

# COMPARATIVE ANALYSIS OF ONE-FOOT BALANCE IN RHYTHMIC GYMNASTICS ATHLETES



Leonardo Shigaki<sup>1</sup>  
Lucas Maciel Rabello<sup>2,3</sup>  
Mariana Zingari Camargo<sup>1</sup>  
Vanessa Batista da Costa Santos<sup>1</sup>  
André Wilson de Oliveira Gil<sup>2</sup>  
Márcio Rogério de Oliveira<sup>2</sup>  
Rubens Alexandre da Silva Junior<sup>2,3</sup>  
Christiane de Souza Guerino Macedo<sup>1</sup>

1. State University of Londrina.  
Physiotherapy and Quality of Life in  
Sports Research Group – CNPQ –  
Londrina, PR, Brazil.  
2. Research Group in Health Sciences,  
Laboratory of Functional and Human  
Motor Performance Assessment –  
Northern Paraná University (UNOPAR) –  
Londrina, PR, Brazil.  
3. Master's Program in Rehabilitation  
Sciences UEL/UNOPAR – Londrina, PR, Brazil.

## Mailing address:

Christiane de S. Guerino Macedo  
Centro de Ciências da Saúde/ Depto de  
Fisioterapia - Av. Robert Koch, 60, Vila  
Operária - 86038-350 – Londrina, PR, Brasil.  
E-mail: chmacedouel@yahoo.com.br

## ABSTRACT

**Introduction:** Rhythmic gymnastics requires a high level of physical quality; therefore, good performance depends on muscular strength and endurance, motor coordination and postural balance. **Objective:** Develop a comparative analysis of postural balance in rhythmic gymnasts. **Methods:** 10 rhythmic female gymnasts were evaluated on a force platform on one-foot and balance functional tests (Side Hop Test and Figure of Eight Hop Test). The anteroposterior and mediolateral of the center of pressure (COP) parameters were used for the functional tests, while for the functional tests, the performance time-seconds was analyzed. **Results:** Significant difference ( $p = 0.01$ ) was found between lower limbs in the mean frequency parameter in the mediolateral direction, in which the non-dominant lower limb presented higher postural stability than the dominant one. For functional tests, there was no significant difference between limbs. **Conclusion:** The difference found in the control of balance of mediolateral direction may be related with different muscular actions of the hip region, which is present during the sport practice for stabilization, trunk maintenance and maneuvers performance with the lower limbs. These results indicate the need of a balance program and pelvic stabilization for the analyzed athletes in order to maintain muscular symmetry of the limbs for high sports performance.

**Keywords:** postural balance, athletes, sports.

## INTRODUCTION

Rhythmic gymnastics (RG) is an essentially female modality based on artistic expressiveness which has technical perfection of complex movements with the body or apparatus such as rope, ball, hoop, clubs and ribbon<sup>1</sup>. The search for perfect synchronization between body and apparatus, combined with music, makes it an extension of the body and vice-versa<sup>2</sup>.

Elegance and beauty of movements are developed due to the level of some physical skills, such as flexibility, which plays an important role in the sport due to its need to perform the movements in a wide range of motion<sup>3</sup>. Performance of these athletes is highly dependent on motor coordination and skills such as posture balance, needed for performance of movements with suitable accuracy<sup>4</sup>.

Body balance and orientation maintenance is necessary for physical and sports performance. The balance offered by the feet refers to the ability to keep the center of gravity within the base of support<sup>5</sup>. Corrections of the body axis by the mechanisms of posture control, mentioned as a consequence of the dynamics itself of the living organism, provides small and constant oscillations to the human body when at standing position, with an important role in the pressure distribution on the soles of the feet. Some factors may interfere on this posture control, among these, we highlight injuries of the lower limbs, muscular fatigue<sup>6</sup>, asymmetry of the sports gesture, dominance<sup>7</sup>, to name some.

However, the literature presents divergence between results and the researched parameters.

Concerning the influence of dominance, Marchetti<sup>8</sup> states that to prioritize the use of one limb over the other may develop adaptations in the biological system, which occur at morphological, structural and functional levels. Moreover, the preference of one leg over the other may be dependent on the complexity of the task<sup>9</sup>; for example, a movement to reach for an object is performed by the dominant limb, while support is performed by the contralateral limb<sup>10</sup>. It is stated that the performance asymmetry consists in different abilities of motor control of homologous contralateral body segments which are presented in different motricity aspects such as accuracy, velocity of performance and coordination to initiate the movement<sup>11</sup>.

Balance assessment is complex; one of the most used research techniques to measure posture control is through stabilometric assessment, which consists in the use of a force platform capable of identifying the neuromuscular and biomechanical strategies in different movement directions for balance maintenance<sup>12</sup>. The stabilometric measurement mostly used in posture control assessment is the area of the center of pressure of the feet (COP), which is defined as the point of application of the result of the vertical forces acting over the support surface<sup>5</sup>. Since the COP dislocation is representative of the posture oscillations, the record is done by the instantaneous calculation of its position in the x and y coordinates, which corresponds to the site in the anteroposterior and mediolateral directions<sup>6</sup>.

Other balance assessment methods include the development of functional tests such as the *Figure 8 Test* and the *Side Hop Test*. It is observed that these tests assess the motor functionality of the athletes since they require posture and neuromuscular control<sup>13</sup> and present lateral dislocation components (side-hop), besides movements which lead to rotational stress (figure-of-8-hop)<sup>14</sup>.

The aim of the present study was to evaluate posture balance between the dominant lower limb (DLL) and contralateral lower limb (CLL) during different balance tasks (platform and functional tests) in RG athletes.

## METHODS

This was a transversal study characterized by a convenience sample composed of ten female RG athletes. The inclusion criteria were: minimum training time in the modality of three years; athletes who participated in state and national competitions, with minimum training of five times a week. The following exclusion criteria were adopted: athletes submitted to surgical procedures or who presented muscle or articular injuries on the lower limbs in the last three months; athletes who presented complaints of muscular fatigue at the moment of the tests; who needed stabilizers to perform the tests and the ones with skin injuries of lower limbs. The legal tutors of each underage athlete signed the free and clarified consent form and all of them were aware of the study protocol and its implications. The research was approved by the ethics committee of the State University of Londrina (legal opinion 050/2011).

Data collection was performed in the Laboratory of Functional Assessment and Human Motor Performance of the University of Northern Paraná (UNOPAR). All participants were evaluated on a force platform BIOMECH400 (EMG System of Brazil, SP). This platform had four load cells in rectangular position, measures 500x500x100 mm and weighs 22 kg. The system uses a 16-bit analog-digital convertor and rejection filters of 50 Hz. The ground vertical force reaction is derived from a 100 Hz sampling for data collection. The digital information is transferred to a computer via a USB universal cable. All the force signals recorded by the platform are filtered with a second-order by-pass filter of 35 Hz (Butterworthfilter) in order to eliminate the electrical noises.

The Bioanalysis software of the BIOMECH400 platform itself, which is compiled with computer routines of stabilographic analyses in the MATLAB (The Mathworks, Natick, MA) was used for acquisition and treatment of the balance parameters. The main balance parameters analyzed were: ellipse area (95%) of the COP in square centimeters (A-COP in cm<sup>2</sup>), mean velocity in centimeters by second (MV in cm/s) and mean frequency in Hertz (MF in Hz) of COP oscillations in both directions of the movement: anteroposterior (A/P) and mediolateral (M/L).

Demographic data of the sample were initially collected (age, weight, height, dominant lower limb, training frequency and duration). After data collection, the athletes were barefoot placed standing on a force platform, at one-leg with the right lower limb, looking at a mark at eye height, in front of the platform, trunk at erect position and upper limbs along the body, while the contralateral lower limb remained with hip at neutral position and knee at 90° flexion. During the test, the athletes were told to stay as still as possible for 30 seconds. This procedure was repeated three times, with 30-second intervals between collections. The same protocol

was repeated with the left lower limb. The mean of the attempts of both limbs was used for the balance parameters analyses.

Five minutes after the tests on the platform, the athletes performed the balance functional tests. The Side Hop Test (SHT) and the Figure of Eight Hop Test (FEHT) were performed and each test was repeated three times, with 30-second intervals between them. In the Side Hop Test the athletes performed ten lateral jumps at one-leg support, 30 centimeters away and at the fastest velocity as possible. The time in seconds was recorded. After one-minute rest, the Figure of Eight Hop Test was initiated. This test consisted in performing two laps at one-leg support in an eight shape in a circuit set by two cones five meters away from each other, as fast as possible. In the two tests, the assessed variable was the time in seconds (s)<sup>15</sup>. The protocol of the two tests was performed on both limbs, dominant and contralateral.

Statistical analysis was performed with the SPSS 15.0 software. The Shapiro-Wilk test was applied to establish the sample normality and as consequence, the paired Student's t and Wilcoxon tests were used to discriminate the dominance influence in the tests. Significance was established at  $p < 0.05$  and data were presented in mean and standard deviation (SD) for the anthropometric characteristics and time values in the functional tests, while for the platform the data were presented as median and interquartile interval.

## RESULTS

The athletes presented the following characteristics: right side dominance; age 13.9 years (SD = 0.8); height 1.53 m (SD = 0.05); weight 41.29 kg (SD = 5.54); BMI 17.4 kg/m<sup>2</sup> (SD = 1.5), with no history of acute injuries of the lower limbs or which had required time away from sports practice in the last three months. These athletes have practiced the modality for seven years and trained five times per week, for four daily hours.

The results obtained for the balance parameters evaluated by the force platform related to limbs dominance of lower limbs are presented in table 1. Significant difference was observed for the mean frequency of COP oscillation in the M/L direction ( $p = 0.01$ ). The contralateral limb (CLL) presented higher posture stability.

The analysis of the functional tests did not present statistically significant difference between the lower limbs, as presented in table 2.

**Table 1.** Results of the parameters assessed by the FP between DLL and CLL in rhythmic gymnastics athletes.

Parameters	DLL median (minimum – maximum)	CLL median (minimum – maximum)	P values
A-COP (cm <sup>2</sup> )	8.46 (4.34 – 14.10)	8.20 (3.94 – 11.12)	0.33
MV AP (cm/s)	2.64 (1.95 – 3.49)	2.48 (2.13 – 3.41)	0.72
MV ML (cm/s)	2.74 (1.84 – 3.70)	2.64 (1.92 – 2.84)	0.13
MF AP (Hz)	0.46 (0.32 – 0.81)	0.53 (0.32 – 0.81)	0.30
MF ML (Hz)	0.89 (0.62 – 1.37)	0.69 (0.55 – 1.09)	0.01*

\*Significant difference; DLL – dominant lower limb; CLL – contralateral lower limb; A-COP – ellipse area of the center of pressure; MV – mean velocity; MF – mean frequency; AP – anteroposterior; ML – mediolateral.

**Table 2.** Comparison between DLL and CLL in the functional tests.

Tests	DLL Mean (SD)	CLL Mean (SD)	P
SHT (s)	6.27 (0.71)	6.37 (0.89)	0.67
FEHT (s)	14.46 (1.01)	14.53 (1.23)	0.83

DLL – dominant lower limb; CLL – contralateral lower limb; SHT – side hop test; FEHT – figure eight hop test.

## DISCUSSION

The anthropometric characteristics of the sample are similar to the ones found by Gonçalves<sup>16</sup>, who assessed 342 RG athletes. These characteristics may be described as middle height gymnasts with body weight lower than the values accepted as normal and mentioned in the literature, which result in lower Body Mass Indexes. It is considered that these gymnasts present the anthropometric profile typical of this sport. Moreover, they may also present bone density higher than the non-athletes girls with the same age<sup>17</sup>.

As far as the authors know, this is the first study which differentiates dominance in the posture control of RG athletes. The results of the present study showed similarities between dominant and contralateral limb in the main investigated variables, except for the balance parameter in frequency in the mediolateral direction.

Part of the results of the present study corroborates the findings by Itoh *et al*<sup>15</sup> who did not find significant difference between lower limbs in balance; however, they found it in non-athlete individuals. The study by Tookuni<sup>18</sup>, which assessed the posture control through pressure sensors in healthy individuals during one-legged support (with eyes open and closed), did not observe significant differences between DLL and CLL either.

However, for the balance parameter in frequency, the CLL presented greater posture stability than the DLL. Although the explanation of these results is not completely clear, they suggest the presence of asymmetry in the muscular activities of the hip region which act in the movement performed in the mediolateral direction. The frequency parameter represents an ondulatory physical quantity indicating the number of posture oscillations in a given time interval. The higher the value in frequency, the greater the posture oscillations. It is well-known that for small disturbances, the ankle strategy is the most used to maintain balance, especially in the A/P direction<sup>19,20</sup>. However, in the presence of great disturbances or imbalance for neuromuscular deficit, great muscle groups such as the hip adductors and abductors should act, especially in the mediolateral direction of the movement, to control the balance losses and maintain suitable functional postures without risk of falling<sup>20,21</sup>. Thus, it is possible that the athletes have become more sensitive to the dominance effects in the hip-trunk muscles (gluteus, hamstrings and lower back) which act in the mediolateral direction during

balance maintenance due to the natural easiness to use the ankle strategy more often in the RG gesture. It is possible that concerning the contractions of the hip-trunk muscles, during the sports practice the CLL naturally works in the posture stabilization, while the dominant limb acts much more in the development of strength for the dynamic activity of the technical gestures, and hence, would decrease its balance maintenance role as the CLL.

When the body weight is supported by one of the lower limbs, the body should be stabilized on the same activity of the hip abducting muscles, with the pelvis stabilization<sup>22</sup>. The lower back-pelvis-hip complex acts to maintain alignment and dynamics posture balance during the functional activities and are fundamental for training, making maximum neuromuscular efficiency possible.

Kendall<sup>22</sup> adds that posture may be influenced by dominance and points out that individuals with right dominance present slight pelvis right swerve and the right hip seems to be slightly higher than the left one. The right gluteus medius is usually weaker than the right one, which makes balance alteration possible; however, this author did not establish results of posture and muscular strength assessment which would statistically corroborate this statement. Additionally, the proof of all these mechanisms would be possible with the complementary use of electromyography to record the behavior of hip-trunk muscles in the time (time information) and frequency domain. Further studies using other posture tasks would be also necessary to corroborate these outcomes.

According to Calavalle<sup>23</sup>, no study had investigated the posture control of RG athletes with the force platform until 2008. Thus, he used the platform to compare RG athletes and college students in two-legged support. These authors found that the athletes presented better posture strategy, mainly in the M/L direction, than the control group. Generally speaking, great part of the literature supports good balance performance of RG athletes in different postures<sup>24,25</sup>. The stabilometric assessment compared with the functional tests is necessary to point the possible alterations in balance of athletes, and, in the presence of neuromuscular deficit, justify the development of rehabilitation programs and prevention of the dynamic posture control. Therefore, the results of the present study have implications for the evaluation and intervention processes in the proposal of posture control exercise for suitable performance of RG athletes without risk of developing injuries.

Thus, there was no influence of dominance in the measurements of posture balance for great part of the assessed variables. Nevertheless, the results of the present study exposed significant difference in the balance parameter in MF in the M/L direction. This result may be related to the strategies of the hip adductor and abductor musculatures used in the sports activity for the trunk stabilization and maintenance during the maneuvers performance through the lower (ankle, knee) and upper limbs. Further studies using a higher number of individuals as well as other posture tasks, besides the one-legged support, are needed in order to better elucidate these results.

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All authors have declared there is not any potential conflict of interests concerning this article.

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