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# Determinants of Sports Performance in Young National Level Swimmers: A Correlational Study between Anthropometric Variables, Muscle Strength, and Performance

Daniel A. Marinho[1,2], Henrique P. Neiva[1,2], Luis Branquinho[1] and Ricardo Ferraz[1,2]

[1]University of Beira Interior, Department of Sport Sciences, Covilhã, Portugal, [2]Research Centre in Sports, Health and Human Development, CIDESD, Portugal

**Abstract**

This study aimed to verify how the anthropometric characteristics and muscle strength levels of young swimmers of both sexes can influence sport performance on 50 m and 400 m freestyle events; 184 swimmers, aged between 13 and 16 years (mean±standard deviation: 14.64±0.80 years, 1.69±0.08 m height, 58.71±7.87 kg in body weight) participated in the study. The evaluation took place over two days. On Day 1, each subject was assessed with regard to anthropometric measures (i.e., body mass, height, wingspan); subsequently, the wingspan/height index and the body mass index, in addition to that, the strength of the lower and upper limbs were measured. On Day 2, swimming performances in 50m and 400m were evaluated, in the morning and afternoon, respectively. For the analysis of the results, the swimmers were divided into two groups, according to the competitive level (i.e., Group A and B). No anthropometric differences were found between male swimmers in the A and B Groups. However, female swimmers in Group A showed significant differences ($p<0.05$) in height and weight that positively affected performance. With regard to muscle strength, male Group A swimmers have a tendency towards higher values, with statistically significant differences in medicine ball throw. Differences in sports performance seem to be related to the biomechanical parameters of swimming, with higher values of the swimming index in male swimmers and gestural frequency in female swimmers. The performance level of young swimmers seems to be determined by anthropometric and muscle strength variables.

*Keywords: freestyles events, anthropometric measures, muscle strength, biomechanical parameters*

## Introduction

Swimming is characterized as a cyclical modality in which the performance can be represented by the time that the swimmer takes to complete the predicted distance under the established rules (Mujika & Padilla, 2000). Previous research has linked swimming performance to biomechanical (Alberty, Sidney, Pelayo, & Toussaint, 2009; Zamparo et al., 2012) and physiological parameters (Holfelder, Brown, & Bubeck, 2013; Palayo, Alberty, Sidney, Potdevin, & Dekerle, 2007). In addition, other investigations (Barbosa et al., 2010; Figueiredo, Pendergast, Vilas-Boas, & Fernandes, 2013) have indicated that these parameters are likely interconnected and provided answers that could help explain performance in different swimming events. The anthropo-

Correspondence:

R. Ferraz
University of Beira Interior, Department of Sport Sciences, Convento de Santo António, 6201-001 Covilhã, Portugal
E-mail: ricardompferraz@gmail.com

metric characteristics of the swimmers, due to the recognized relationship with drag and propulsion, also seem to be determinants of performance (Morais et al., 2012).

A study conducted with young male swimmers (Lätt et al., 2009) found a significant relationship between body height and arm span with time in 400 m freestyle events with young male swimmers. Another investigation (Morais et al., 2012) found a strong correlation between arm span, height, chest circumference, hand surface area, foot surface area, trunk cross area, and the results of 100 m freestyle in young swimmers of both sexes. Furthermore, the association between anthropometric characteristics and sports performance was also considered a relevant indicator for identifying talents in the athletes' long-term development process (Sammoud et al., 2018). A previous study suggested that anthropometric characteristics are among the critical factors used as early predictors of talented athletes (Morais, Silva, Marinho, Lopes, & Barbosa, 2017). In addition, young male swimmers are characterized as taller and heavier, with greater wingspans in comparison to young female swimmers, and these characteristics play a major role in the differences observed in performance between genders (Schneider & Meyer, 2005). Correlations between anthropometric characteristics and swimming speed in young male and female swimmers have also been previously reported (Geladas, Nassis, & Pavlicevic, 2005).

However, particularly over short distances (i.e., 50 m ), performance was strongly correlated to muscle strength and power, with the ability to apply force in the aquatic environment a crucial factor for success during competition (Crowley, Harrison, & Lyons, 2017). In this regard, a previous study inferred that the characteristics of strength and power of the lower limbs were characterized as predictors of performance in swimming (West, Owen, Cunningham, Cook, & Kilduff, 2011), distinguishing swimmers with different levels of performance (Jones, Pyne, Greg Haff, & Newton, 2018). In addition, positive correlations between muscle strength and upper limb power with swimming performance have been shown in the literature (Garrido et al., 2010a), and this topic still needs further investigation, especially regarding young people. Young athletes of a highly competitive level also present higher values of gestural frequency (GF) (Craig & Pendeegast, 1979), cycle distance (CD), and swimming index (SI) (Lätt et al., 2009; Morais et al., 2013), which also represent excellent predictors of performance (Jürimäe et al., 2007; Lätt et al., 2009).

The literature has reported a strong association between anthropometric characteristics, strength, power, and performance in pure sports swimming; however, to the best of our knowledge, there is a gap in the literature on the impact of these characteristics on the performance of young swimmers. Although several studies (Geladas et al., 2005; Jürimäe et al., 2007; Sammoud et al., 2018) have investigated the importance of anthropometric characteristics in swimming performance in different age groups, knowledge about the effects of some variables on performance remains unclear. In addition, few studies have made specific comparisons between swimmers of different sexes and similar chronological ages who belong to different competitive levels. In this sense, the present study aimed to verify how the anthropometric characteristics and strength levels of young swimmers of different sexes can influence their sports performance in 50m and 400m freestyle events at different levels.

## Methods

### Study Design

The present investigation consisted of a cross-sectional study that aimed to verify the impact of anthropometric characteristics and strength levels on sports performance in young swimmers (14–16 years) at a national level, in the 50 m and 400 m freestyle swimming events. Thus, all participants were analysed with regard to their anthropometric characteristics (height, body mass, body mass index, and wingspan), 50m and 400m freestyle swimming performance, and biomechanical variables.

### Participants

One-hundred-and-eighty-four (184) swimmers, aged between 13 and 16 years (mean±standard deviation: 14.64±0.80 years, 1.69±0.08 m height, 58.71±7.87 kg in body weight) participated in the study. These swimmers belonged to the U-16 and U-15 levels, 92 of whom were female (14.08±0.56 years; 1.64±0.06 m height; 53.37±4.97 kg weight) and 92 of whom were male (15.21±0.60 years; 1.75±0.07 m in height; 64.06±6.49 kg weight). The sample was composed of members familiar with the practice of the competitive sport of swimming and the methodologies used for evaluation. After being selected, all swimmers and guardians were informed of the procedures, and only those who agreed to sign the informed consent form participated in the study. In addition, the swimmers were informed that they could withdraw from the study at any time. All procedures were carried out following the Helsinki Declaration.

The participants in the study were selected because they were a regular presence at internships carried out by the Portuguese Swimming Federation at the beginning of the season between 2014 and 2018, where the highest scorers in the national championships held at the end of the previous season were present. The swimmers were divided into two groups for the analysis of the results, according to the International Swimming Federation (FINA) score obtained in the 400 m freestyle. Therefore, all swimmers with a time shorter than that corresponding to 500 FINA points (296 s for female swimmers and 268 s for male swimmers) were considered to belong to Group A (n=82), while the remainder of the swimmers were considered to belong to Group B (n=102).

### Procedures

During the internship period, the evaluations were performed, which took two days and comprised four training and evaluation sessions. All individuals were assessed during the sports season (October). The tests were carried out with sufficient rest between sessions to avoid energy expenditure and accumulate fatigue before the strength and specific performance tests, which could negatively influence performance.

On the day of the assessment, after arriving at the site and five minutes of rest, each subject was assessed with regard to anthropometric measures such as body mass, height, wingspan and, subsequently, the wingspan/height index (WHI) and the body mass index (BMI). Then the subjects performed the evaluation of the strength of the lower limbs through the horizontal jump. In the afternoon session, the

subjects performed the assessment of the strength of the upper limbs by throwing a medicine ball. On the following day, they performed the performance evaluation, with the 50 m freestyle in the morning and the 400 m freestyle in the afternoon. With these results, the critical swimming speeds were later calculated.

*Anthropometric Measures*

All measures were assessed according to international standards for anthropometric assessment (Marfell-Jones, Olds, Stewart, & Lindsay Carter, 2006) and were obtained before any physical performance test. Participants were barefoot and dressed in underwear or as little clothing as possible during the assessment. To measure body height (in m), a precision stadiometer with a scale of 0.001 m was used. BMI was obtained by dividing the body mass value by the square of height. Wingspan was determined by measuring the athletes with a tape measure placed on a precision wall with a scale of 0.001 m.

*Strength Assessment*

To assess the strength of the lower limbs, each swimmer performed three horizontal jumps, with a three-minute pause between each jump. The swimmers stood with their legs shoulder-width apart and, with the help of their arms, they pushed their body forward, trying to move as far as possible. For analysis, there was an average between the three jumps performed and the best jump performed. The responsible investigator relied on the collaboration of the national technical director of the pre-junior classes to verify the correct position of the swimmers in the execution of each jump. The reliability of the performance of the horizontal jump was determined by the intraclass correlation coefficient (ICC), with an average value of 0.9 and a coefficient of variation (CV) of 3.6%.

The medical ball launch (BM) was measured through the horizontal distance reached after launching a 3 kg ball. To perform the evaluation, each subject sat on the floor with their backs against a rectilinear structure (wall). Each individual held the ball in front of them with both hands (close to the chest) to achieve the greatest amplitude, speed, and distance possible and without rotating the torso and hips during the execution of movements. Two experienced evaluators assisted in the correct verification of the launch and in the obtained range. Three attempts were counted with a 3kg medicine ball, with a one-minute rest period between each throw. The distance from the starting position to where the ball touched the ground was measured (Castro-Piñero et al., 2009). Overall, the launch of the medicine ball showed an average ICC of 0.9 and a CV of 2.8%.

Both the assessment of the horizontal jump and the launch of the medical ball were also recorded on camera, and the confirmation of the observed values was obtained by the subsequent analysis of the footage using Kinovea® software (version 0.8.15).

*Swimming Performance Evaluation*

The evaluation of specific swimming performance was performed by simulating the 50 m freestyle and 400 m freestyle swim. The 50 m freestyle swim was performed in the morning, while the 400 m freestyle was performed in the late afternoon to provide sufficient time for the partic-

ipants to recover. After performing a 1000 m warm-up using the usual structure based on the protocols described by Neiva, Marques, Barbosa, Izquierdo and Marinho (2014), each swimmer performed a simulated race (50 or 400 m). The evaluation protocols were applied in a 25 m covered swimming pool at an average temperature of 28º C and an average humidity below 70%, with departure from the block and official voices. The timing was recorded using a stopwatch (Finis 3x100 Stopwatch, Livermore, California). The swims were also filmed and subsequently analysed using Kinovea® software (version 0.8.15). Biomechanical variables were evaluated for both simulations. Thus, the evaluation of gestural frequency (GF) was performed using a chronometer in three stroke cycles and later converted to units of measurement in the international system (Hz). Cycle distance (CD) was measured by estimation using the following equation (Craig & Pendeegast, 1979):

$$CD = v/GF \quad (1)$$

Where CD is the cycle distance (m.c-1), v is the average speed of the swimmer (m.s-1), and GF is the gestural frequency of swimming. The swimming index (SI) was then estimated using the following equation (Costill et al., 1985):

$$SI = CD \times v \quad (2)$$

Where SI represents the swimming index ($m^2$ c-1 s-1), CD is the cycle distance (m.c-1), and v is the average swimming speed (m.s-1). The speed variables (GF, CD, and SI) were evaluated in the second 25 m of each 50 m (either in the 50 m event or 400 m event) and used to determine the average measure in the 400 m freestyle swim based on analysis in the Kinovea® software (version 0.8.15).

*Statistical Analysis*

Data analysis was performed using the IBM SPSS statistical software (Statistical Package for Social Sciences), version 22.0, for Microsoft Windows (Armonk, NY, EU: IBM Corp.). The level of significance was set at 5%. The calculation of means, standard deviations, differences, and confidence intervals (95% CI) were performed using standardized statistical methods. Reliability was measured by CV and ICC in the three tests performed for the launch of the medicine ball and for the horizontal jump. The Kolmogorov-Smirnov test (n>30) was used to verify that the data had a normal distribution. Thus, parametric tests were used for data analysis. To compare the results obtained among the juveniles of the best sports level with the rest, the t-test for independent samples was used. For the bivariate correlations, we used Pearson's coefficient, and the determination coefficient ($r^2$) was also calculated. The ratio was considered very high for values between 0.90 and 1.00, high for values between 0.70 and 0.90, moderate between 0.50 and 0.70, low for values between 0.30 and 0.50 and small for values between 0.10 and 0.30. The effect size was also calculated using Cohen's d, for comparison between the groups analysed (Cohen, 2013). The magnitude of the effect was considered trivial (<0.2), small (0.2-0.59), moderate (0.60-1.19), high (1.2-1.99) or very high (>2.00) (Hopkins, Marshall, Batterham, & Hanin, 2009).

## Results

Table 1 shows the values of the anthropometric characteristics assessed in male swimmers in Group A and Group B. No statistically significant anthropometric differenc-

**Table 1.** Comparison between the mean values±standard deviation of the anthropometric variables of male and female swimmers belonging to Group A and Group B

| Variables | Male Swimmers | | | | | | Female Swimmers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A (n=28) M±SD | B (n=64) M±SD | Difference (CI 95%) | | p-value | Effect size M±SD | A (n=54) M±SD | B (n=38) M±SD | Difference (CI 95%) | | p-value | Effect size |
| | | | Higher | Lower | | | | | Higher | Lower | | |
| Height (m) | 1.75 ± 0.08 | 1.75 ± 0.06 | -0.03 | 0.02 | 0.85 | 1.75 ± 0.08 | 1.65 ± 0.05 | 1.62 ± 0.06 | 0.01 | 0.06 | 0.01** | 0.53 |
| Weight (kg) | 64.73 ± 6.98 | 63.76 ± 6.30 | -1.61 | 3.54 | 0.46 | 64.73 ± 6.98 | 54.28 ± 4.74 | 52.08 ± 5.07 | -0.20 | 4.61 | 0.07 | 0.45 |
| BMI (kg/m2) | 21.15 ± 1.26 | 20.80 ± 1.41 | -0.29 | 0.99 | 0.28 | 21.15 ± 1.26 | 19.93 ± 1.50 | 19.91 ± 1.50 | -0.59 | 0.61 | 0.98 | 0.01 |
| Wingspan (m) | 1.80 ± 0.10 | 1.81 ± 0.07 | -0.04 | 0.02 | 0.57 | 1.80 ± 0.10 | 1.66 ± 0.06 | 1.65 ± 0.08 | -0.15 | 0.05 | 0.32 | 0.14 |
| Wingspan/ Height | 1.03 ± 0.02 | 1.03 ± 0.02 | -0.02 | 0.01 | 0.61 | 1.03 ± 0.02 | 1.01 ± 0.03 | 1.02 ± 0.03 | -0.02 | <0.01 | 0.06 | 0.34 |

Legend: BMI - body mass index; CI - Confidence interval

es were detected between male swimmers. Furthermore, Table 1 shows the values of the anthropometric characteristics assessed in female swimmers in Group A and Group B.

The values showed a small magnitude difference in height, with Group A registering higher values than Group B.

Table 2 shows the muscular strength values of the up-

**Table 2.** Comparison between the mean values (± standard deviation) of the muscle strength variables of male and female swimmers belonging to Group A and Group B

| Variables | Male Swimmers | | | | | | Female Swimmers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A (n=28) M±SD | B (n=64) M±SD | Difference (CI 95%) | | p-value | Effect size | A (n=54) M±SD | B (n=38) M±SD | Difference (CI 95%) | | p-value | Effect size |
| | | | Higher | Lower | | | | | Higher | Lower | | |
| Horizontal jump - average (m) | 2.22 ± 0.16 | 2.14 ± 0.22 | -0.01 | 0.16 | 0.09 | 0.40 | 1.70 ± 0.18 | 1.71 ± 0.18 | -0.10 | 0.07 | 0.74 | 0.06 |
| Horizontal jump - maximum (m) | 2.27 ± 0.16 | 2.19 ± 0.23 | -0.01 | 0.17 | 0.08 | 0.38 | 1.75 ± 0.19 | 1.77 ± 0.20 | -0.11 | 0.06 | 0.62 | 0.20 |
| Medical ball throw - average (m) | 4.81 ± 0.39 | 4.50 ± 0.56 | 0.11 | 0.52 | <0.01** | 0.61 | 3.20 ± 0.43 | 3.17 ± 0.37 | -0.16 | 0.23 | 0.72 | 0.08 |
| Medical ball throw - maximum (m) | 5.02 ± 0.39 | 4.67 ± 0.59 | 0.13 | 0.57 | <0.01** | 0.66 | 3.38 ± 0.45 | 3.31 ± 0.39 | -0.14 | 0.27 | 0.52 | 0.17 |

per and lower limbs in young male and female swimmers, respectively. There was a tendency toward higher values in the horizontal jump and in the throw of the medicine ball in the case of male swimmers, with moderate effects in the throw of the medicine ball. No statistically significant differences were observed for the female swimmers.

With regard to swimming performance, Table 3 shows that male swimmers in Group A registered better performance in the 50 m and 400 m freestyle than male swimmers in Group B, with a significantly higher SI, even without significant differences in GF and CD. The critical speed was also significantly higher for individuals in Group A

**Table 3.** Comparison between the mean values (± standard deviation) of the swimming performance variables in the 50m freestyle and 400m freestyle, as well as the gestural frequency (GF), cycle distance (CD), swimming index (SI) and critical speed of male and female swimmers belonging to Group A and Group B

| Variables | Male Swimmers | | | | | | Female Swimmers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A (n=28) M±SD | B (n=64) M±SD | Difference (CI 95%) | | p-value | Effect size | A (n=54) M±SD | B (n=38) M±SD | Difference (CI 95%) | | p-value | Effect size |
| | | | Higher | Lower | | | | | Higher | Lower | | |
| 50m freestyle (s) | 27.15 ± 0.65 | 28.01 ± 0.82 | -1.28 | -0.42 | <0.01** | 1.12 | 30.88 ± 0.82 | 31.58 ± 1.48 | -1.11 | -0.29 | <0.01** | 0.54 |
| 50m GF (5-20m) (Hz) | 52.40 ± 5.15 | 52.08 ± 4.45 | -1.74 | 2.39 | 0.76 | 0.07 | 50.04 ± 4.45 | 50.09 ± 4.70 | -1.99 | 1.89 | 0.96 | 0.01 |
| 50m CD (m.c-1) | 2.10 ± 0.29 | 2.02 ± 0.18 | -0.01 | 0.18 | 0.08 | 0.37 | 1.92 ± 0.19 | 1.87 ± 0.20 | -0.04 | 0.13 | 0.28 | 0.26 |

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| Variables | Male Swimmers | | | | | | Female Swimmers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A (n=28) M±SD | B (n=64) M±SD | Difference (CI 95%) | | p-value | Effect size | A (n=54) M±SD | B (n=38) M±SD | Difference (CI 95%) | | p-value | Effect size |
| | | | Higher | Lower | | | | | Higher | Lower | | |
| 50m SI (m2 c-1 s-1) | 3.85 ± 0.88 | 3.51 ± 0.33 | 0.12 | 0.54 | <0.01** | 0.62 | 3.05 ± 0.36 | 2.90 ± 0.38 | -0.05 | 0.35 | 0.13 | 0.41 |
| 400m freestyle (s) | 262.10 ± 3.46 | 277.49 ± 7.97 | -18.38 | -12.40 | <0.01** | 2.24 | 290.87 ± 4.17 | 308.45 ± 8.83 | -20.45 | -14.72 | <0.01** | 2.30 |
| 400m GF (Hz) | 36.04 ± 3.09 | 35.01 ± 3.91 | -0.63 | 2.70 | 0.22 | 0.28 | 38.23 ± 3.50 | 35.41 ± 4.11 | 1.22 | 4.41 | <0.01** | 0.72 |
| 400m CD (m.c-1) | 2.58 ± 0.20 | 2.50 ± 0.26 | -0.03 | 0.18 | 0.19 | 0.33 | 2.19 ± 0.21 | 2.23 ± 0.27 | -0.15 | 0.06 | 0.41 | 0.16 |
| 400m SI (m2 c-1 s-1) | 3.91 ± 0.30 | 3.62 ± 0.38 | 0.14 | 0.45 | <0.01** | 0.82 | 3.00 ± 0.29 | 2.90 ± 0.36 | -0.04 | 0.25 | 0.17 | 0.30 |
| Critical speed (m.s-1) | 1.42 ± 0.07 | 1.36 ± 0.07 | 0.04 | 0.09 | <0.01** | 0.87 | 1.35 ± 0.02 | 1.27 ± 0.04 | 0.06 | 0.10 | <0.01** | 2.30 |

Legend: *p<0.05; **p<0.01

than Group B. For female swimmers, the swimming performance proved to be higher in the 50 m and 400 m freestyle for Group A than Group B, as shown in Table 3. Swimmers in Group A were able to swim with a higher GF compared to Group B in the 400 m freestyle. The critical speed was also significantly higher for swimmers in Group A than Group B.

In order to understand the influence of anthropometric and strength variables on the 50 m and 400m performance, the correlations between variables were analysed for all of the swimmers. There was a moderate negative linear correlation between height ($r = -0.64$ and $r = -0.60$, p<0.01), body mass ($r = -0.67$ and $r = -0.60$, p<0.01), wingspan ($r = -0.66$ and $r = -0.58$, p<0.01) with the 50 m freestyle and 400 m freestyle time, as can be seen in Figures 1a. 1b, 1c, 1d, 1e, 1f respectively.
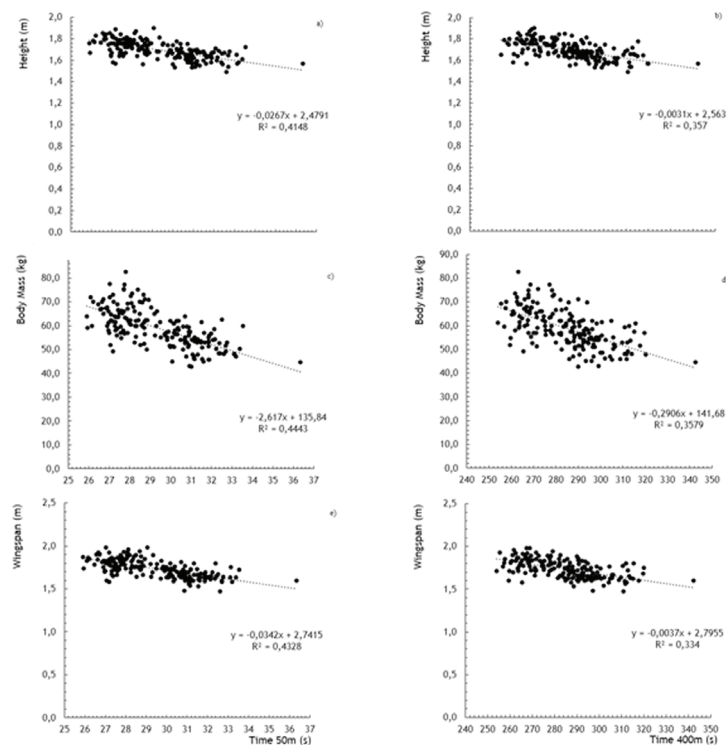


FIGURE 1. Graphical representation of the relationship between the height, body mass and wingspan with the time of the 50 m free and the time of the 400 m free

With regard to muscle strength, there was a strong negative linear correlation between the launch of the medicine ball and the 50m freestyle time ($r = -0.80$, p<0.01) and the 400m freestyle time ($r = -0.70$, p<0.01) (Figure 2a and Figure 2b). The horizontal jump was also negatively correlated with the 50m freestyle time ($r = -0.78$, p <0.01) and the 400m freestyle time ($r = -0.61$, p<0.01) (Figure 2c and Figure 2d).
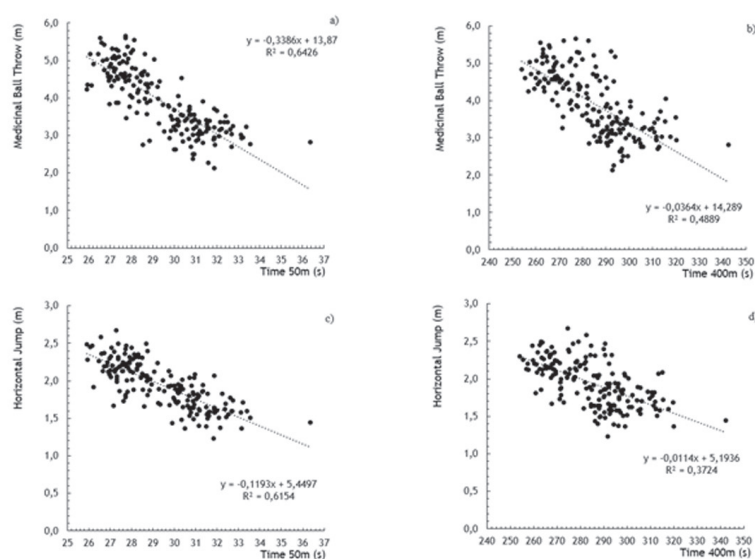
FIGURE 2. Graphical representation of the relationship between the average value of the medical ball throw (BM) and horizontal jump with the 50 m freestyle time and the 400 m freestyle time

## Discussion

The present study aimed to verify how the anthropometric characteristics and strength levels of young swimmers of different sexes can influence their sports performance in 50 m and 400 m freestyle events at different levels. In addition, we sought to understand how these characteristics can be decisive in sports performance for U-16 and U-15 swimmers with the 50 m and 400 m freestyles. Regarding anthropometric characteristics, it was found that male swimmers of a higher competitive level (Group A) did not show significant differences compared to male swimmers of a lower level (Group B). However, female swimmers at a higher competitive level tend to be taller and heavier than those at a lower level, which is in line with a study by Malina, Bouchard and Bar-Or (2004) that emphasized that body composition is a determinant in swimmers' performance. Male swimmers in Group A showed a tendency towards higher muscle strength values compared to male swimmers in Group B, with a clear difference in the throw of the medicine ball, supporting findings from a previous study (Garrido et al., 2010b). No significant differences were found in female swimmers regarding muscle strength. These data highlight the potential importance of strength for swimming performance, taking into account that differences were not observed in relation to anthropometric characteristics among male swimmers. Thus, it is likely important that swimmers perform strength training that allows them to increase their ability to move and propel their upper limbs in the aquatic environment (Marques et al., 2020), thereby increasing their performance. In addition, strength training combined with swimming training shows better results for swimmers than swimming training alone (Amaro, Marinho, Marques, Batalha, & Morouço, 2017).

As expected, the performance of Group A male and female was superior to that of Group B, both in the 50 m and 400 m freestyle. This difference may be the result of higher SI values in the 50 and 400 m freestyle for male swimmers and higher GF values in female swimmers during the 400 m freestyle. Furthermore, these results may be related to the fact that swimmers in Group A of both sexes are more advanced in maturational terms compared to Group B. According to Malina et al. (2004), maturation progress is directly associated with improved motor performance and is based on the skeletal and sexual maturation of individuals. When analysing the entire sample, a significant relationship was found between all of the variables analysed. However, the correlation values between performance and muscle strength should be emphasized: the upper limbs showed higher values than the lower limbs. Thus, it was found that the level of performance seems to be determined mainly by anthropometric variables in young female swimmers and by strength in young male swimmers. However, through the correlations found, it can be observed that the fastest swimmers in the 50 and 400 m freestyle seem to be influenced by both anthropometric and muscle strength variables, which contradicts what was reported in a previous study (Zampagni et al., 2008).

With regard to the horizontal jump, there was less discrepancy in values found in the 50 m freestyle than in the 400 m freestyle. This observation may explain the correlation values between the explosive strength of the lower limbs and the swimming performance, which showed a lower correlation in the 400 m freestyle race. Therefore, the explosive strength of the lower limbs seems to be a major factor in the performance of young swimmers, especially in shorter events (i.e., 50 m freestyle). These data show that strength training allows for better specific performance in short swimming events, as previously reported in the literature (Crowley et al., 2017; Lopes, Neiva, Gonçalves, Nunes, & Marinho, 2020). Considering the importance of planning in strength training, it is necessary to reflect on the training load quantification. After setting the objectives, the next step in developing a plan is determining the quality and quantity of load needed to produce the desired effect. The training load can be manipulated through its components, such as, volume, intensity, density, and complexity (Mujika et al., 1995). Another important factor to mention is the critical speed, which presented statistically significant variations in both groups analysed and for both sexes. In fact, critical speed is related to aerobic capacity and aerobic power, and it seems to be an important determinant to distinguish performance levels, which contradicts what was previously reported in the literature (Toubekis & Tokmakidis, 2013).

In addition, it is important to note that the biomechanical variables were different between performance levels. In a previous investigation, Strass (1988) observed an increase in CD and possible improvement in sports performance when applying muscle strength training program. The importance of speed depends on the swimming technique and the distance of the race, which is linked to technical coordination and the nature of the effort in terms of intensity and duration. Even in longer events, speed is important, especially in changes of pace and at the end of the race (Navarro, Castañón, & Gaia, 2003).

This study shows that the strength of upper limbs is likely related to the speed of the swim, which is consistent with a previous study (Garrido et al., 2010b), which also found that the muscular strength of the upper limbs seems to increase performance more in swimming events of short distance (50 m) in comparison with long-distance swimming events (100 m).

## Conclusion

This study aimed to verify how the anthropometric characteristics and strength levels of young swimmers of different sexes can influence their sports performance in the 50

m and 400 m freestyle events at different competitive levels. Male swimmers with a higher competitive level (Group A) did not show differences in anthropometric characteristics in relation to male swimmers with a lower competitive level (Group B). However, in the case of female swimmers, those of higher competitive level (group A) demonstrated differences in height and weight that positively influenced their performance.

Regarding muscle strength, the higher-level male swimmers (Group A) showed a tendency towards higher values in relation to the lower-level male swimmers (Group B), with a clear difference in the launch of the medicine ball. The differences in sports performance in the 50 m and 400 m freestyle seem to be related to biomechanical parameters of swimming, with higher values of SI in male swimmers and GF in female swimmers. Furthermore, the level of performance seems to be determined by anthropometric and muscle strength variables, with the launch of the medicine ball and the horizontal jump determining the performance. Future studies could complement the present results and analyses with an accurate assessment of the maturational state of the sample under study.

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