Original Article

Strength in Portuguese rhythmic gymnasts of different competition levels

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Abstract:

The present study aimed to: (1) compare the strength level in Portuguese rhythmic gymnasts across competitive levels; (2) investigate the strength variables with higher discriminatory power between the groups and (3) determine which strength variables better explain performance. Participants included young gymnasts (n=164) in three competitive levels (Base, 1st division and Elite). Six specific strength tests were used. For the statistical analyses, Kruskal-Wallis test, Discriminant Function, Person Correlation and Linear Regression were applied. The 1st division and Elite reached higher results than Base in all strength tests. We observed a statistically significant superiority from Elite only in 50% of tests (Back power kick; Partial trunk elevations and Rope skipping tests). The partial trunk elevations and rope skipping tests were the strength variables with higher discriminatory power between the competition levels. 59.1% of gymnasts were well reclassified in the original groups. Finally, rope skipping test explained 7.2% of the variance in performance with some differences in the variables explaining performance across levels.

KeyWords: rhythmic gymnastics; performance; gymnasts; resistance strength; muscular endurance; explosive strength

Introduction

Rhythmic gymnastics (RG) is a sport that demands a hard, prolonged and constant physical training throughout the entire sports career (Román, del Campo, Solana, & Martín, 2012). The high performance is achieved through carefully organized and planned training according to requirements of the sport (Laffranchi, 2001). For a correct technical execution of the elements and movements in RG, with the appropriate range and intensity, is necessary a high level of development of the strength (Bobo & Sierra, 1998).

The RG requires explosive strength vertically and horizontally in the jumps, which must have high range and quick execution, explosive strength of upper limbs to execute big throws of apparatus, explosive strength and resistance strength to execute and to keep the balances and rotations (Silva, Oliveira, Leme, Nascimento Júnior, & Anversa, 2016). The strength contributes to a better performance evaluation of the RG elements (Miletić, Sekulic, & Wolf-Cvitak, 2004). Thus, the increase in strength levels extends the motor repertory of gymnasts (Román et al., 2012), improves the physical and technical performance (Gateva, 2013), and the speed with which competitive routines are executed (Miletić, Sekulic, et al., 2004). Therefore, strength has been identified as one of determinants variables in the competitive performance in this sport (Di Cagno et al., 2009; H. Douda, Toubekis, Avloniti, & Tokmakidis, 2008; Rutkauskaitė & Skarbalius, 2009, 2011; Silva et al., 2016). Generally, the strength has been evaluated in rhythmic gymnasts with exercises that are far from the reality of RG. Several authors analyzed the explosive strength through only the vertical jump (Benck et al., 2002; Del Vecchio, Primeira, Silva, Dall'Agnol, & Galliano, 2014; Kums, Erelina, Gapeyeva, & Pääsuke, 2005; Menezes & Fernandes Filho, 2006; Román et al., 2012) or vertical and horizontal jumps (Dobrijević, Dabović, & Moskovljević, 2014; Stadnik, Ulbricht, Perin, & Ripka, 2010). Di Cagno et al. (2009) assessed the vertical jump and included three RG specific jumps in their study. Other authors extended the evaluation of strength with tests of explosive and resistance strength (Donti, Bogdanis, Kritikou, Donti, & Theodorakou, 2016; Helen Douda, Avloniti, Kasabalas, & Tokmakidis, 2007; H. Douda et al., 2008; Gateva, 2011, 2013; Miletić, Katić, & Maleš, 2004; Miletić, Sekulic, et al., 2004; Rutkauskaitė & Skarbalius, 2009, 2011, 2012). However, the studies do not usually use tests with specific movements of RG. Few studies (Batista-Santos, Lebre, & Ávila-Carvalho, 2016; Donti et al., 2016; Gateva, 2011, 2013; Rutkauskaitė & Skarbalius, 2009, 2011, 2012) had at least one strength test with similar characteristics of the sport specific requirements.

Several authors (Barker & Armstrong, 2011; Lebre, 1993; McGuigan, 2014) emphasize the importance of the specificity of the tests performed in the studies with athletes. This specificity is the great advantage of field research, as it enables the collection of motor performance levels of athletes, and allows the acquisition of relevant data to the coaches (Santos & Soares, 2001). According to McGuigan (2014), general tests do not always correlate well with athletes' competitive performance. Thus, due to the necessity of a standard

assessment of motor performance in RG, the International Federation of Gymnastics (FIG) created tests (Klentrout et al., 2010) with body movements' patterns and RG elements, to ensure a close result to the context of the sport. The objectives of this study were: (1) compare the strength level in Portuguese gymnasts across competitive levels; (2) investigate the strength variables with higher discriminatory power between the groups and (3) determine the strength variables that better explain RG performance.

Material & methods

Participants: 164 Portuguese gymnasts who participated in the district and/or national competitions during the 2013/2014 season, in three different levels: Base, 1st division and Elite.

Age and training characteristics: chronological age, practice experience (number of years of RG training), age of training onset and training volume were collected using questionnaires (Table 1).

Table I: Age and training characteristics of the sample gymnasts

Variables	Base (n=84) $\bar{x} \pm sd$	1 st division (n=71) $\bar{x} \pm sd$	Elite (n=9) $\bar{x} \pm sd$
Age (years)	13.5 $\pm$ 2.3	13.6 $\pm$ 2.1	14.8 $\pm$ 1.8
Training onset (years)	7.2 $\pm$ 2.6	6.4 $\pm$ 2.2	6.0 $\pm$ 1.5
RG practice (years)	5.7* $\pm$ 3.1	6.7* $\pm$ 2.8	8.2* $\pm$ 1.9
Training volume (h/week)	13.9* $\pm$ 6.3	18.7* $\pm$ 6.2	31.2* $\pm$ 6.2

Legend – $\bar{x}$: mean; sd: standard deviation; h/week: hours per week; *p $\leq$ 0.05: significant differences

Ethical Considerations: Ethics Committee of the Faculty of Sport, University of Porto – Portugal and Scientific Committee of the Portugal Gymnastics Federation, approved the study protocol. The assessments were performed in accordance with the ethical standards of the Helsinki Declaration.

Strength Measurement: The FIG recommended tests (Klentrout et al., 2010) were used to assess the resistance strength, muscular endurance and explosive strength levels using RG specific movements. Six tests were performed. Part of these tests (Table 2) are exercises characterized by execution of energetic, fast and continuous movements, by performing the maximum number of repetitions in a given time (30 seconds): front power kicks (FPK), back power kicks (BPK), partial trunk elevations (PTE), partial curl-ups (PCU) and rope skipping (RSK). Therefore, it required the gymnasts to have a good level of strength, due to the requirement of repetitions with maximum power, i.e., a maximum rhythm, keeping the optimal range of motion with short rest periods. The exercises execution was recorded in video and the valid repetitions for each gymnast were counted. In addition, the gymnasts performed the vertical jump test (VTJ) (Sargent, 1921) according to the vertical jumping technique with countermovement jump, which is the rapid flexion and hip extension, knee and ankle, in a body projection movement vertical (Komi & Bosco, 1978) (Table 2). The jumping technique was explained in detail verbally, repeated and demonstrated as needed. In the jump time, it was allowed to freely flex the LL and move the upper limbs, to provide the largest possible vertical impulse.

Table II: Strength tests (Klentrout et al., 2010)

TEST	Front power kick (FPK)	Back power kick (BPK)	Partial Trunk Elevations (PTE)	Partial Curl-Ups (PCU)	Rope skipping (RSK)	Vertical Jump (VTJ)
PURPOSE	To measure resistance strength and muscular endurance (lower limbs).	To measure resistance strength and muscular endurance (lower limbs).	To measure resistance strength and muscular endurance (back).	To measure resistance strength and muscular endurance (abdomen).	To measure RG resistance strength, muscular endurance (lower limbs) and coordination.	To measure explosive strength (lower limbs).
EQUIPMENT	Stopwatch			Stopwatch and masking tape	Stopwatch	Ink and scale. (21x120cm, 1.6 – 2.0m from the ground).
POSITION	Lying on the back with legs straight.	Lying on the stomach with legs straight.	Lying on the stomach with legs straight.	Lying on the back, knees bent at 90°, feet flat on the floor, legs slightly apart, arms straight and parallel to the trunk with palms of hands resting on the floor. The head is in contact with the floor.	Standing with the rope stop behind the body or with movement in eight.	Standing with dominant shoulder half a foot away from the wall. The middle finger of the dominant hand is covered ink. After, touch in the scale fixed to the wall, and mark the first measure (M1), which is the highest point reached with feet flat on the ground.
ACTION	Lifting each leg to vertical position and alternating as many times as possible.	Lifting each leg to vertical position and alternating as many times as possible.	Lifting the trunk to the vertical with maximum speed. The	Initial phase involves “flattening out” of lower back region, followed by a slow	Double jumps with the rope.	Execution of vertical jump according to the vertical jumping technique with countermovement jump,

	possible. The hips in retroversion, upper limbs extended and apart, contracted abdomen, spine upright and fully supported on the ground.	The hips in retroversion, upper limbs in forward, next to the body or the elbows used as support, contracted abdomen and fully supported on the ground.	hips in retroversion, contracted abdomen, lower limbs extended and hands on the head.	“curling up” of the upper spine. Keeping heels in contact with the floor, the hands move forward, without to lift of the floor, towards the heels. Return the start position.		to mark the second measure (M2), that it refers to the highest point reached during the jump, with the same body segment. Three trials are allowed.
MEASURE	Maximum repetitions in 30 seconds.					The highest distance (cm) from M1 to M2.

The tests were conducted in training environment following strictly the protocol proposed. Two cameras (Nikon D5300, Tokyo-Japan and Samsung VP DX 100, South Korea) were used to register the videos. Two international judges analyzed the tests in two different occasions 10 days apart. We observed high values of intra-examiner reliability – Kendall Coefficient of Concordance (0.94-0.99) and inter-examiner reliability – Intraclass Correlation Coefficient (0.85-0.99), which confirms a high quality of information.

Additional data: Scores in the Portuguese National Championship determined the competitive performance in the sport season 2013/2014.

Statistical Procedures: Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS 23.0). The significance level was set at 5%. Descriptive statistics were performed using the mean and standard deviation. Kruskal-Wallis test was used to compare strength scores across competition levels. For the construction of strength profile, the variables were transformed into score Z. We used also the Discriminant function for identify the variables that maximally separate the groups of gymnasts by competition level. Person correlation and linear regression were used to verify the variables that better explain the RG performance.

Results

Strength tests: The 1st division and Elite reached higher results than Base in all strength tests (Table 3). The Elite achieved better results than 1st division in all strength tests, except in VTJ test, despite significant differences were found only in BPK, PTE and RSK tests. Thus, we observed a statistically significant superiority from Elite comparing to Base and 1st division only in 50% of tests (BPK, PTE and RSK). A positive point found in the analysis of the results obtained by Elite can be interpreted by the standard deviation values, as it is possible to observe a lower inter-individual variability in all strength tests.

Table III: Strength tests by competition level

Competition levels Variables		Complete sample (n=164)	Base (n=84)	1st division (n=71)	Elite (n=9)	p value
		$\bar{x} \pm sd$	$\bar{x} \pm sd$	$\bar{x} \pm sd$	$\bar{x} \pm sd$	
Physical tests	VTJ (cm)	32.7 $\pm$ 5.3	31.1 $\pm$ 4.8	34.5 $\pm$ 5.5	34.1 $\pm$ 2.9	p=0.050* ^{1,2}
	FPK (rep)	27.8 $\pm$ 3.7	26.9 $\pm$ 4.1	28.8 $\pm$ 3.1	28.9 $\pm$ 1.8	p=0.008* ^{1,2}
	BPK (rep)	19.6 $\pm$ 8.0	16.7 $\pm$ 8.0	22.0 $\pm$ 7.0	27.2 $\pm$ 2.1	p<0.000* ^{1,2,3}
	PTE (rep)	14.5 $\pm$ 8.5	10.2 $\pm$ 8.7	18.6 $\pm$ 5.4	22.2 $\pm$ 3.2	p<0.000* ^{1,2,3}
	PCU (rep)	15.5 $\pm$ 3.3	14.7 $\pm$ 3.7	16.4 $\pm$ 2.6	16.6 $\pm$ 1.6	p=0.008* ^{1,2}
	RSK (rep)	24.2 $\pm$ 15.2	17.4 $\pm$ 13.8	29.8 $\pm$ 13.3	42.4 $\pm$ 3.8	p<0.000* ^{1,2,3}

Legend – $\bar{x}$: mean; sd: standard deviation; VTJ: vertical jump test; FPK: front power kick; BPK: back power kick; PTE: partial trunk elevations; PCU: partial curl-ups; RSK: skipping with rope; *p<0.05: significant differences – *¹: Base versus 1st division; *²: Base versus Elite; *³: 1st division versus Elite.

Strength Profile: Figure 1 presents the strength profiles by competitive level. We verified a clear disadvantage of Base in all strength tests, once that this group obtained the lower results in all tests and with below average values.

The 1st division showed a higher stability in the results with above average values in all tests. The Elite presented a higher oscillation in the results, with a less linear profile, once that were verified values above the average (BPK, PTE and RSK tests) as well as values near the mean and similar to the 1st division (VTJ, FPK and PCU tests).

Fig. 1: Strength profiles by competitive levels

Legend – VTJ: vertical jump test; FPK: front power kick; BPK: back power kick; PTE: partial trunk elevations; PCU: partial curl-ups; RSK: skipping with rope.

Discriminatory power of strength variables: PTE (Δ de Wilks = 0.0757, $F = 15.453$, $p < 0.001$) and RSK test (Δ de Wilks = 0.718, $F = 10.542$, $p < 0.001$) were the variables that maximally separate the groups of gymnasts by competition level. The reclassification in the original groups based on the results of the discriminant function showed that 59.1% of gymnasts were well reclassified (Table 4).

Table IV: Classification of gymnasts in the different competition levels (Base, 1st division and Elite)

	Competition Level	Predicted Group Membership*			Total
		Base	1 st division	Elite	
Cross-validated	Count				
	(%)				
	Base	57 (67.9%)	18 (21.4%)	9 (10.7%)	84 (100%)
	1 st division	15 (21.1%)	32 (45.1%)	24 (33.8%)	71 (100%)
	Elite	0 (0%)	1 (11.1%)	8 (88.9%)	9 (100%)

Legend – *59.1% of cases grouped with cross-validation correctly classified.

We observed that the lower errors of reclassification occurred in Elite (11.1%). In Base, 32.1% of gymnasts were reclassified in the other competition levels: 21.4% to 1st division and 10.7% to Elite. The 1st division was the competition level with higher errors of reclassification (54.9%): 21.1% of gymnasts were reclassified to Base and 33.8% to Elite.

Strength variables and performance: Analyzing all strength variables and the performance, we observed that the tests BPK ($p = 0.038$; ρ of Pearson = 0.162) and RSK ($p < 0.001$; ρ of Pearson = 0.278) were significantly correlated with the performance score. Thus, the higher the results in these tests, higher the performance score. However, only the RSK test presented statistical significance in the model of linear regression ($p < 0.001$; $F = 13.600$). According to R^2 adjusted, this variable explained 7.2% of variance of performance. The regression equation was: Performance score = $27.627 + 0.488 \cdot \text{RSK}$; therefore, increases in the RSK promotes an increase in the performance score.

On the other hand, analyzing the group by competition level, significant correlations were found in the final performance score and different strength variables: Base (VTJ: $p = 0.006$, ρ of Pearson = 0.296; and RSK: $p < 0.001$, ρ of Pearson = 0.376); 1st division (PTE: $p = 0.003$, ρ of Pearson = 0.348; PCU: $p = 0.005$, ρ of Pearson = 0.328; RSK: $p = 0.025$, ρ of Pearson = 0.265); and Elite (without significant correlations). Thus, there is no common pattern in the results of linear regression across competition levels. Specifically, only RSK explained part of the performance in the Base level ($p < 0.001$; $F = 13.505$; R^2 adjusted = 0.131; $y = 30.387 + 0.648 \cdot \text{RSK}$), while for 1st division the predicting variables were PTE and PCU ($p = 0.001$; $F = 7.168$; R^2 adjusted = 0.150; $y = 36.597 + 1.437 \cdot \text{PTE} + 2.620 \cdot \text{PCU}$). In Elite, no significant variables were found in the model of linear regression.

Discussion

In RG in Portugal, there is three competitive levels (Base, 1st division and Elite). The Elite is the main and higher competitive level. Thus, Elite is formed by best Portuguese gymnasts selected by Portugal Gymnastics Federation through predefined criteria. This group represents the individual Portugal National Team. The 1st division is the second competitive level. From this group the gymnasts are selected for Elite. Therefore, the 1st division is formed by quality gymnasts with aspirations to integrate the National Team. Base is the third

competitive level with lower demands. However, the gymnasts competing in the Base and 1st division levels are selected by their coaches.

The training process in RG has high demands in the technical elements with a high complexity level (Bobo-Arce & Méndez-Rial, 2013). According to Miletic, Katic, et al. (2004), appropriate levels of strength are a precondition for proper performance of all basic body elements in RG. Lower limb explosive strength is a key ability in elements in the body group jumps/leaps. Back and abdominal muscle control are the basis for a successful technical performance in elements of other body groups: rotations and balances (Gateva, 2013).

Thus, a proper physical preparation level is an essential prerequisite for an excellent technical performance (Gateva, 2013). In contrast, a limited physical preparation level is one of the major problems appearing into the RG practice. According to Monem, Sands, Salmela, P., and Gateva (2011) is often a result of the coaches' negligence due to their focusing mainly on the technical preparation.

The strength is one of the main physical capacities that have been identified as contributing factors to performance in RG (Di Cagno et al., 2009; H. Douda et al., 2008; Rutkauskaitė & Skarbalius, 2009, 2011; Silva et al., 2016). However, there are few studies about the physical capacities in RG in which specific problems as strength is reviewed (Gateva, 2013). The choice of tests should consider the specificity of the sport, to approach the most of the main characteristics (Barker & Armstrong, 2011; McGuigan, 2014). According to McGuigan (2014), general tests do not always correlate well with athletes' competitive performance. Therefore the author considers essential to critically examine which tests are used and do not choose tests solely because they have been used or because the equipment and expertise are available.

Gateva (2015) explains that some adequate fitness tests to assess the cardiovascular and specific endurance in RG had to be created in her study: submaximal treadmill test (2 minutes) and specific modified gymnastics routine (2 minutes). Some other sports also have lack of specific assessment as a study in climbing (Michailov et al., 2014).

The strength tests recommended by FIG (Klentrou et al., 2010) used in our study present exercises widely used in training sessions and competition routines that provides results close to the reality of RG. These tests measure the main and most important muscle groups in rhythmic gymnasts' body according to the specificity of the referred sport. Thus, the gymnasts of all competition levels demonstrated familiarity with most of the exercises evaluated, as these are daily used in the training sessions in order to develop mainly capabilities as flexibility and strength. Thus, the main peculiarities observed in the accomplishment of each strength test are presented below:

- In Front Power Kick (FPK), some gymnasts showed lack of coordination in the proposed motion. A LL performs the action of battement while the other remains supported on the ground. The second LL only starts the action when the first LL returns to the starting position. The most common mistake among the gymnasts was the elevation of the second LL during the time of the return of the first LL, performing a movement of "scissors" with the LL. This error was probably verified because, overall, the battements exercises with LL forward are executed with a higher number of repetitions with each LL.

- In Back power kicks (BPK), the main difficulties observed were: elevation of LL until 90° and/or maintenance of hip position during the execution of the movement. Some gymnasts needed to raise the hip from the ground to achieve the desired range of LL (90°), which was not allowed. Thus, each time the gymnast did not reach the correct form of the evaluated exercise, repetition was considered invalid. We also verified gymnasts who achieved the required range only with the dominant lower limb.

- In Partial Trunk Elevations (PTE), some gymnasts presented difficulty to correctly perform the desired movement probably because they had a limited degree of flexibility in the spine joints and therefore these gymnasts did not show facility to raise the trunk to the vertical. However, other gymnasts with extreme flexibility did not also achieve excellent results in this test due to low capacity explosive strength and muscular endurance in the spinal region.

- The partial curl-up (PCU) is a less familiar exercise between the gymnasts, as it has some rules and details (such as the arms/hands movement in the exercise execution) rarely used in the training practice. However, it is true that the gymnasts perform daily various types of abdominal exercises and so this is a muscular area quite worked.

- In skipping with the rope (RSK), several gymnasts had difficulties in the correct execution of the skipping and the lack of technical apparatus was the main cause of the low results in this test. In the proposed time (30") many gymnasts made more attempts than double skips with rope. Some gymnasts did not fail to perform a single repetition. In addition, there were gymnasts with better technical apparatus level that presented poor results because they failed in one or two skipping by inattention.

- In the vertical jump test (VTJ), the jumping technique was explained in detail verbally, repeated and demonstrated as needed. No gymnast showed difficulty in the execution of this test. However, the height of the jump can be affected by the effective use of arms and how the gymnast flexes her knees before jumping (Komi & Bosco, 1978).

All details of the tests FPK, BPK, PTE and PCU had been previously explained and the gymnasts made at least one repetition of the exercise, in order to verify the correct execution. However, many gymnasts had repetitions cancelled because they did not perform the proposed movement correctly during the evaluation. In

these tests, overall, there is common pattern in the results across competition levels, in the following order: FPK, BPK, PTE, PCU, except in the Base, which the gymnasts achieved better results in the PCU than PTE test.

The characteristics of the tests help to justify the results found. The FPK and BPK tests had better results probably due to the weight of the trunk and upper limbs to be higher than weight of the lower limbs, which perform the movement in practice. Thus, the body remains stable on the ground and the gymnast can execute the faster repetitions. On the other hand, in the PTE and PCU tests, to lift the trunk up to the vertical, as the lower limbs are lighter, there is higher instability in the body. Therefore, is natural that the gymnasts present higher difficulty and need to apply a higher strength level for the accomplishment of each repetition and as consequence, the movement becomes slower.

The BPK test obtained lower results than FPK test, probably because although these tests have a similar execution, different muscular groups are requested. To the execution of the FPK test is necessary muscular endurance in the abdomen and hip flexors, while that to the BPK test imply muscular endurance especially in the hip extensors and back extensors.

To the execution of the PTE test, the strength concentration is especially in the back extensors and to the PCU test in the abdomen. However, to do a good execution in the PTE test a minimum of spinal flexibility is required. The gymnasts from 1st division and Elite achieved better results in PTE than PCU test, probably due mainly to the smaller familiarity shown by gymnasts in this test or perhaps by a lower abdominal than back strength. On the other hand, the gymnasts from Base obtained higher results in PCU than PTE test. During the evaluation, it was clear the difficulty of the gymnasts of this group to perform the PTE test due to limited back flexibility and strength. These gymnasts also showed a slight familiarity with the PCU test.

Overall, the differences verified in these tests (FPK, BPK, PTE and PCU) also can be justified by a probable higher strength in the muscles of the hip and lower limbs than in the muscles of the abdomen and spine. The VTJ and RSK tests were not included in this comparison because they have different characteristics. Although the RSK test was also evaluated according to the number of repetitions in 30", the executed movement is naturally faster than the remaining strength tests. Furthermore, the VTJ test is a single movement and evaluated in centimeter. Thus, as expected, the best results in the strength repetitions tests were achieved in the RSK test (1st division and Elite). However, the technical ability has influence in this test. The gymnasts from Base presented a lower conjunction between technical execution and strength.

Comparing the results obtained by gymnasts in the strength assessment, according to the competition level, we observed that, as expected, the 1st division and Elite reached higher results than Base in all tests. The Elite also achieved better results than 1st division in all strength tests (except in the VTJ test), despite significant differences were found only in BPK, PTE and RSK tests. Thus, we observed a statistically significant superiority from Elite comparing to Base and 1st division only in 50% of strength tests (BPK, PTE and RSK). In the RSK test was possible to verify higher supremacy of Elite. This group reached on mean 42.4 ± 3.8 repetitions in 30", which corresponds to about 1.41 repetitions per second. The high number of repetitions and reduced standard deviation value demonstrate that the Elite had excellent technical and physical quality in the exercise assessed, as a higher inter-individual homogeneity.

A similar test to the RSK test was used in three studies (Rutkauskaitė & Skarbalius, 2009, 2011, 2012), which were aimed at determine the impact of specific training on sport performance in rhythmic gymnasts with 11-12, 13-14 and 14-15 years, respectively. According to the authors, among the physical fitness tests used in these studies, the "test of jumping into rope with double turns" evaluated the specific muscular endurance. However, the results of each test were not presented.

In the BPK test the Elite almost reached on mean one repetition per second (0.91 repetitions per second). Thus, in this test, the Elite needed only 18.4" and 24.1" to obtain the marks achieved by Base (16.7 ± 8.0 rep) and 1st division (22.0 ± 7.0 rep) in 30", respectively, probably due to a higher strength in the hip extensors and back extensors. Therefore, the order of results reached in the PTE test can be also supported by this justification. The higher backstrength of Elite probably ensured the better results in the PTE test: Elite (22.2 ± 3.2 rep); 1st division (18.6 ± 5.4 rep) and Base (10.2 ± 8.7 rep). The strength in back extensors is important in order to hyperextend the trunk in jumps, balances, rotations and acrobatic elements, and regain a firm standing position throughout all movements especially in the a competitive routine (Kritikou, Donti, Bogdanis, Donti, & Theodorakou, 2017).

In the Kritikou et al. (2017) study, they analyzed the association between artistry score, physical abilities and anthropometric characteristics in 46 national level competitive rhythmic gymnasts (aged 9.9 ± 1.3 years). Among the physical tests, the authors used the back extension endurance test with characteristics and requirements of the PTE test used in our study. However, the arms position was not explained in the test description and during the movement execution, the examiner assisted by anchoring the gymnasts' feet on the ground. The back extension endurance test presented a significantly negative correlation with artistry score as well as to its separate sub-components, expression, music and movement (in deduction points). Thus, the authors verified that the higher the number of repetition in the back extension endurance test, lower the artistry penalization, showing the importance of the musculature of this region. Results from the regression analysis revealed that muscular endurance of the back extensors significantly contributed to the expression score.

The gymnasts presented on mean 24.0 ± 4.0 repetitions in the back extension endurance test (Kritikou et al., 2017) and therefore, higher results than all groups in our study. Yet, some details in the movement execution' requirements can provide higher easiness or difficulty in the performance. Consequently, they influence the total number of repetitions performed by gymnasts. In the spinal extension movement, the fixation of the feet and/or lower limbs on the ground, assisted by some support or a person, allow the execution of the movement with more velocity and amplitude. Thus, whereas Kritikou et al. (2017) used the movement assisted by an examiner (anchoring the gymnasts' feet on the ground), in our study the gymnasts performed the spinal extension movement without any support or help, which increase the intensity muscular contraction in the exercise. Therefore, the tests have different difficulty levels and the lower results by Portuguese gymnasts can be justify by this difference in the movement execution.

In the FPK and PCU tests, although the Elite achieved higher results than 1st division and Base levels, significant differences were not observed in Elite and 1st division, once that these groups presented the same number of repetitions by second. In the FPK and PCU tests, the gymnasts from 1st division and Elite levels reached on mean 0.96 and 0.55 repetitions per second respectively, while the Base obtained 0.90 (FPK test) and 0.49 (PCU test) repetitions per second.

Miletić, Sekulic, et al. (2004) conducted a study with 55 gymnasts (7.1 ± 0.3 years) and one of the physical tests was the sit-ups. This test has the some different characteristics of the PCU test, performed in our study, and it was performed with twice the execution time. Thus, the gymnasts achieved 22.7 ± 8.6 repetitions in 60". The test with 60" implies a higher endurance so it is not possible to do a direct relation with the results and to conclude that in the half of this time (30") the gymnasts can reach half of the total number of repetitions.

Finally, the elite (34.1 ± 2.9 cm) and 1st division (34.5 ± 5.5 cm) gymnasts presented a higher lower limbs' explosive strength level than base gymnasts (31.1 ± 4.8 cm), according to the results achieved in the VTJ test. The vertical jump is widely used in the different elements in RG (Menezes, Novaes, & Fernandes-Filho, 2012), so, several previous research resorted to different devices to evaluate the vertical jump of gymnasts (Del Vecchio et al., 2014; Donti et al., 2016; H. Douda et al., 2008; Gateva, 2011, 2013; Grigoriu, Pelin, Netolitzchi, & Pricop, 2015; Kritikou et al., 2017; Menezes & Fernandes Filho, 2006; Miletić, Katić, et al., 2004; Miletić, Sekulic, et al., 2004; Román et al., 2012; Rutkauskaitė & Skarbalius, 2009, 2011, 2012; Silva et al., 2016; Stadnik et al., 2010). The VTJ test is still highly used for its simplicity and easy application.

Thus, Miletić, Sekulic, et al. (2004) found lower values in the VTJ test (21.2 ± 4.4 cm) in younger gymnasts (7.1 ± 0.3 years). Menezes et al. (2012) observed higher values than in our study: 35.1 ± 3.5 cm, 38.0 ± 4.3 cm and 40.1 ± 2.7 cm, respectively at state, national and international levels. Further, the authors verified that the gymnasts, who had already menstruated, presented higher results in the vertical jump.

Therefore, generally, it was expected a statistically superior result from Elite in all strength tests, once that this group should be composed of the best Portuguese gymnasts. However, this group was statistically superior to the Base and 1st division levels only in 50% of strength tests (BPK, PTE and RSK). Other negative point was shown in the strength profile. The Elite presented the higher oscillation in the results, with a less linear profile, once that this group showed values above the average (BPK, PTE and RSK tests), as well as values near the mean and similar to the 1st division (VTJ, FPK and PCU tests). The 1st division had a lower variability in the results with above average values in all tests.

The low inter-individual variability in all strength tests can be considered a positive point found in the analysis of the results obtained by Elite.

According to results observed in the strength tests, the variables that maximally discriminate the groups of gymnasts by competition level were PTE and RSK tests. The reclassification in the original groups based on the results of the discriminant function showed that 59.1% of gymnasts were well reclassified. Thus, the other 40.9% of gymnasts presented results in the PTE and RSK tests very different from those reached by gymnasts belonging to their competition level. Therefore, they were reclassified and included in the groups that showed closer results. The lower errors of reclassification occurred in Elite, once that only 11.1% of gymnasts were reclassified to the 1st division. In Base, 32.1% of gymnasts were reclassified in the other competition level: 21.4% to 1st division and 10.7% to Elite. The 1st division was the competition level with higher errors of reclassification (54.9%). There were gymnasts with results closer to the Base (21.1%) and the Elite (33.8%).

For the evolution of RG training and performance, Donti et al. (2016) explain that there is a need to identify the physical fitness variables that can be improved in the training process and are more important for the developing athlete. Thus, we investigate the strength variables that better explained the performance. Initially, we verified that BPK and RSK tests were significantly correlated with the performance score and so, the higher the results in these tests, higher the performance score. However, only the RSK test presented statistical significance in the model of linear regression, and this variable explained 7.2% of variance of performance. Therefore, the increases in the RSK promotes an increase in the performance score.

Analyzing the group by competition level, significant correlations were found in the performance score and different strength variables: Base (VTJ and RSK tests); 1st division (PTE, PCU and RSK tests) and Elite (without significant correlations). Thus, there is no common pattern in the results of linear regression and therefore, different variables explaining the variance in performance in each competition level: RSK test in Base

(13.1%); PTE and PCU tests in 1st division (15%) and no significant variables were found in the model of linear regression in Elite level.

Thereby, different strength variables showed to make the difference in the competition success in RG. In this sense, according to several authors (Di Cagno et al., 2009; H. Douda et al., 2008; Rutkauskaitė & Skarbalis, 2009, 2011; Silva et al., 2016), the strength is considered one of the main components of physical fitness that contribute to the performance in RG. This study provides information on values of physical fitness (strength) of rhythmic gymnasts from different competition levels from Portugal. It is extremely important to know the national reality, as well as to verify the differences in the groups in varied domains, besides the competitive results, thus, helping coaches monitoring training and selection processes.

Conclusions

The 1st division and Elite levels reached higher results than Base in the strength tests. However, the statistically significant superiority from Elite comparing to Base and 1st division levels was observed only in 50% of strength tests (BPK, PTE and RSK). The PTE and RSK tests were the strength variables with higher discriminatory power between the competition levels. 59.1% of gymnasts were well reclassified in the original groups. Furthermore, RSK test presented statistical significance in the linear regression model and this variable explained 7.2% of variance in performance with some differences in the variables explaining performance across levels. Whereas the RSK test explained 13.1% of performance in Base, in 1st division the predicted variables were PTE and PCU tests, which explained 15% of variance in performance. In Elite, no significant variables were found in the model of linear regression.

Conflicts of interest - The authors have not any conflicts of interest.

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