JUMP ABILITY AND FORCE-VELOCITY PROFILE IN RHYTHMIC GYMNASTICS

Luciana Ferreira Melo de Sá[1], Isaura Leite[1], Amanda Batista Santos[2], Maria de Lurdes Tristão Ávila Carvalho[1]

[1]Faculty of Sport, University of Porto, Portugal
[2]Higher Institute of Educational Sciences of the Douro (ISCE Douro), Portugal

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Abstract
The jump is one of the main body elements in Rhythmic Gymnastics (RG). To perform it correctly, gymnasts must develop appropriate force and velocity levels to reach enough jump height to show the body shape during flight, as defined by the RG Code of Points. Jumping performance is influenced by the mechanical force-velocity (F-V) profile and the maximum power generated by the lower limbs. The F-V profile identification can provide a more accurate and complete mechanical representation of its capabilities and needs. This study aimed to analyse the F-V profile during the countermovement jump of RG athletes, identify the magnitude and direction of the imbalance between the two variables (force and velocity), and compare the jumping ability and mechanical variables of different age groups. Eighteen Portuguese gymnasts (average age 12.2±1.8 years) were evaluated, according to age group: beginner and youth gymnasts (G1- ages 10 to 12) and junior and senior gymnasts (G2 - ages 13 to 16), and according to the F-V profile imbalance detected. The data collection was performed after a covid-19 lockdown period. Results showed anthropometric differences between age groups but no differences in the F-V profile related variables. When gymnasts were compared according to the deficit, differences were found in variables force and velocity. Furthermore, 72.3% of the gymnasts presented force deficit, 11% presented velocity deficit and 16.6% were balanced. Considering the deficits found, the demands of the sport and of each athlete, it is essential to include strength training in the regular training routines of rhythmic gymnasts.

Keywords: *rhythmic gymnastics; profile; jump; force; velocity.*

INTRODUCTION

Rhythmic gymnastics (RG) is a sport characterized by a high level of technical difficulty and extreme physical demand, aiming to obtain a perfect execution of body movements with different types of apparatus: rope, hoop, ball, clubs and ribbon (Batista, Garganta, & Avila-Carvalho, 2019a; Monteiro, 2000). The body elements in rhythmic gymnastics are subdivided into jumps, balances and rotations. Each group has different elements organized according to their difficulty degree and elements type. In balances case, in addition to those performed on flat foot and half pointe (*relevê*), this group of elements also includes balances on different body parts, body waves and dynamic elements that require different execution techniques. The rotations group include rotations on flat foot and on *relevê*, as well as rotations connected with heel support and on different body parts that also require different execution techniques. In jumps case, all elements belonging to this group are executed with the same technique, that is, preparation, take-off, flight phase and landing.

To achieve high levels of performance, physical training must be carefully organized and planned, focusing on the development of physical skills and repetition of specific technical movements (Laffranchi, 2001; Lebre, 1993; Román, del Campo, Sabido, & Morenas, 2012). Studies have showed that some physical skills are key for achieving success in RG, such as 1) flexibility as the main motor capacity in RG (Moraru, 2016); 2) strength is highlighted for competitive success and identification of potential talent (Bobo & Sierra, 1998), (Douda, Toubekis, Avloniti, & Tokmakidis, 2008) and Laffranchi (2001); 3) explosive strength as a precondition for proper performance of all basic body elements (Miletić, Katić, & Males, 2004), and 4) motor coordination, also linked with RG success, due to the physical demand coordinated with the apparatus handling (Bozanic & Miletic, 2011). Although flexibility is considered the main motor capacity, it does not guarantee the amplitude and intensity levels required in technical elements execution, especially in the jumps body element group. When performing different types of jumps, gymnasts' jump height should be enough to show the shape of the jump and should not be followed by a heavy landing (FIG, 2022).

The action of jumping, or ballistic performance, is defined as the ability to accelerate a mass as fast as possible and in the shortest possible time, and is considered fundamental to achieve a high sports performance (Pierre Samozino, Morin, Hintzy, & Belli, 2008). The countermovement jump (CMJ) is generally used to evaluate the power of the lower limbs, since this type of movement is similar to several jumping actions performed in different sports (Ávila-Carvalho et al., 2022). The ability to jump is also influenced by the athlete's force-velocity (F-V) profile (Samozino et al. 2008).

The analysis of jumping ability, through the vertical jump, according to the F-V profile evaluation, emerges in the literature following the studies by Samozino et al. (2013), Jiménez-Reyes et al. (2014) and Jiménez-Reyes, Samozino, Brughelli, & Morin (2017). The F-V profile, when related to body mass, represents the ratio between the external force developed and the maximum velocity capacity which is determined by the slope of the F-V profile curve (Jiménez-Reyes et al., 2017, 2014; Samozino, Rejc, di Prampero, Belli, & Morin, 2012). However, there is no real consensus among researchers about the best tests and instruments for the evaluation of vertical jump capacity in RG (Batista, Garganta, & Avila-Carvalho, 2019b). The International Federation of Gymnastics presented test protocols with assessments of flexibility, strength, balance and motor coordination. For the assessment of explosive strength, there are only the Standing Long Jump (horizontal) and the Sargent Jump Tests (vertical), only providing information regarding the jump height (cm). The other motor capacities have several and different tests. Therefore, new possibilities of assessment of explosive strength with complementary information can help coaches to plan the training individually, according to the needs and characteristics of each gymnast.

In this sense, the aim of this study was to analyse the F-V profile during the CMJ of rhythmic gymnasts, identify the magnitude and direction of the imbalance between the two variables, and compare the jumping ability and mechanical variables of gymnasts of different age groups. We hypothesized that the majority of the rhythmic gymnasts would present a force deficit, even though we were not able to quantify its magnitude, and we also expected differences between younger and older gymnasts in F-V profile related variables.

METHODS

The sample was composed by 18 Portuguese female rhythmic gymnasts affiliated to the Portuguese Gymnastics Federation, from clubs in the north of the country, that participated in regional and/or national competitions during the 2020/2021 sports season, in two distinct performance levels: Base (lower level) and 1st division (higher level).

The following inclusion criteria were established for the sample: I. registered in the educational institution participating in the study, and II. absence of injury in the last 6 months and during the evaluation period. After a full explanation of the data collection procedures, gymnasts' legal guardians signed a consent form agreeing with the procedures of this research, since all the gymnasts were under 18 years of age. The study was conducted in accordance with the ethical standards of the Declaration of Helsinki.

Gymnasts were divided in two groups according to their age: G1 included beginner and youth gymnasts, with average age of 10.7 ± 0.7 years (ages between 10 and 12), 5.6 ± 1.7 years of practice and training volume of 13.3 ± 1.6h/week. G2 comprised junior and senior gymnasts with average age of 13.7 ± 1.1 years (ages between 13 and 16), 7.8 ± 2.0 years of practice and training volume of 13.7 ± 1.6h/week. Both groups had 9 gymnasts each.

The data collection was performed in May and June 2021, 8 months after the start of the sports season. Although the evaluation was carried out after a 4-month covid-19 lock down period (January to April 2021), the gymnasts had physical training in home environment during this period, essentially to improve the flexibility and strength levels.

A questionnaire was used to collect information about the gymnasts: chronological age, years of practice and training volume. Then, the following anthropometric measurements were taken: body mass (kg), height (cm), lower limb length (LLL) (cm) and distance from the greater trochanter to the ground in squatting position with knee flexion at 90° (cm). For the measurement of the LLL, gymnasts remained lying down and with their lower limbs fully extended. The LLL consisted of the length between the greater trochanter and the tip of the toes, with the ankle flexed. Gymnasts then squatted down with 90º of knee flexion to measure the distance from the greater trochanter to the ground (Height

90°) (Álvarez, García, da Conceição, & Jiménez-Reyes, 2020; Jiménez-Reyes et al., 2014).

The measurements required to determine the optimal F-V profile during the performance of a vertical jump were the athlete's body mass, jump height, and HPO, which is defined as the difference between the extended LLL (from the greater trochanter to the metatarsal) and the vertical distance between the greater trochanter and the ground in squat position (Álvarez, Reyes, Sousa, Conceição, & García, 2020; Jiménez-Reyes et al., 2014). Body mass was measured with a scale (Diagnostic Scale, Hoffen), and height and lower limbs measures were collected using a measuring tape and a goniometer.

At the beginning of the testing session, gymnasts performed their usual warm-up exercises. Then, they were instructed to stand with their hands on their hips to perform the CMJ. The position of the hands, described previously, was maintained throughout the movement. According to Jiménez-Reyes et al. (2014, p. 4) from this position, "participants will start a downward movement until they reach the squat position with an angle of approximately 90° at the knees followed by a jump with maximum height (immediately to the CMJ)".

Each gymnast performed four maximal CMJs with two to three overload conditions, using weighted vests. Loads were applied progressively, the first load corresponding to five kilograms and each increment was approximately five kilograms. From the moment the participants demonstrated fatigue, and consequently, difficulty in maintaining the correct technique of movement, load was not increased any further. One repetition without load with a 2-minute interval was performed, and three repetitions with additional loads with a 4–5-minute interval between them (Samozino et al., 2013).

For the measurement of jump height and subsequent calculation of the F-V profile, a scientifically validated smartphone app was used: *Myjump2* (Balsalobre-Fernández, Glaister, & Lockey, 2015).This instrument is easy to apply in the field since it immediately provides the desired variables: F0 (theoretical maximal force), V0 (theoretical maximal velocity) e Pmax (theoretical maximal power developed by the lower limbs); as well as the F-Vimb (difference between the current and the ideal F-V profile) of each gymnast (Jiménez-Reyes, Samozino, Pareja-Blanco, et al., 2017; Morin & Samozino, 2016; Samozino et al., 2012).The method used by *Myjump2* is based on the fundamental laws of mechanics, and proposes an accurate and reproducible field method to assess lower limb power with a precision similar to that obtained with specific ergometers (such as the force platform) (Samozino et al., 2008). This instrument can be used to measure the athletes' performance without expensive laboratory equipment or moving the athletes from their usual practice zone. It allows assessing the external force developed and the maximum speed capacity related to body mass (Jiménez-Reyes, Samozino, Brughelli, et al., 2017; Jiménez-Reyes et al., 2014; P. Samozino et al., 2013), thus personalizing the results to the characteristics of individual athletes (Ávila-Carvalho et al., 2022).

All data obtained were analysed using the statistical program *Statistical Package for the Social Sciences* (SPSS) 27.0, and the significance level was set at 5% ($p \leq 0.05$). Descriptive statistics were presented using the mean, standard deviation and minimum and maximum values. An exploratory data analysis was performed to determine the existence of assumptions for the use of parametric statistics through the *Shapiro-Wilk* normality tests. According to the normality test applied, the variables were considered non-normal. Therefore, we used the nonparametric *Mann Whitney* test for data comparisons.

RESULTS

Table 1 shows the morphological (body mass, height, lower limb length - LLL and Height 90º) and training characteristics (years of practice and weekly training volume) of the whole sample and according to age group (G1- beginner and youth gymnasts with ages between 10 and 12; and G2 - junior and senior gymnasts with ages between 13 and 16).

No significant differences were found between groups in the training characteristics (years of practice and training volume), while in morphological characteristics, the groups differ in all analysed variables (Table 1).

Myjump2 was used to plot the gymnasts' F-V profile, and provided variables related to jumping ability (CMJ, Pmax, V0, F0), as well as the direction and magnitude of the imbalance between force and velocity capabilities (F-Vimb). Table 2 shows the performance and mechanical variables of the vertical jump of the entire sample and by age groups (G1 and G2).

According to Table 2, no significant differences were found in CMJ height, as well as in the variables related to the F-V profile between the two groups (G1 versus G2), except for the HPO measure.

Table 1
Morphological and training characteristics of whole sample and by age group

Age Group	Whole Sample (n=18)		Beginners/Youth G1 (n=9)		Juniors e Seniors G2 (n=9)		Mann-Whitney test
Variables	$\bar{x}$±sd	Min-Max	$\bar{x}$±sd	Min-Max	$\bar{x}$±sd	Min-Max	
Age (years)	12.2±1.8	10-15	10.7±0.7	10-12	13.7±1.1	12-16	**0.000***
Years of practice (years)	6.7±2.1	2.5-11.0	5.6±1.7	2.5-7.0	7.8±2.0	5.0-11.0	0.083
Training volume (h/week)	13.5±1.5	12.0-15.0	13.3±1.6	12.0-15.0	13.7±1.6	12.0-15.0	0.460
Body mass (kg)	42.9±9.3	23.7-56.6	36.7±7.9	23.7-48.3	49.0±6.2	39.3-56.6	**0.001***
Height (cm)	151.3±11.8	127-170	142.3±9.0	127-156	160.2±6.0	151-170	**0.003***
LLL (cm)	99.2±9.3	81.9-116.0	92.6±7.1	81.9-104.0	105.7±6.1	98.4-116.0	**0.001***
Height 90º (cm)	63.4±6.4	54.0-77.3	58.6±4.4	54.0-66.7	68.1±4.3	62.0-77.3	**0.001***

Legend – LLL: lower limb length; Height 90º: in squatting position with knees bent at 90º; G1: Group 1; G2: Group 2; Min-Max: minimum and maximum value; $\bar{x}$: average; sd: standard deviation; * p≤0.05: significant differences between groups.

Table 2
Performance and mechanical variables of whole sample and according to age group

Age Group	Whole sample (n=18)		Beginners/Youths G1 (n=9)		Juniors e Seniors G2 (n=9)		Mann-Whitney
Variables	x̄±sd	Mín-Máx	x̄±sd	Mín-Máx	x̄±sd	Mín-Máx	test
HPO (m)	36.0±4.9	26.3-47.1	33.9±5.0	26.3-40.0	38.1±4.0	33.0-47.1	**0.034***
CMJ (cm)	28.3±4.7	22.9-40.7	26.6±3.2	22.9-32.1	29.9±5.6	23.0-40.7	0.083
Pmax (W/kg)	24.5±5.9	18.2-38.2	22.5±4.8	18.2-32.8	26.5±6.6	18.5-38.2	0.408
V0 (m/s)	3.5±1.6	2.0-7.2	3.1±1.2	2.0-6.0	4.0±1.8	2.2-7.2	0.315
F0 (N/kg)	29.9±6.2	21.2-44.8	31.0±6.7	22.0-44.8	28.8±5.9	21.3-38.2	0.633
% F-Vimb	39.2±24.6	1.3-79.5	37.2±23.2	3.5-73.8	43.2±26.6	1.3-79.5	0.897

Legend – HPO: distance travelled by the center of mass during push-off; CMJ: Countermovement jump; Pmax: maximum power developed by the lower limbs; V0: maximum velocity; F0: maximum force; F-Vimb: difference between the current and the ideal profile of each gymnast; Min-Max: minimum and maximum value; x̄: average; sd: standard deviation; * $p \leq 0.05$: significant differences between groups; G1: Group 1; G2: Group 2.

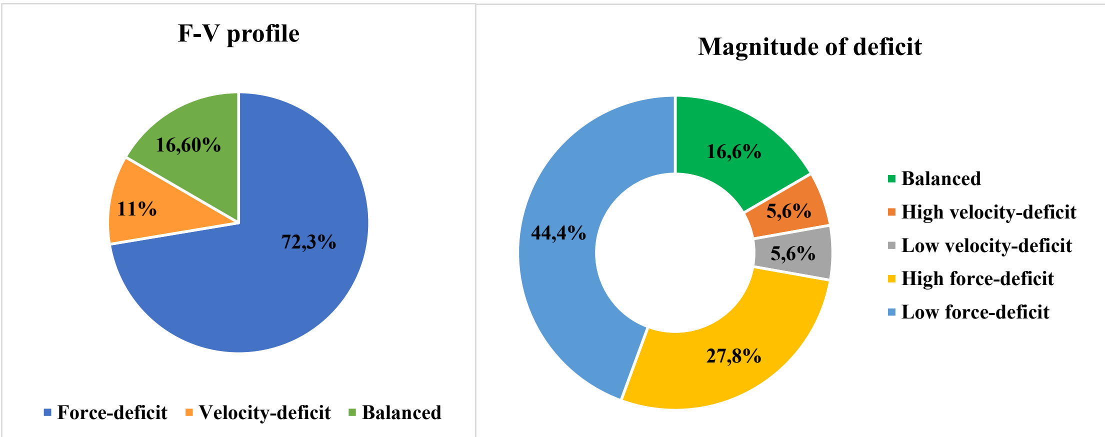

Figure 1: Percentage value of force-velocity (F-V) profile deficit and magnitude in all gymnasts.

Figure 1 shows the percentage of gymnasts that presented each classification. Gymnasts were classified according to the magnitude of F-Vimb, as follows: >40%, high velocity or force deficit; between 40% and 10%, reduced force or velocity deficit; and <10% balanced (Jiménez-Reyes et al, 2017). We highlight that 72.3% of the gymnasts' present force deficit and 11% have velocity deficit. Regarding the deficit magnitude, it is important to detail that 44,4% presented low force deficit and 27.8% high force deficit. We also analysed the classification according to the magnitude of the deficit of the gymnasts according to age group (G1 - Beginners/Youths and G2 - Juniors/Seniors) and there were no differences between groups.

Finally, we analysed the gymnasts according to the type of deficit presented. Thus, Table 3 shows the morphological, training, jumping performance and mechanical characteristics of each group, organized by type of deficit verified.

When we compare the two groups, significant differences were found in variables F0 and V0 (Table 3).

Table 3
Morphological, training and jump variables according to the type of deficit (force or velocity) verified in the force-velocity profile.

F-V profile Variables	Force deficit (n=16)		Velocity deficit (n=2)		Mann-Whitney test
	x̅±sd	Min-Max	x̅±sd	Min-Max	
Age (years)	12.1±1.7	10-15	13.0±2.8	11-15	0.549
Years of practice (years)	6.8±2.2	2.5-11.0	6.0±1.4	5.0-7.0	0.641
Training volume (h/week)	13.3±1.5	12.0-15.0	15.0±0.0	15.0-15.0	0.261
Body mass (kg)	42.7±8.9	23.7-56.2	44.5±17.2	32.3-56.6	0.837
Height (cm)	151.3±10.6	127-164	151.5±16.3	133-170	0.941
HPO (m)	36.0-5.1	26.3-47.1	36.0±4.2	33.0-39.0	0.941
CMJ (cm)	28.3±5.0	22.9-40.7	27.7±0.3	27.6-27.9	0.941
Pmax (W/kg)	24.9±6.2	18.2-38.2	21.2±1.0	20.5-21.9	0.641
V0 (m/s)	3.7±1.6	2.3-7.2	2.1±0.1	2.0-2.2	**0.013***
F0 (N/kg)	28.4±4.7	21.2-35.2	41.5±4.7	38.2-44.8	**0.013***
% F-Vimb	39.6±25.8	1.3-79.5	36.4±17.1	24.3-48.5	0.941

Legend – HPO: distance travelled by the center of mass during push-off; CMJ: Countermovement jump; Pmax: maximum power developed by the lower limbs; V0: maximum velocity; F0: maximum force; F-Vimb: difference between the current and the ideal profile of each gymnast; Min-Max: minimum and maximum value; x̅: average; sd: standard deviation; * $p \leq 0.05$: statistically significant differences between groups.

DISCUSSION

The aim of this study was to analyse the F-V profile during the CMJ of rhythmic gymnasts, identify the magnitude and direction of the imbalance between the two variables, and compare the jumping ability and mechanical variables of gymnasts of different age groups. Our first hypothesis was confirmed since 72.3% of gymnasts presented force deficit. This work allowed us to quantify the magnitude of this deficit (44.4% - low force deficit and 27.8% - high force deficit). We also expected differences between younger and older gymnasts in F-V profile related variables, which was not verified in this work.

The age groups have different ages and morphological characteristics. However, their years of practice and training volume did not differ. The studied groups included gymnasts of different age groups: beginner and youth gymnasts (G1 - ages 10-12) and junior and senior gymnasts (G2 - ages 13-16). As a result, morphological differences were expected since older individuals are usually taller and heavier, similar to previous studies (Pinto et al., 2018). Regarding the training characteristics, the lack of differences may highlight a continuous work in terms of training volume across ages, regardless of the level of competition. The study by Dallas, Pappas, Ntallas, Paradisis, & Exell, 2020 evaluated gymnasts of ages lower than the gymnasts in G1, but with years of practice close to that presented by the gymnasts in our study, which highlights a clear early specialization, similar to other gymnastics disciplines. In fact, both groups included base and 1st division gymnasts and the groups selection was based only on age.

Another study found differences in years of practice and training volume in Portuguese gymnasts of different performance levels, and with ages similar to our sample (Batista et al., 2019b). However, these authors used a much larger sample (n=164), which allowed for higher generalization, and three competitive levels (Base, 1st division and Elite), which supports the differences found.

Among the variables of jump performance, only the HPO diverged between groups. This difference was expected since HPO is directly related to the anthropometric variables, specially the LLL. The remaining F-V profile variables showed no significant differences between age groups. Previous studies also found no differences in explosive force of lower limbs between distinct maturational levels (Pinto et al., 2018), but the sample included sedentary school girls. The jump height of 10 to 19-year-old gymnasts indicated a gradual increase in jump height with age, but also without significant differences (Gateva, 2013). Nevertheless, all the mean values reached by G2 were higher than in G1, except in the F0 variable, perhaps due to the lack of strength training in their usual training routine. This indicates that our sample developed the jump height, V0 and Pmax capacities across age groups, except for F0. Usually, younger rhythmic gymnasts spend more training time learning new skills and body movements than the older ones. The limited level of physical preparation is one of the main problems in the RG practice, and is often related to the greater emphasis placed by coaches on technical preparation (Gateva, 2013). Coaches plan gymnasts' training that covers all RG components, that is, artistic body technique, apparatus technique and physical preparation. In addition, training should be organized with respect to the gymnasts' age. This investigation highlights the lack of specific physical preparation for improving jumping performance in RG, which may be a result of repeated training adaptations where physical preparation is one of the components most frequently neglected.

Despite no statistically significant differences between jump height and F-V profile related variables between age groups, our results show a tendency for rhythmic gymnasts' jumping performance to increase with age. Younger gymnasts (8.0 ± 0.8 years old) in another study presented lower CMJ values than ours (Dobrijević, Moskovljević, Marković, & Dabović, 2018). Eleven-year-old gymnasts achieved higher values than our G1 (Gateva, 2013) and Portuguese 1st division gymnasts with ages corresponding to the G2 also jumped higher than this group (Batista et al., 2019b). Nevertheless, these two studies performed vertical jumps with free arms, allowing an execution with indirect forces. Spanish senior gymnasts obtained a lower CMJ value (24.6 ± 3.6cm) (Rodríguez, Sampedro, Rivilla-García, & Bofill 2010) than the G2. Older dancers (18.9 ± 1.3 years old) presented a lower CMJ height than G2 gymnasts in our sample (Álvarez et al. 2020). These data are meant to compare both groups of our sample with other published results from gymnasts and dancers, trying to understand their level. This suggests that further studies are required that will lead to more concrete conclusions that can be applied to RG reality. For instance, it would be interesting to investigate the influence of jump height improvements in specific RG technical elements, namely the jumps, evaluated according to the RG Code of Points.

Regarding the Pmax variable, experienced ballet dancers (average age of 18.9 years) and senior gymnasts, respectively (Rodríguez et al., 2010, Álvarez et al. 2020) achieved lower Pmax values than the values obtained by G2. The relativization of body mass could be a factor that explains the values reached.

Finally, F0 and V0 differ significantly when the morphological, training and jump variables were compared according to the type of deficit presented. These findings clearly show that knowledge of the F-V profile facilitates the detection of force and/or velocity deficits (Samozino et al. 2014), and it should be analysed regularly to achieve better accuracy and balance between force and velocity capabilities (Jiménez-Reyes et al., 2017a). A larger sample would be required to better understand the magnitude of the deficit according to age group (G1 - Beginners/Youths and G2 - Juniors/Seniors). Nevertheless, this highlights that there are deficits across all ages, perhaps due to the lack of strength training since early ages.

Most gymnasts presented a force deficit (72.3%), while 11% had a velocity deficit. In fact, two studies found that entire samples of 46 ballet dancers (Álvarez, Fuentes García, et al., 2020) and 87 dancers (Álvarez, Reyes, et al., 2020) presented force deficit. This information could be used for planning a more specific training program to improve jump performance (Álvarez et al., 2020; Jiménez-Reyes et al., 2017a; Jiménez-Reyes et al., 2019). In fact, jumping ability was improved through a training program based on F-Vimb as it is more efficient than training programs guided by increasing Pmax (Jiménez-Reyes, Samozino, Brughelli, et al., 2017). No studies were found in the literature about F-V profile or training programs directed to the F-Vimb of RG athletes. However, there are studies that have proven effectiveness of the training programs that improve jumping performance of GR athletes (Dallas et al., 2020; Dobrijević et al., 2018; Piazza et al., 2014; Rodríguez et al., 2010). A 16-week training program showed improvements in CMJ performance, maximum speed and power of ballet dancers (Ávila-Carvalho et al., 2022). The present evaluation moment was performed after a Covid-19 lockdown period (January to April/2021). However, gymnasts had physical training in home environment during this period, essentially to improve the flexibility and strength levels, and have not been in a period of recovery, rest or physical inactivity. Nevertheless, it would be interesting to apply a training program based on the F-V profile of rhythmic gymnasts in upcoming investigations.

In this sense, based on our results and the studies presented, the imbalance of the F-V profile is an important parameter to be considered when we evaluate the jump ability and plan the gymnasts' training. It is known that the action of jumping is highly required in both training and competition routines of RG athletes. According to deficits found in our study, where most gymnasts presented a force deficit, and considering the demands of the sport and each athlete, it becomes essential to include strength training in the usual training routines of rhythmic gymnasts.

LIMITATIONS

We must acknowledge some limitations found in this work. The small sample size is related to the fact that this study was conducted in a pandemic year (covid-19), reflecting the difficulty of integrating gymnasts from other regions and other clubs in Portugal. Another limiting factor is related to the data collection period, which took place in May and June 2021, right after the lockdown period that lasted from January to April 2021. We must highlight that this is not an investigation intended to assess the consequences of the lockdown period for jumping performance of rhythmic gymnasts since only one evaluation moment was performed. The fact that we were not able to implement a specific training protocol that would allow us to understand the changes promoted in the jump height, in the mechanical variables and in the F-V profile is a limitation that would be interesting to see solved in future studies.

Thus, we suggest that further studies can be conducted using a higher number of gymnasts, different ages and performance levels. Furthermore, individualized training plans, oriented to the individual F-V profile, can be tested for the improvement of deficits between these two abilities and consequent improvement of rhythmic gymnasts' jump performance.

Finally, we also suggest the use of specific RG jumps to understand the influence of jump height on specific RG technical elements.

CONCLUSIONS

The rhythmic gymnasts from clubs in the north of Portugal, of different age groups (G1-Beginner/Youth and G2-Junior/Senior), presented similar years of practice and training volume. However, the groups differ in all morphological variables analysed (body mass and height).

Furthermore, regarding the vertical jump performance and the magnitude of the imbalance between force and velocity capabilities, the groups also did not show statistically significant differences in jump height (CMJ) and in the variables related to F-V profile. When gymnasts were divided by the type of deficit, differences were found in F0 and V0 variables, suggesting that future investigations should evaluate each deficit separately.

Based on the analysis of the F-V profile of all gymnasts, we verified that 73.2% presented force deficit, while 11% had velocity deficit. In addition, different magnitudes of deficits were observed. For these reasons, coaches should plan gymnasts' training in such a way that it covers all RG components and is organized with respect to the gymnasts' age. This investigation highlights the lack of specific physical preparation for improving jumping performance in RG, which may be a result of repeated training adaptations where physical preparation is one of the components most frequently neglected.

We found a small number of research studies evaluating jump performance using the F-V profile, and specifically, using the *MyJump2* app as an analysis tool. Our study provided information on the effectiveness of this methodology and encourages the use of F-Vimb variable to identify the force or velocity deficit of jumps in gymnasts' performance.

Considering the results found, this study may be useful for gymnastics coaches who wish to assess the lower limb force of their team's gymnasts in a practical way in the training environment. Furthermore, we suggest that fitness (and/or a supplementary training program) should be implemented in addition to the usual training routine, and that it should be planned, whenever possible, on an individual basis and be guided by the deficit presented by each gymnast.

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Corresponding author:

Luciana Ferreira Melo de Sá
Faculty of Sport, University of Porto
Rua da Boavista, 682, 3° Dir. Tras. - 4050-105, Porto, Portugal
(+351) 930620636
luciana.fmelosa@gmail.com

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