

Article

Core Stability and Electromyographic Activity of the Trunk Musculature in Different Woman's Sports

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Abstract: Volleyball players and gymnasts need strength training to achieve their optimum sport performance. The aims of this study were to describe body composition, strength, performance, and characteristics of trunk muscle activation in volleyball players and gymnasts, and to analyze the differences between the sports. The sample consisted of 40 female athletes: rhythmic gymnasts ($n = 24$; age 13.95 ± 2.77 years) and volleyball players ($n = 16$; age 19.81 ± 5.55 years). Body composition, maximum voluntary contraction (MVC) of isometric tests in an isokinetic dynamometer, McGill core endurance test, and surface electromyography (EMGrs) of the trunk muscle during the McGill test and isometric tests were recorded. Rhythmic gymnasts presented lower body composition values than volleyball players ($p < 0.05$). The volleyball players presented higher isometric strength than rhythmic gymnasts in terms of MVC in trunk flexion ($p < 0.05$, $d = 1.3$) and trunk extension ($p < 0.001$, $d = 1.3$). EMGrs from the rhythmic gymnasts were greater for trunk flexor muscles ($p < 0.01$, $d = 0.7$) and trunk extensor muscles ($p < 0.001$, $d = 1.3$) during McGill endurance tests compared to the volleyball players. In the isometric test, EMGrs from the rhythmic gymnasts were greater for trunk flexor muscles in flexion ($p < 0.01$, $d = 0.9$) and extension tests ($p < 0.05$, $d = 0.7$). In conclusion, the volleyball players exhibited higher peak strength, despite the fact that the gymnasts showed greater muscle activity during the maximum voluntary contraction.

Keywords: strength; isokinetic; muscular endurance test; muscular performance

1. Introduction

The number of professional female athletes and disciplines they practice have increased over the past few years [1]. Among the most practiced sports by women, some research highlights rhythmic gymnastics, and collective sports, such as volleyball to be the most practiced [2]. Rhythmic gymnastics requires a high degree of physical, technical, and psychological skills for both motor control and movement harmony [3], and volleyball is an intermittent high-intensity team sport that requires a combination of physical characteristics and aerobic and anaerobic power [4]. Therefore, these highly technical demands and the prolonged training time required, might induce structural changes in the musculoskeletal system, with strength training as a useful tool to improve the performance of female athletes [5]. Moreover, trunk muscle (core) strength is a key factor in sports performances and activities of daily living [6], as well as in reducing injury rates [7]. Consequently, volleyball players and gymnasts need strength to achieve their optimum sports performance [8,9].

Several studies indicate that for some athletes, such as shooters with isometric actions, weight and height do not influence performance [10]; however, other research positively associates variables such as weight, height, body mass index, and lean mass with strength [11,12]. Therefore, it is interesting to measure the body composition values of both sport groups, because, as with gymnasts, they are associated with low body mass and fat mass values when compared to other athletes or control subjects [13], as fat mass in gymnasts is not associated with improvements in strength and performance [14].

Quantitative measurements of maximum voluntary strength are made with isokinetic (concentric and eccentric) and isometric tests [15]. Flexion and extension of the trunk from a standing position depend on a complex system involving sensory, neural, active, and passive structures [16], and maximum voluntary contraction (MVC) measurements on flexion and extension quantify trunk muscle strength [17]. Moreover, for the measurement of endurance strength in athletes, core tests, such as the McGill test, are usually used to assess the endurance capacity and stability of the central part of the trunk [18]. In some sports, improving trunk strength and endurance makes it possible to increase the ability to generate and maintain force [19]. In addition, core stability contributes to performance as it facilitates the transmission of forces generated by the lower body to the upper body and vice versa [20]. In fact, it has been proven that core strength training significantly enhances trunk extensor strength [6]. Assessment tests of activation of musculature, such as surface electromyography (sEMG), are also considered appropriate tools for measuring muscle strength. sEMG provides access to the activation signal that causes the muscle to generate force and produce movement. It has been used in research and sport to evaluate the relationship between muscle activation and force. Muscle activation in sport is related to performance and evaluating injury risk factors [21].

In addition, a strong core is thought to allow an athlete to fully transfer forces generated within the lower extremities, through the trunk, to the upper extremities. A weak core interrupts the transfer of energy resulting in worse sport performance. Thus, there is an assumption that an increase in core strength will result in enhanced sport performance [22]. The load transfer capacity of this musculature helps to explain its functionality as well as the risk of injury. Evidence suggests that decreased core stability may predispose to injury and that appropriate training may reduce injury [23], and there may be a relationship between core stability status and lower extremity injuries or low back pain [24].

Several researchers highlight the importance of athletes' muscle strength for sport coaches [25], as well as core endurance training and its positive influence on performance [26–28]. However, there are currently few studies that determine the differences in strength, muscle activation, and core stabilization, between collective and individual sports with different specific strength training, such as rhythmic gymnastics and volleyball. It is of interest to define the effect of training and strength development in these two sports studied. Rhythmic gymnastics is mainly a technical sport, with training based on the specific development of strength and motor control from the athletes' initiation in the sport; however, volleyball deals with more tactical or positional aspects. Physical abilities such as flexibility, balance, and explosive strength can define the muscular differences of the sample [29]. These differences may be interesting for the development of certain physical abilities, such as strength. Therefore, the purposes of this study were: a) to describe the body composition, MVC in core, performance, and characteristics of trunk muscle activation in gymnasts and volleyball players and b) to analyze the differences between athletes.

2. Materials and Methods

2.1. Participants

Forty national female athletes ($n = 40$) participated in the study, and were divided into 2 groups according to their sport discipline: rhythmic gymnastics ($n = 24$; age 13.95 ± 2.77 years; height 151.39 ± 12.34 cm; weight 43.00 ± 12.82 kg) and volleyball players ($n = 16$; age 19.81 ± 5.55 years; height 167.62 ± 4.99 cm; weight: 61.87 ± 6.48 kg). The inclusion criteria were if participants: (1) had

training experience of 2 years, (2) compete in a national category, and (3) had 9 h of training per week. All participants and their parents/guardians received written and verbal information regarding the nature of this investigation and provided written informed consent before the beginning of the study. The study was approved by the local ethics committee, with number 112/2015, Hospital Virgen de la Salud. This study complied with the ethical principles of the Declaration of Helsinki.

2.2. Measures

The body composition, densitometry, isometric peak torque, McGill test and sEMG of the core during the endurance test and isometric tests were recorded. Body composition and densitometry measurements were taken following the standardized techniques of the International Society for the Advancement of Kinanthropometry (ISAK). Fat mass (FM, in kg), total lean mass (LM, in kg), bone mass (BM, in kg) fat tissue percentage (FT%) and trunk lean mass (Trunk LM, in kg) were assessed using dual-energy X-ray absorptiometry (DXA) (Lunar iDXA, General Electric Healthcare, Fairfield, CT, USA).

Isometric tests for maximum strength of trunk were performed with a Biodex isokinetic dynamometer (Biodex System 3; Biodex Medical Systems, Inc, Shirley, NY, USA). Muscle strength was evaluated in terms of peak torque (PT, in N* m) and peak torque related to LM (PT/LM, in N* m/Kg).

Core endurance was measured with reference to the McGill test [18] in a static position for as long as possible. The endurance tests were the extensor endurance test or Biering–Sorensen test (Sorensen), the side bridge test (right bridge or left bridge), the prone bridge test (prone bridge) and the flexor endurance test (trunk flexor). The time was measured in each test (s).

sEMG was measured during the McGill and isometric tests. An 8-channel sEMG ME 6000 TE (Mega Electronics, Kuopio, Finland), was used for data collection. Average values of muscle activation (EMGrms, in μ V) were measured. sEMG signals were considered as groups of flexor and extensor muscles of the trunk.

2.3. Design and Procedures

All the measurements were taken by the authors and the instruments were calibrated prior to use. The stature and body mass were measured on a portable scale with a stadiometer (model 700, Seca, Hamburg, Germany). Participants were familiarized with the test starting with a 90 s warm-up and familiarization trial of isokinetic trunk flexion and extension at a moderate intensity [16]. All the athletes were asked to warm up on a bicycle ergometer for 5 min using a self-chosen resistance of 40–60 rpm (20–30 watts), followed by 5 min of stretching exercises for the trunk and lower extremities [30]. Furthermore, the participants were placed in a supine position on the table and body composition parameters were recorded by DXA [31]. Subsequently, MVC for trunk isometric flexion and extension were recorded following the protocols described by Waldhelm and Li (2012) [32]. Trunk flexion and extension were performed while standing, with the pelvis stabilized, and without upper extremity support (Figure 1). The mean of three maximal voluntary isometric flexion and extension contractions of 5 s were executed with 30 s period in between. The participants executed three contractions with 2 min of rest in between [30].

Five core endurance tests were performed with reference to the McGill test [18]. The endurance tests were the Sorensen test, side bridge test (right and left), prone bridge test, and trunk flexor test (Figure 2). Subjects maintained these positions for as long as possible. The Sorensen test began with the subjects lying prone with the lower body manually fixed and hips extended over the edge of the test surface with their hands resting on the opposite shoulders (a). The side bridge test was performed with the subjects lying on their sides, with legs extended, feet placed together (one on top of the other), and supporting themselves on one elbow and their feet. The uninvolvement arm was held along the body (c). The prone bridge test was performed on the ground. The participants had to maintain the prone position supported on their feet and forearms with shoulders and elbows in 90° flexion. The forearms needed to remain pronated (d). The trunk flexor test required subjects to sit and place the upper body

at an angle of 60° , indicated by the authors. Both the knees and hips were flexed to 90° . The hands rested on the opposite shoulders (b).

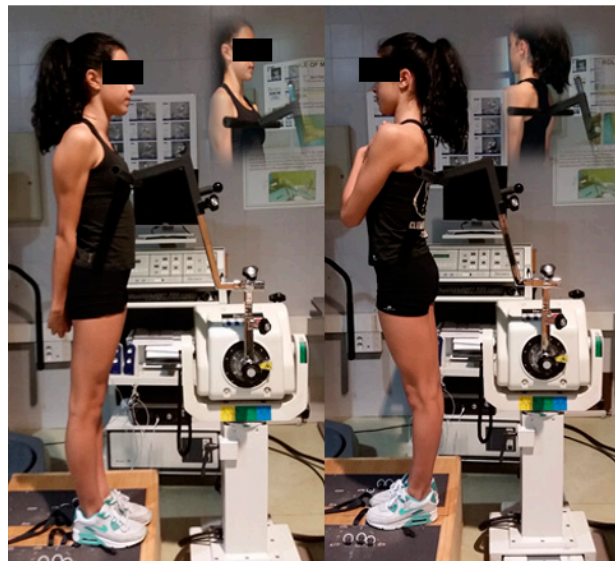


Figure 1. Isometric tests.

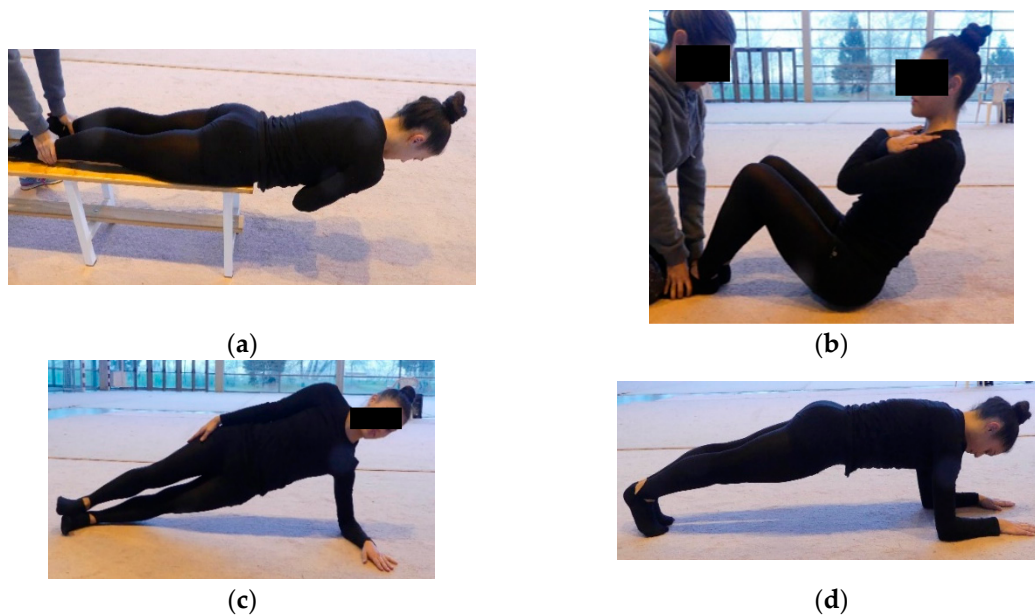


Figure 2. (a): Sorensen; (b): flexor trunk; (c): right or left bridge; (d): prone bridge.

Core sEMG was recorded during the McGill and the isometric tests performed on the isokinetic dynamometer. Each participant's skin was prepared for sEMG evaluation according to the SENIAM organization [33], including scrubbing and cleaning with alcohol. Electrodes were placed on trunk flexor muscles (rectus abdominal, external oblique abdominis) (front trunk) and trunk extensor muscles (erector spinae) (back trunk). sEMG signals were considered as groups of trunk flexor and extensor muscles, using two Ag-AgCl surface electrodes 10 mm in diameter. The sampling rate was set at 1000 Hz per channel. The raw data were stored and subsequently processed. The sEMG signal was fully rectified and smoothed and the root mean square was normalized to the peak maximum value recorded.

2.4. Data Analysis

Statistical analysis was performed using the Statistical Package (SPSS 24). Descriptive statistics were performed using the mean and standard deviation. The Shapiro–Wilk test was used to analyze normal data distribution. The variables that followed a normal distribution were FT, BM and FT%. To compare scores between groups, Student's *t* test, or the nonparametric equivalent (U-Mann–Whitney test) was used. An effect was considered statistically significant when $p < 0.05$. Effect size was calculated using the Cohen *d* coefficient. An effect size greater than 0.80 was considered large; around 0.5, moderate; less than 0.2, small [34].

3. Results

Table 1 shows the descriptive data from body composition analysis. The rhythmic gymnasts showed less FT (large effect, $d = -2.0$), a lower %FT (large effect, $d = -1.4$), LM (large effect, $d = -1.1$), BM (large effect, $d = -1.2$) and Trunk LM (large effect, $d = -1.2$) than the volleyball players ($p < 0.001$).

Table 1. Anthropometric characteristics of body composition and densitometry.

	Rhythmic (<i>n</i> = 24) Mean ± SD	Volleyball (<i>n</i> = 16) Mean ± SD	Mean Difference	95% Confidence Interval		<i>p</i>	<i>d</i>
FM (kg)	9.6 ± 3.6	17.4 ± 4.3	−7.8	−10.3	−5.2	< 0.001	−2.0
LM (Kg)	31.8 ± 8.6	40.7 ± 6.8	−6.1	−9.4	−2.8	0.001	−1.1
BM (Kg)	1.8 ± 0.6	2.5 ± 0.3	−8.9	−14.0	−3.7	< 0.001	−1.2
%FT (%)	22.9 ± 3.8	29.1 ± 5.2	−0.6	−0.9	−0.2	< 0.001	−1.4
TrunkLM (Kg)	15.2 ± 4.4	21.4 ± 5.9	−6.1	−9.0	−3.3	< 0.001	−1.2

FM: Fat mass; LM: lean mass; BM: bone mass; %FT: average fat tissue; Trunk LM: trunk lean mass; SD, standard deviation; 95% CI: 95% confidence interval; $p \leq 0.005$.

On the other hand, no significant differences were found between the rhythmic gymnasts and volleyball players in the McGill Core endurance test (Table 2). However, EMGrms from the rhythmic gymnasts were greater for trunk flexor muscles ($d = 0.7$) and trunk extensor muscles ($d = 1.3$) during Sorensen tests compared to the volleyball players. Although, greater EMGrms values for trunk extensor muscles were found in the volleyball players in the prone bridge test ($d = -0.0$).

Figure 3 shows the peak torque for female athletes in the present study. Significant differences were found between groups in isometric peak torque, the volleyball players showed higher isometric strength values than rhythmic gymnasts in MVC during the trunk flexion test ($p < 0.05$, $d = 1.3$) and trunk extension test ($p = 0.001$, $d = 1.3$). However, when the peak is relative to the LM, no significant differences were found between the rhythmic gymnasts and volleyball players (Figure 4).

Figure 5 shows the results of core sEMG in the isometric tests. Rhythmic gymnasts had greater EMGrms in the front trunk during the isometric flexion test ($p < 0.05$, $d = 0.9$) and during the isometric extension test ($p < 0.05$, $d = 0.7$).

Table 2. Performance in McGill test and electromyography values.

		Rhythmic (<i>n</i> = 24) Mean ± SD	Volleyball (<i>n</i> = 16) Mean ± SD	Mean Differences	95% Confidence Interval		<i>p</i>	<i>d</i>
Sorensen	EMG _{rms} Front (μV)	54.1 ± 32.2	33.4 ± 17.7	13.0	3.0	28.0	<0.01	0.7
	EMG _{rms} Back (μV)	272.3 ± 61.2	193.0 ± 53.0	79.2	41.3	117.2	<0.001	1.3
	Time (s)	35.5 ± 16.1	35.2 ± 23.7	0.0	−12.6	12.7	0.996	
Right Bridge	EMG _{rms} Front (μV)	227.6 ± 107.9	208.5 ± 94.0	19.1	−47.9	86.2	0.619	
	EMG _{rms} Back (μV)	77.9 ± 25.8	88.1 ± 25.5	−10.1	−26.9	6.6	0.228	
	Time (s)	19.6 ± 12.0	17.0 ± 12.9	2.5	−5.5	10.6	0.523	
Prone Bridge	EMG _{rms} Front (μV)	285.2 ± 130.5	273.8 ± 98.0	11.3	−66.1	88.9	0.768	
	EMG _{rms} Back (μV)	20.8 ± 18.0	21.0 ± 4.9	−3	−6	0.0	<0.05	0.0
	Time (s)	29.5 ± 15.0	29.9 ± 23.8	−0.3	−12.7	11.9	0.949	
Left Bridge	EMG _{rms} Front (μV)	197.5 ± 77.5	197.0 ± 87.7	0.52	−52.8	53.9	0.984	
	EMG _{rms} Back (μV)	94.0 ± 38.8	102.9 ± 42.5	−8.9	−35.2	17.4	0.497	
	Time (s)	27.8 ± 18.0	21.1 ± 16.4	6.7	−4.5	18.1	0.236	
Trunk Flexor	EMG _{rms} Front (μV)	228.2 ± 147.1	163.5 ± 92.1	64.6	−19.1	148.5	0.125	
	EMG _{rms} Back (μV)	25.0 ± 10.9	22.8 ± 6.6	2.2	−4.0	8.4	0.414	
	Time (s)	37.1 ± 27.4	31.4 ± 24.5	5.7	−11.4	22.8	0.506	

EMGrms: average electromyography activity; SD, standard deviation; 95% CI: 95% confidence interval; $p \leq 0.005$.

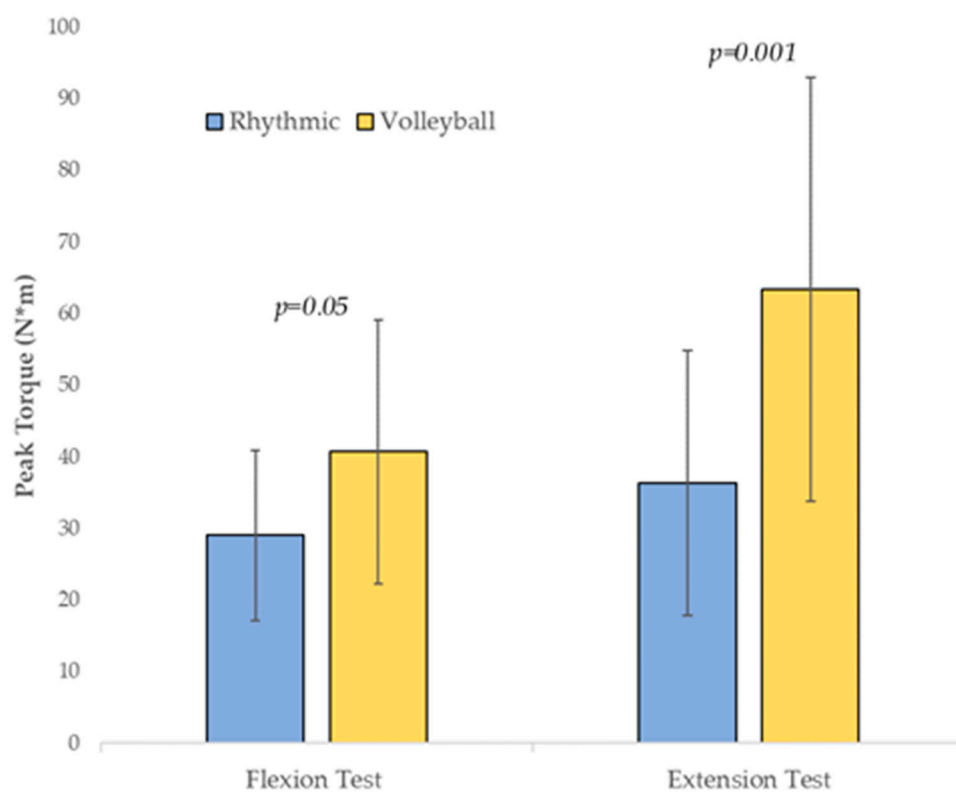


Figure 3. Performance isometric peak torque.

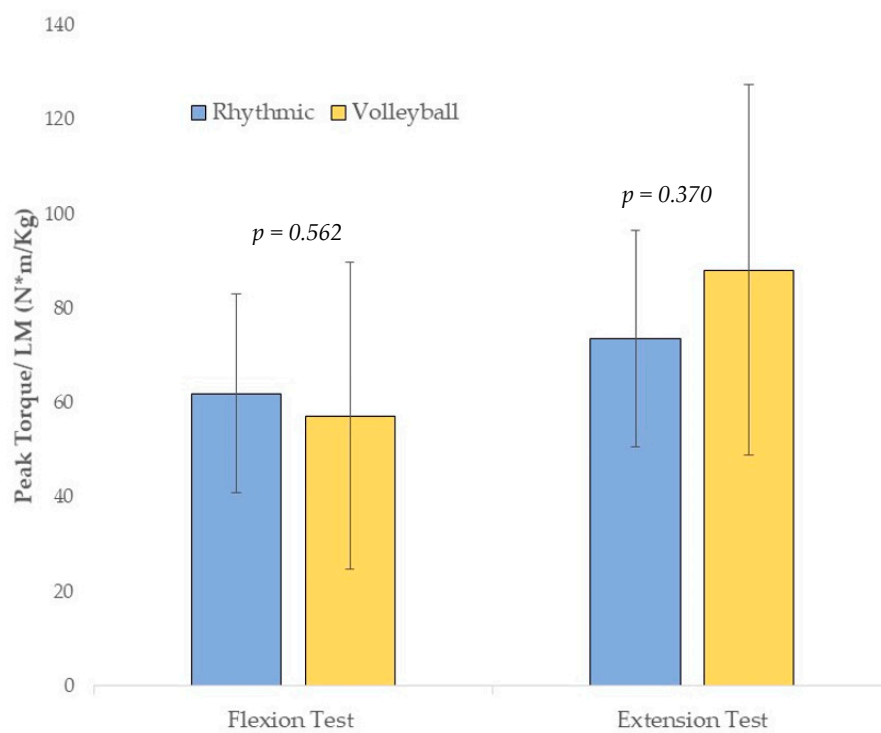


Figure 4. Performance isometric peak torque/lean mass.

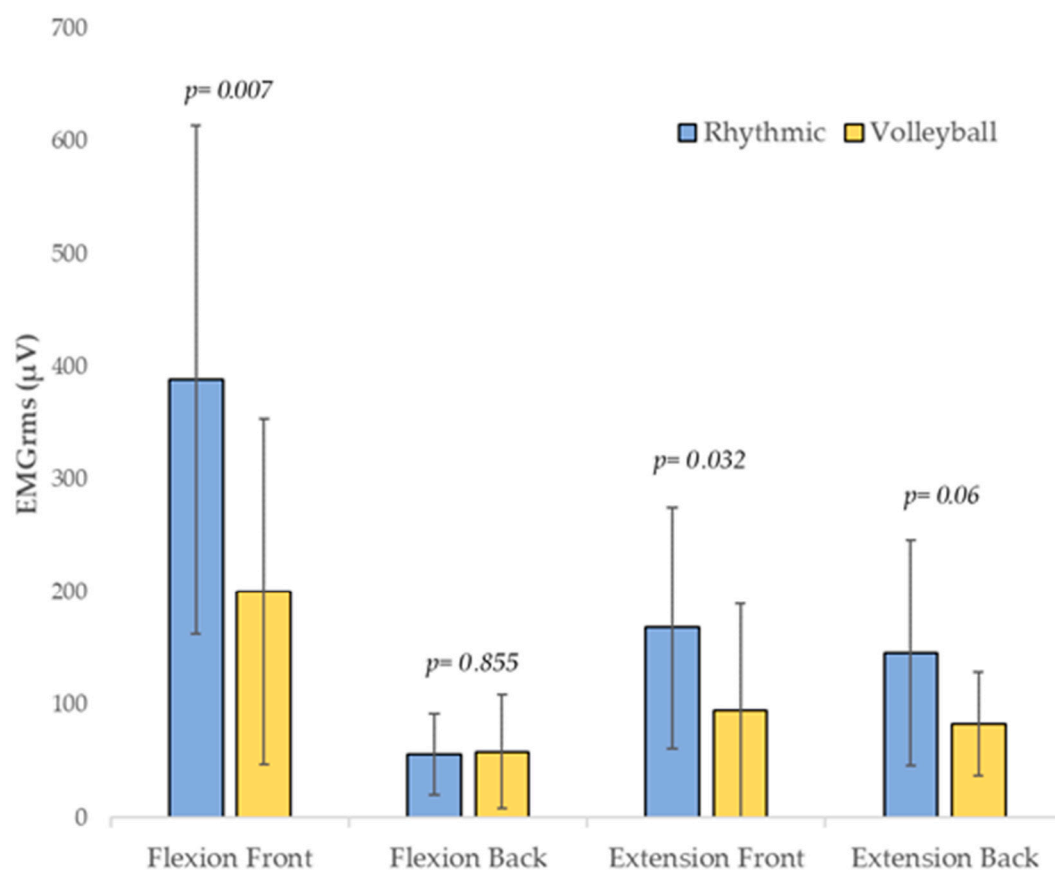


Figure 5. Significant difference EMG in isometric test.

4. Discussion

The aim of this study was to describe body composition, MVC, core performance, and characteristics during a McGill test and isometric tests and to analyze the differences in core performance between sports. The main findings were that the rhythmic gymnasts had lower body composition values than the volleyball players. The volleyball players showed higher peak strength than the rhythmic gymnasts; by contrast, no significant differences were observed in McGill tests between sports. However, rhythmic gymnasts showed increased muscle activity (EMG) during the tests—less in the back trunk during the prone bridge for volleyball players.

In agreement with the results obtained in body composition, Santos et al. (2014) [35] determined lower fat mass (11.8 Kg), percentage fat mass (22.7%), and lean mass (38.7 Kg) for rhythmic gymnasts in comparison with volleyball or handball players. Low values of body mass and fat tissue are associated, in gymnasts, with the ideal physique necessary for performing the complex movements of this sport [14]. Additionally, it is considered that fat mass does not provide improvements in strength and low percentages of fat imply more efficient movements [36]. Therefore, a negative relationship can be established between the percentage of fat mass and the performance of gymnasts. This justifies the lower body composition values obtained in gymnasts.

The total fat mass in the volleyball players was 17.4 Kg; this result supports evidence from previous studies [35,37–39], where the players in an NCAA division I woman's volleyball team (17.4 Kg) and female players in competitive clubs in Portuguese Midland (17.7 Kg) showed similar values of fat mass. Our results support the findings on body composition and somatotype characteristics of elite female volleyball players [40], determining that body composition correlates with success, such that sport performance is improved with a higher presence of fat free mass and absence of fat mass [39].

In relation to core endurance performance, no significant differences were found between the rhythmic gymnasts and volleyball players in the McGill core test. There are no studies on core strength

in gymnasts, but our results showed lower values than those found in other studies with dancers. Watson et al. (2017) [27] studied core endurance in female collegiate dancers (age 19.7 years) with competitive dance experience of 9.30 years, getting values of 88.34 s in the back-extensor endurance test and 108.08 s in the abdominal flexor endurance test. Another study by Ambegaonkar et al. (2016) [41] found that female collegiate modern dancers (18.3 years) with 12.5 years dance experience, recorded 170.8 s in front bridge, 75.7 s in right lateral plank, and 65.1 s in left lateral plank. Similarly, no studies were found in the literature investigating the relationship between female volleyball players and core endurance tests. Ambegaonkar et al. (2014) [42] measured core endurance values in forty female collegiate athletes (19.6 years) recruited from university lacrosse and soccer teams, obtaining 57.12 s in the trunk flexor test, 71.00 s in the trunk extensor, 36.51 s in right lateral plank, and 36.85 s in left lateral plank. Our athletes have lower core endurance values when compared to another studies. This could be because the average age of the sample and years of experience may be determinants in the performance of these tests, and average age was 13.95 years for the rhythmic gymnasts and 19.81 years for the volleyball players and the training experience of the participants involved in the study was 2 years. As mentioned in the literature review, anthropometry, physical fitness, training, previous experience, and age are significantly and positively associated with performance [43–45].

Although the endurance time in the McGill tests showed no significant differences, the gymnasts reflected greater muscle activation during the Sorensen test, in contrast with volleyball players who showed greater EMG values in the trunk extensor muscles in the prone bridge. No data were found for EMG in endurance tests in gymnasts and volleyball players. The results obtained in volleyball players can be explained by the findings of Smidt et al. [46], who determined that the higher activation of spinal erectors in the prone bridge is probably due to the lower performance of females in isometric flexion. Additionally, these results corroborate the findings of other studies, which showed that extension was stronger than flexion in volleyball players [47–49]. Kim and Jeoung (2016) [49] indicated that the reason for this is that the cross section during trunk extension is bigger than during flexion. During a volleyball match, the players are required to serve, pass, set the ball, spike, and attack. In the spike and serve, volleyball players bend the lower back, generating maximum power in the lower back trunk. Therefore, specific volleyball training can increase the ability to generate more force in trunk extension movements.

The specific training of volleyball therefore justifies the tendency for volleyball players to have higher values of strength in the back of the trunk. These facts also serve to justify that the volleyball players in our study reflected higher values of maximum isometric strength than the gymnasts in the test extension trunk [47–49] and test flexion trunk, due to higher lean mass values both in the whole body and in the trunk [50]. However, when maximum isometric strength was divided by muscle mass, no significant differences were found. Gymnasts, therefore, despite having lower muscle mass values, do not present differences when performing peak strength tasks. This may be due to the type of muscle contraction and strain required for rhythmic gymnastics training, performing isometric positions with a lot of body and technical control [3]. In addition, no significant differences were observed in the McGill tests. This lack of difference could be due to the fact that the gymnasts showed greater muscle activity during the tests. In this way, muscle activity is considered a determining factor for core performance, as opposed to maximum strength [51]. In contrast to the results of Kim and Park (2016) [52], for isometric muscular strength in professional female volleyball players, our players did not reach the average values of this study, indicating a more limited development of maximum trunk strength. There are few studies on trunk peak torque in gymnasts, but one study by Helge and Kanstrup (2002) [53] determined that maximal trunk strength was significantly greater in artistic and rhythmic gymnastics groups than the control group.

The volleyball players, due to their training and their maturity, present higher values of maximum strength in flexion and extension of the trunk. However, because training in rhythmic gymnastics requires a high degree of physical, technical, and psychological skill for both motor control and movement harmony [3], gymnasts experience a greater development of muscle activation.

There were some possible study limitations. There were differences in maturity between the athletes, due to the early specialization in rhythmic gymnastics [54], but mainly the hours of training and the level of performance were considered. The number of participants was low, because access to the sample was complex due to the high number of training hours. However, the strength of the study is that it is the first study to analyze possible differences in core performance between the two modalities of young athletes.

5. Conclusions

The results obtained in this study suggest that rhythmic gymnasts had lower body composition values than volleyball players. Differences in peak strength between rhythmic gymnasts and players were observed and no differences in core strength were found. However, the electromyographic activity measured in the endurance and isometric tests reflects a higher value in rhythmic gymnasts compared to volleyball players. This is due to improved trunk muscle performance in gymnasts due to the influence of training in rhythmic gymnastics which generates greater muscle activity.

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