was noted for COP velocity, which was twice as high in the younger athlete as in the older one in this exercise. As stated by Garcia et al. [17], the lower value of COP velocity in a given position is evidence of better postural control. Their study showed that lower average velocity of lateral COP displacements was characteristic for young rhythmic gymnasts in comparison with their untrained peers, who were found to have a higher velocity of COP displacement in a natural standing position. The coefficients of variation of the balance parameters described in this study in the second exercise (Fig. 1b), which were lower in the older gymnast than in the younger one, confirm a smaller dispersion of the results and thus better postural control in the older athlete than in the younger one in this position.

The third balance position (Fig. 1c) is the most difficult of the ones described in the paper, which is reflected in the judging rules. The results for the back split without hand support show a difference in the skill level of the two athletes. This exercise requires much more activation of all muscles because in this one-leg stance with the free leg positioned vertically in a split, the trunk must be bent forward as close to the horizontal direction as possible. As argued by Asseman et al. [14], individual body movement or muscle strength regulation aimed at maintaining the balance of the body is specific for a characteristic task. Standing in such a position, even on the whole foot of the supporting leg, requires minimising all movements in the ankle and hip joints, and the positioning of the remaining body segments does not make this easier. The magnitude of COP amplitude in the anterior-posterior direction and COP velocity was greater in the younger gymnast than in the older one, but the variability of these two parameters in the older one was significantly greater than in the younger one. It seems that in this difficult back split position, the older gymnast was able to minimise movements in the joints of the body, but she did it with more variability than the younger gymnast, which in this case may be a sign of better postural control. Caron et al. [18] and Błaszczyk et al. [10] found that ballet dancers had higher values of COP amplitude and longer path lengths of COP displacement than the control groups during maximal voluntary forward leaning of the body in a double-leg stance. The length of the COP path may be related to COP velocity as the path and velocity of the COP displacements carry the same information. Such conclusions can be reached when analysing the results of a postural control study conducted on snowboarders [19]. The authors of that study compared the COP path length in samples of the same duration. The results for the balance tasks with eyes open and closed showed that the COP path was significantly longer in the more difficult task of controlling postural balance without visual stimuli both in the group of novice and more advanced athletes; a longer COP path for the same duration of the test indicated higher COP displacement velocity was higher in the closed-eyes test [19]. This means that difficulty in postural control, and thus its deterioration, manifests itself in increased length of the COP path and increased velocity of COP displacement. As claimed by Błaszczyk et al. [10], the ballet dancers in their study, despite having increased postural sway (COP amplitude values), had a significantly increased dynamic stability margin and greater COP variability compared to the control group of non-dancers. It can therefore be concluded that greater experience in postural control in difficult balance positions is manifested in greater variability in the performance of the task due to a greater margin of safety when maintaining balance, which was found for the gymnast with more experience in our study in the back split position.

Conclusion

In the easier balance exercises described above, the postural control of the younger female rhythmic gymnast was characterised by almost two times greater and more rapid displacement of the COP of the foot of the supporting leg than was the case for the gymnast with more training experience. However, this did not apply to medial-lateral COP displacements. Variability in the performance of the balance tasks was generally twice as high in the younger subject as in the older one.

However, in the back split without hand support, the more experienced gymnast showed greater variability of postural control with less COP displacement than the less experienced gymnast, which would mean she was more flexible in controlling the balance of her body compared to the younger athlete.

Rhythmic gymnastics training should include exercises strengthening the muscles acting on the ankle and hip joints, which could improve the stability of these joints during the performance of difficult balance exercises. Improving the stabilising function of these muscles helps to minimise anterior-posterior movements in these joints.

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