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The relationship between anthropometric characteristics and sports performance in national-level young swimmers

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Abstract: The main aim of this study was to verify associations between the anthropometric characteristics of young swimmers of different genders and different competitive levels with sports performance in 50m and 400m freestyle races at different levels (U-13 - Swimmers A and U-12 - Swimmers B). In addition, it was also intended to investigate the magnitude of the correlations between some specific variables (i.e., height, weight and wingspan) and the swimming performance. All participants were analyzed, regarding their anthropometric characteristics and their performance in the 50m and 400m freestyle swim. A total of 98 swimmers aged between 11-13 years old (mean ± standard deviation: 12.63 ± 0.76 years of age, 1.59 ± 0.08m height, 47.11 ± 7.82kg body weight) participated in the study. The results suggest that anthropometric characteristics have a positive relationship in the performance of swimmers when comparing genders ($p< 0,01$), furthermore positive linear correlations was found in height ($r = 0.305$ and $r = 0.253$, $p <0.01$), weight ($r = 0.202$ and $r = 0.140$, $p <0.01$), and wingspan ($r = 0.227$ and $r = 0.203$, $p < 0.01$) for 50m and 400m freestyle swim. The swimmers' efficiency of segmental movements was related to anthropometric characteristics and strongly associated with the length of the swimmers' segments. These results may be due to the fact that swimmers' maturational status may have played an important role, in the observed results. In addition, when comparing genders, the height and weight values of male swimmers tended to be higher. Furthermore, the differences observed in the 50m and 400m freestyle swimming events were related to the relationship that anthropometric characteristics have on the biomechanical parameters of swimming, which influence swimming performance. This study concluded that the improvement of performance of each young national-level swimmer is strongly related to the rate of growth, development and maturation

Keywords: physical demands; GPS, high-intensity actions; accelerations; decelerations.

1. Introduction

In pure sport swimming, young swimmers are subjected to intense training programs from an early age so that they can withstand competitive periods and achieve high sporting performance (Martínez et al. 2011). Pure sport swimming is characterized as an individual, cyclical, continuous, closed, and mixed activity that depends on genetic, contextual, psychological (Fernandes, R., Aleixo, I., Soares, S., & Vilas-Boas 2008), biomechanical, energetic (Barbosa et al.

2010), hydrodynamic (Morais et al. 2012), and anthropometric factors (Jürimäe et al. 2007). This type of swimming differs from other sports activities due to the nature of the environment in which it occurs (i.e. the aquatic environment), which requires particular spatio-temporal and energetic adaptations (Marinho et al. 2007). Since they constantly interact with the aquatic environment, swimmers seek the production of propulsive forces that maintain or accelerate their travel speed (Kwon and Casebolt 2006). Swimming performance depends on the ability to generate propulsive force and minimize the hydrodynamic drag that opposes displacement (Berger, Hollander, and De Groot 1997; Martínez et al. 2011), which can be stimulated by improving biomechanical patterns (Vantorre, Chollet, and Seifert 2014) and swimming technique (Scorţenschi 2019). Additionally, performance can also be affected by the variability of body composition (Charmas and Gromisz 2019) and anthropometric characteristics (i.e. weight, body mass index, height, and wingspan) (Morais et al. 2012; Zuniga et al. 2011).

The anthropometric characteristics of swimmers are closely related to each other and serve major roles in sports performance (Fernandes, Barbosa, and Vilas-Boas 2002a). Additionally, a previous study by Damsgaard et al. (2001) demonstrated that participation in sports competitions from a young age is directly related to the specific body composition and body proportions of each individual. Thus, the association between anthropometric characteristics and sports performance is a relevant indicator for identifying talent in the long-term development process of athletes (Sammoud, et al. 2018). Young male swimmers have been characterized as taller and heavier with a greater wingspan when compared to young female swimmers, and these characteristics contribute to differences in performance between genders (Schneider and Meyer 2005). Fat mass is an important body composition feature that seems to vary between sports. Typically, the lower the fat mass, the better the performance (Martínez et al. 2011). However, swimming seems to be an exception since advantages associated with a higher proportion of fat mass have been reported, such as greater buoyancy that results in lower energy expenditure (Fernandes et al. 2002a; Wells, Schneiderman-Walker, and Plyley 2006; Zuniga et al. 2011). Female swimmers seem to enjoy this advantage since—according to what has been reported in previous investigations (Fernandes et al. 2002a; Greco and Denadai 2005; Rodrigues et al. 2001; Wells et al. 2006)—they have a greater amount of fat mass compared to male swimmers.

A further investigation (Morais et al. 2013) has shown that anthropometric factors explain approximately 45.8% of the performance of 15-year-old male swimmers in 100m crawl tests, and 63.8% of the performance in freestyle swim tests among 13-year-old swimmers of both sexes (Bond et al. 2015). Anthropometric variables such as weight, body mass index, height, and wingspan seem to be strongly related to performance during swimming tests in young people and can thus potentially influence performance (Morais et al. 2013). On the other hand, young athletes of a high competitive level also present higher values of stature, and wingspan as well as conclusively higher values of gestural frequency (GF) (Craig and Pendeegast 1979), cycle distance (CD), and swimming index (SI) (Morais et al. 2013) (when these performance variables are used as performance indicators) (Craig and Pendeegast 1979; Lätt et al. 2009, 2010; Morais et al. 2012). According to Chollet et al. (2000) (Chollet, Chalies, and Chatard 2000), GF is defined as the number of stroke cycles per unit of time and is expressed as "cycles.seg-1 (Hz)". Variations in speed result from correlations between increases and decreases in GF and CD, respectively (Toussaint et al. 2006). According to Maglisho (1999), CD was characterized as the average horizontal distance traveled during the completion of a complete stroke cycle (m). A swimmer's transformation of muscle strength into propulsive force enables an increase in CD, which is derived from the

physical capacity to produce strength and the technical capacity applied in segmental paths, with an emphasis on the orientation of the most propulsive surfaces. Therefore, variables such as wingspan and height can condition the achievement of higher CD values (Anderson et al. 2006; Franken, Pivetta, and Antônio De Souza 2007), which represents an indicator of propulsive efficiency. Swimmers with more representative wingspan values tend to have higher CD (Barbosa et al. 2009; Franken et al. 2007) and SI (Jürimäe et al. 2007) values, with CD having a significant correlation with performance (Morais et al. 2012). SI is expressed as a swimmer's ability to move at a certain speed with a greater or lesser number of strokes and essentially derives from the relationship between CD and speed (Caputo et al. 2000). It is measured in m/s and is an excellent performance indicator for young swimmers (Jürimäe et al. 2007) since a swimming speed with greater CD and less GF translates into an inefficient and ineffective technique (Caputo et al. 2000). Like the other variables referenced, SI also represents an excellent predictor of performance (Lätt et al. 2009, 2010).

Therefore, a range of performance variables is useful in training programming and control which, when related to athletes' anthropometric characteristics, seem to contribute to understanding and improving their performance through rigorous control and monitoring of training. Thus, the training of young swimmers must be regularly monitored so that the prescription is adequate for improving performance based on the particular characteristics of each swimmer (Marinho et al. 2011). Although the differences are not always significant in relation to anthropometric characteristics, growth, and maturation differences between genders at both prepubescent and pubescent ages (Malina, Bouchard, and Bar-Or 2004), it remains important to continue investigating this topic. The maturation of an athlete involves the organs and structures of the body and translates into morphological changes observed throughout the growth process, which reaches its peak during puberty. Thus, growth and development processes are strongly linked to the improvement of motor performance in children and adolescents (Beunen and Malina 2008). Therefore, based on this relationship, growth and physical development indicators should be considered because biological maturation does not start at the same age in both genders and does not have the same duration in all individuals (Erlandson et al. 2008). In fact, the literature has reported a strong association between anthropometric characteristics and performance in pure sport swimming. However, this relationship requires further investigation to clarify its impact on the performance of young swimmers of national level, both genders in a precise age range. Although some studies (Geladas et al. 2005; Jürimäe et al. 2007; Nevill, Oxford, and Duncan 2015; Sammoud, Alan M. Nevill, et al. 2018; Sammoud, Alan Michael Nevill, et al. 2018) have inferred about the importance of anthropometric characteristics for swimming performance in different age groups, knowledge about the effects of some variables (i.e., height, weight, Body mass index, wingspan, wingspan / height, GF, CD and SI) on performance remains to be investigated, particularly among genres of the competitive ranks of U-13 and U-12. In addition, few studies have made a specific comparison between swimmers of different genders and similar chronological ages who belong to different competitive levels. Thus, the present study aimed to verify associations between the anthropometric characteristics of young swimmers of different genders and different competitive levels with sports performance in 50m and 400m freestyle races at different levels (U-13 - Swimmers A and U- 12 - Swimmers B). In addition, it was also intended to investigate the magnitude of the correlations between some specific variables and the swimming performance.

2. Materials and Methods

Subjects

A total of 98 swimmers aged between 11 and 13 years old (mean ± standard deviation: 12.63 ±

0.76 years of age, 1.59 ± 0.08m height, 47.11 ± 7.82kg body weight) participated in the study.
All the swimmers belonged to the U-13 and U-12 level, with 48 females and 50 males. The female sample consisted of 25 of the U-13 (Swimmers A) - (12.48 ± 0.30 years of age; 1.60 ± 0.06m in height; 47.25 ± 7.95 kg of body weight) and 23 at the U-12 level (Swimmers) B) - (11.63 ± 0.28 years of age; 1.52 ± 0.04m in height; 42.76 ± 5.99 kg of body weight). While the male sample was composed of 26 belonging to the U-13 level (Swimmers A) - (13.62 ± 0.25 years of age; 1.64 ± 0.07 m in height; 52.08 ± 7.68 kg of body mass) and 24 belonging to the U -12 level (Swimmers B) - (12.69 ± 0.26 years of age; 1.58 ± 0.08m in height; 45.75 ± 6.70 kg of body weight).

Design

The present study consisted of a cross-sectional study that aimed to verify the impact of anthropometric characteristics on sports performance in national-level young swimmers (e.g., 12 -13 years), in the 50m and 400m freestyle swimming events. Additionally, we sought to determine whether differences existed between genders and between swimmers of the same gender at different competitive levels (U-13 - Swimmers A and U-12 – Swimmers B), and was also intended investigate the correlations between some fundamental variables (i.e., height, weight and wingspan) and the swimming performance The inclusion criteria established for the sample were; a) the swimmers must have been present in the last 3 calls of the Portuguese national swimming team b) the swimmers could not have episodes of injuries in the last 6 months. As an exclusion criterion, it was established that; a) swimmers with reports or episodes of indisposition or illness, in the days prior to the evaluation were excluded from the sample. All participants were analyzed with regard to their anthropometric characteristics (height, body mass, body mass index, and wingspan), 50m and 400m freestyle swimming performance, and biomechanical variables. All participants were fully informed verbally and in writing regarding the nature of the study. They were informed that they could withdraw from the study at any time, even after giving their written consent. All parents provided their informed consent allowing the voluntary participation of their children in the study, which had the approval of the Academy's Ethical Advisory Commission and was conducted in accordance with the Declaration of Helsinki.

Methodology

The evaluations were performed during the team internship period. All individuals were evaluated at the same point in the sports season (January). The evaluation sessions were spread over the two days of the internship and the tests were performed without the need for energy expenditure or the accumulation of fatigue (anthropometry) before the swimming performance tests. Sufficient rest was allowed between sessions to ensure that no fatigue was accumulated that would negatively influence performance. After arriving at the internship site on the day of the assessment, each subject was assessed after 5 minutes of rest with regard to anthropometric measures such as body mass, height, wingspan. Body mass index (BMI) was also calculated. They performed the 50m freestyle swim performance evaluation in the morning session and the 400m freestyle swim performance evaluation during the afternoon session.

Anthropometric Measures. All measures were assessed according to international standards for anthropometric assessment (Marfell-Jones et al. 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 (meters) 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.

Swimming Performance Evaluation. The evaluation of specific swimming

performance was performed through simulating the 50m freestyle and 400m freestyle swim. The 50m freestyle swim was performed in the morning, while the 400m freestyle was performed in the late afternoon to provide sufficient time for the participants to recover. After performing a 1000 m warm-up using the usual structure based on the protocols described by Neiva et al. (2014), each swimmer performed a simulated race (50 or 400m). The evaluation protocols were applied in a 25m 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 analyzed using the program Kinovea® version 0.8.15. Biomechanical variables were evaluated for both simulations. Thus, the evaluation of GF was performed using a chronometer in three stroke cycles and later

converted to units of measurement in the international system (Hz). CD was measured by estimation using the following equation (Craig and 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. SI was then estimated using the following equation (Costill et al. 1985):

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

Where SI represents the swimming index ($m2\ c^{-1}\ s^{-1}$), DC is the distance per cycle ($m.c^{-1}$), and v is the average swimming speed ($m.s^{-1}$). The speed variables, FG, DC, and IN were evaluated in the second 25m of each 50m (either in the 50m event or 400m event) and were used to determine the average measure in the 400m freestyle swim. To analyze these variables, the program Kinovea® (version 0.8.15) was used.

Statistical Analysis

Data analysis was performed using the statistical software IBM Statistical Package for Social Sciences (SPSS, version 24.0) for Microsoft Windows (Armonk, NY, EU: IBM Corp.). The significance level was set at 5%. The calculation of means, standard deviations, differences, and 95% confidence intervals (95% CI) was performed using standardized statistical methods. The normality of the distribution was verified using the Kolmogorov-Smirnov test (n>30) and not all data had a normal distribution. Thus, parametric (t-test) and nonparametric (Mann-Whitney test) tests were used for data analysis. For bivariate correlations, Pearson's coefficient was used for normal data, Spearman's correlation was used for non-normal data, and the determination coefficient (r2) was also calculated. Ratios were considered very high for values between 0.90 and 1.00, high between 0.70 and 0.90, moderate between 0.50 and 0.70, low

Table 1. Comparison between the mean values (± standard deviation) of the anthropometric variables of the Female Children belonging to the Swimmers A and to the Swimmers B. The significance values, confidence interval of the difference and the effect size are also presented.

Variables	Swimmers A (Female) (n=25)	Swimmers B (Female) (n=23)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
Height (m)	1,60 ± 0,06	1,52 ± 0,05	0,10	0,04	0,001**	1,44
Weight (kg)	47,25 ± 7,95	42,7 ± 5,99	8,61	0,37	0,003**	0,64
BMI (kg/m^2)	18,31 ± 2,20	18,26 ± 2,08	1,30	-1,19	0,934	0,02
Wingspan (m)	1,63 ± 0,07	1,55 ± 0,06	0,12	0,04	0,001**	1.22
Wingspan / Height	1,01 ± 0.01	1.01 ± 0,02	0,82	0,80	0,808	0.01

Note: BMI= body mass index; CI= Confidence interval *p<0.05; **p<0.01

between 0.30 and 0.50, and very low between 0.10 and 0.30. The effect size was also calculated using Cohen's d for the comparison between analyzed groups (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 et al. 2009).

3. Results

Table 1 presents the mean values of the anthropometric variables for female

Swimmers belonging to the A and the B groups. Statistically significant differences were observed for height ($p < 0.01$; $d = 1.44$), weight ($p < 0.01$; $d = 0.64$), and wingspan ($p < 0.01$; $d = 1.22$), with a high effect size for all variables.

Table 2 presents the mean values of the anthropometric variables for male Swimmers belonging to the A and B groups. Statistically significant differences ($p < 0.05$) were observed for height and wingspan, with a high ($d = 0.79$) and very high ($d = 3.88$) effect size, respectively. Statistically significant differences ($p < 0.01$) were also observed for weight and BMI, with a high effect size.

Table 3 presents the mean values of the anthropometric variables resulting from the comparison between male and female belonging to Swimmers A group. Statistically significant differences were observed for the variable's height and weight ($p < 0.05$; $d = 0.61$), with a high effect size.

Table 4 presents the mean values of the anthropometric variables resulting from the comparison between male and female Swimmers B. Statistically significant differences were observed for height ($p < 0.01$; $d = 0.89$) and wingspan ($p < 0.05$; $d = 0.65$), with a high effect size.

Table 2. Comparison between the mean values (± standard deviation) of the anthropometric variables of Male Children belonging to Swimmers A and Swimmers B. The values of significance, confidence interval of difference and size of the effect are also presented.

Variables	Swimmers A (Male) (n=26)	Swimmers B (Male) (n=24)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
Height (m)	1,64 ± 0,07	1,58 ±0,08	0,01	0.10	0,019*	0,79
Weight (kg)	52,08 ± 7,68	45,75 ± 6,70	2,20	10,43	0,003**	0.87
BMI (kg/m²)	19,20 ± 1,81	18,10 ± 1,45	0,16	2,04	0,002**	0,67
Wingspan (m)	1,67 ± 0,10	1,60 ± 0,09	0,02	0,12	0,014*	3,88
Wingspan / Height	1,01 ± 0,02	1,01 ± 0,01	0,11	0,10	0,109	0,05

Note: BMI= body mass index; CI= Confidence interval *p<0.05; **p<0.01

Table 3. Comparison between the mean values (± standard deviation) of the anthropometric variables between genders of the children of Swimmers A. The significance values, confidence interval of the difference and the effect size are also presented.

Variables	Swimmers A (Male) (n=26)	Swimmers B (Female) (n=25)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
Height (m)	1,64 ± 0,07	1,60 ± 0,06	-0,01	-0,08	0,04*	0,61
Weight (kg)	52,08 ± 7,68	47,25 ± 7,95	-0,42	-9,22	0,03*	0,61
BMI (kg/m²)	19,20 ± 1,81	18,31 ± 2,20	0,24	-2,02	0,12	0,44
Wingspan (m)	1,67 ± 0,10	1,63 ± 0,07	0,02	-0,09	0,10	0,46
Wingspan / Height	1,01 ± 0,02	1,01 ± 0.01	0,73	0,71	0,71	0.01

Note: BMI: body mass index; CI: Confidence interval *p<0.05; **p<0.01

Table 4. Comparison between the mean values (± standard deviation) of the anthropometric variables between the gender of the Children in Grade B. The significance values, confidence interval of the difference and the effect size are also presented.

Variables	Swimmers B (Male) (n=24)	Swimmers B (Female) (n=23)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
Height (m)	1,58 ±0,08	1,52 ± 0,05	-0,02	-0,09	0,005**	0,89
Weight (kg)	45,75 ± 6,70	42,70 ± 5,99	0,75	-6,74	0,114	0,47
BMI (kg/m²)	18,10 ± 1,45	18,26 ± 2,08	1,21	-0,88	0,755	- 0,09
Wingspan (m)	1,60 ± 0,09	1,55 ± 0,06	-0,01	-0,10	0,021*	0,65
Wingspan/Height	1,01 ± 0,01	1.01 ± 0,02	0.288	0,265	0,276	0.14

Note: BMI: body mass index; CI: Confidence interval *p<0.05; **p<0.01

Table 5. 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 (DC), swimming index (IN) and critical speed of female children belonging to the Swimmers A and B. Significance values, difference confidence interval and effect size are also presented.

Variables	Swimmers A (Female) (n=25)	Swimmers B (Female) (n=23)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
50m freestyle (s)	34,48 ± 2,34	36,52 ± 1,85	-0,80	-3,27	0,002**	-0,51
50m GF (5-20m) (Hz)	48,57 ± 4,13	50,07 ± 5,15	1,20	-4,20	0,271	-0,32
50m CD (m.c^{-1})	1,80 ± 0,19	1,65 ± 0,19	0,26	0,04	0,010*	0,78
50m SI (m² c^{-1} s$^{-1)}$	2,63 ± 0,38	2,27 ± 0,31	0,56	0,15	0,001**	1,03
400m frestyle (s)	330,75 ± 25,92	364,18 ± 26,36	0,001	0,001	0,001**	-1,12
400m GF (Hz)	37,20 ± 3,94	37,37 ± 4,53	0,92	0,91	0,918	-0,04
400m CD (m.c^{-1})	1,98 ± 0,23	1,80 ± 0,24	0,009	0,005	0,007**	0,76
400m SI (m² c^{-1} s$^{-1)}$	2,42 ± 0,36	1,99 ± 0,35	0,001	0,001	0,001**	1,21

Note: CI: Confidence interval; GF: Gestural frequency; DC: Cycle distance; SI: Swimming index; * p <0.05; ** p <0.01

Table 6. 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 children belonging to Swimmers A B. The values of significance, difference confidence interval and effect size are also presented.

Variables	Swimmers A (Male) (n=26)	Swimmers B (Male) (n=24)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
50m freestyle (s)	31,08 ± 1,69	33,20 ± 1,98	-1,07	-3,17	0,001**	-1,15
50m GF (5-20m) (Hz)	54,68 ± 6,42	54,32 ± 6,32	3,99	-3,26	0,841	0,05
50m CD (m.c^{-1})	1,76 ± 0,21	1,68 ± 0,20	0,20	-0,03	0,170	0.39
50m SI (m² c^{-1} s$^{-1)}$	2,81 ± 0,43	2,53 ± 0,40	0,51	0.03	0,025*	0.67
400m freestyle (s)	310,52 ± 19,78	326,48 ± 16,94	0,001	0,001	0,001**	-0,86
400m GF (Hz)	38,74 ± 4,92	40,83 ± 5,37	0,24	0,22	0,229	-0.40
400m CD (m.c^{-1})	2,03 ± 0,27	1,84 ± 0,24	0.02	0,01	0,016*	0.74
400m SI (m² c^{-1} s$^{-1)}$	2,64 ± 0,39	2,25 ± 0,32	0,001	0,001	0,001**	1.09

Note - CI: Confidence interval; GF: Gestural frequency; DC: Cycle distance; SI: Swimming index; * p <0.05; ** p <0.01

Table 5 presents the mean values for specific swimming performance. Female Swimmers A registered better performance in the 50 and 400m freestyle swim ($p < 0.01$; $d = -0.51$; $p < 0.01$; $d = -1.12$) with a moderate and high effect size, respectively. Additionally, SI and CD were significantly higher, even without differences in GF ($p > 0.05$).

Table 6 presents the mean values of specific swimming performance for male children. Male Swimmers A registered better performance in the 50 and 400m freestyle swim, with a significantly higher SI. Significant differences in CD were also observed for the 400m freestyle swim.

Table 7 presents mean values of specific swimming performance for male Swimmers A compared to female Swimmers A. Male swimmers A registered better performance in the 50 and 400m freestyle swim with statistically significant differences ($p < 0.01$) and small effect sizes ($d = -1.66$ and $d = -0.87$, respectively). However, no statistically significant differences were observed with respect to GF, CD, and SI, except for the gestural GF of the 50m freestyle swim event, for which the male Swimmers A, exhibited a significant difference ($p < 0.01$).

Table 8 presents mean values related to the specific swimming income of male Swimmers B compared to female Swimmers B. Male Swimmers B registered better performance in the 50 and 400m freestyle swims with statistically significant differences ($p < 0.01$) and small effect sizes ($d = -1.73$ and $d = -1.70$, respectively). Additionally, statistically significant differences were observed for GFFG ($p < 0.05$; $p < 0.01$) for the 50m and 400m freestyle swims, respectively. Regarding the other analyzed variables, statistically significant differences ($p < 0.05$; $p < 0.01$) were observed for GF in the 50m and 400m freestyle swim as well as for SI ($p < 0.05$) in the 50m.

Table 9 presents the results of correlations between anthropometric variables and 50m and 400m freestyle swim times. The results revealed significant differences in positive linear correlations between height ($r = 0.305$ and $r = 0.253$, $p < 0.01$), weight ($r = 0.202$ and $r = 0.140$, $p < 0.01$), and wingspan ($r = 0.227$ and $r = 0.203$, $p < 0.01$) for the 50m and 400m freestyle swims, respectively (see Figures 1, 2, and 3).

4. Discussion

The main aim of this study was to quantify and compare the external loads imposed upon Ultimate Frisbee players during matches according to sex. This is the first investigation to describe the external loads measured upon elite Ultimate Frisbee players, as well as during mixed-sex competition. The main results of the study showed males performed greater external loads, especially high-intensity actions (distance covered at high-intensity and high-speed running as well as medium-high accelerations and decelerations) than females.

Despite being developed over 25 years ago (Marfleet, 1991) and accruing a large number of participants worldwide (Scanlan et al., 2015), only two studies have quantified the external loads encountered by players during Ultimate Frisbee matches (Krustrup & Mohr, 2015; Madueno et al., 2017). While some research has quantified the external loads imposed upon male Ultimate Frisbee players (Krustrup & Mohr, 2015) limited data are available for female players (Madueno et al., 2017) with no data reported during mixed-sex matches. More precisely, Madueno et al. (2017) examined recreational college players reporting male players to cover 2949 ± 519 m and female players to cover 2935 ± 500 m per match. While these data are considerably lower than the total distances presently observed according to sex (males: 4092 ± 960 m; females: 3656 ± 1061 m), differences between studies could be due to the modified rules adopted by Madueno et al. (2017) where matches consisted of 2 x 18-min halves on a reduced-size pitch (60 x 30 m). In addition, Madueno et al. (2017) examined recreational athletes likely possessing less training experience and reduced conditioning to the

Table 7. Comparison between the average values (± standard deviation) of the swimming performance variables in the 50m freestyle and 400m freestyle, as well as the values of the gestural frequency (FG), cycle distance (DC), swimming index (IN) and critical speed between gender of Swimmer A. The values of significance, confidence interval of the difference and the size of the effect are also presented.

Variables	Swimmers A (Male) (n=26)	Swimmers B (Female) (n=25)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
50m freestyle (s)	31,08 ± 1,69	34,48 ± 2,34	4,55	2,25	0,001**	-1,66
50m GF (5-20m) (Hz)	54,68 ± 6,42	48,57 ± 4,13	-3,05	-9,16	0,001**	1,13
50m CD (m.c^{-1})	1,76 ± 0,21	1,80 ± 0,19	0,16	-0,72	0,457	0,19
50m SI (m^2 c^{-1} s$^{-1)}$	2,81 ± 0,43	2,63 ± 0,38	0,05	-0,40	0,131	0,44
400m frestyle (s)	310,52 ± 19,78	330,75 ± 25,92	0,002	0,001	0,001**	-0,87
400m GF (Hz)	38,74 ± 4,92	37,20 ± 3,94	0,285	0,262	0,270	0,34
400m CD (m.c^{-1})	2,03 ± 0,27	1,98 ± 0,23	0,656	0,631	0,642	0,19
400m SI (m^2 c^{-1} s$^{-1)}$	2,64 ± 0,39	2,42 ± 0,36	0,081	0,067	0,071	0,58

Note: CI: Confidence interval; GF: Gestural frequency; DC: Cycle distance; SI: Swimming index; * p <0.05; ** p <0.01

Table 8. 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 (FG), cycle distance (DC), swimming index (IN) and critical speed between gender of the Swimmer B. The values of significance, confidence interval of the difference and the size of the effect are also presented.

Variables	Swimmers A (Male) (n=24)	Swimmers B (Female) (n=25)	Difference (CI 95%)		p- value	Effect size
			Higher	Lower		
50m freestyle (s)	33,20 ± 1,98	36,52 ± 1,85	4,44	2,18	0,001**	-1.73
50m GF (5-20m) (Hz)	54,32 ± 6,32	50,07 ± 5,15	-0,84	-7,64	0,015*	0,73
50m CD (m.c^{-1})	1,68 ± 0,20	1,65 ± 0,19	0,09	-0,13	0,706	0,15
50m SI (m^2 c^{-1} s$^{-1)}$	2,53 ± 0,40	2,27 ± 0,31	-0,05	-0,47	0,016*	0,72
400m frestyle (s)	326,48 ± 16,94	364,18 ± 26,36	0,001	0,001	0,001**	-1,70
400m GF (Hz)	40,83 ± 5,37	37,37 ± 4,53	0,008	0,004	0,008**	0.69
400m CD (m.c^{-1})	1,84 ± 0,24	1,80 ± 0,24	0,73	0,71	0,714	0,16
400m SI (m^2 c^{-1} s$^{-1)}$	2,25 ± 0,32	1,99 ± 0,35	0,01	0,008	0,013	0,77

Note - CI: Confidence interval; GF: Gestural frequency; DC: Cycle distance; SI: Swimming index; * p <0.05; ** p <0.01

Table 9. Results of the correlations between the different anthropometric variables and the different swimming distances (50m free and 400m free). The significance (p) values are also shown.

Correlated Variables	R	p-value	R square
Height - time 50m	-0,553	0,001*	0,305
Weight - time 50m	-0,450	0,001*	0,202
Wingspan - time 50m	-0,477	0,001*	0,227
Height - time 400m	-0,577	0,001*	0,253
Weight - time 400m	-0,434	0,001*	0,140
Wingspan - time 400m	-0,500	0,001*	0,203

Note: *p<0.01

demands of Ultimate Frisbee than the elite players we recruited. However, the total distance observed in the present study for male players was lower than that previously reported in other research during official matches (4700 ± 470 m) (Krustrup & Mohr, 2015) with less high-speed running distances achieved (110 ± 82 m vs. 210 ± 110 m). These differences could be explained by the inclusion of only male matches in the study completed by Krustrup and Mohr (Krustrup

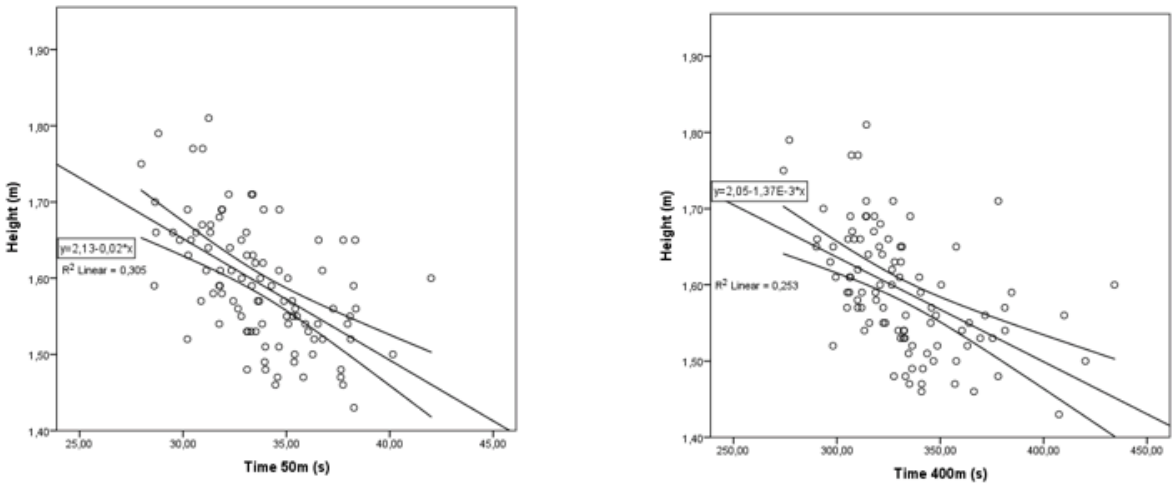

Figure 1. Graphical representation of the relationship between the height and time of the 50m free (left) or the time of the 400m free (right).

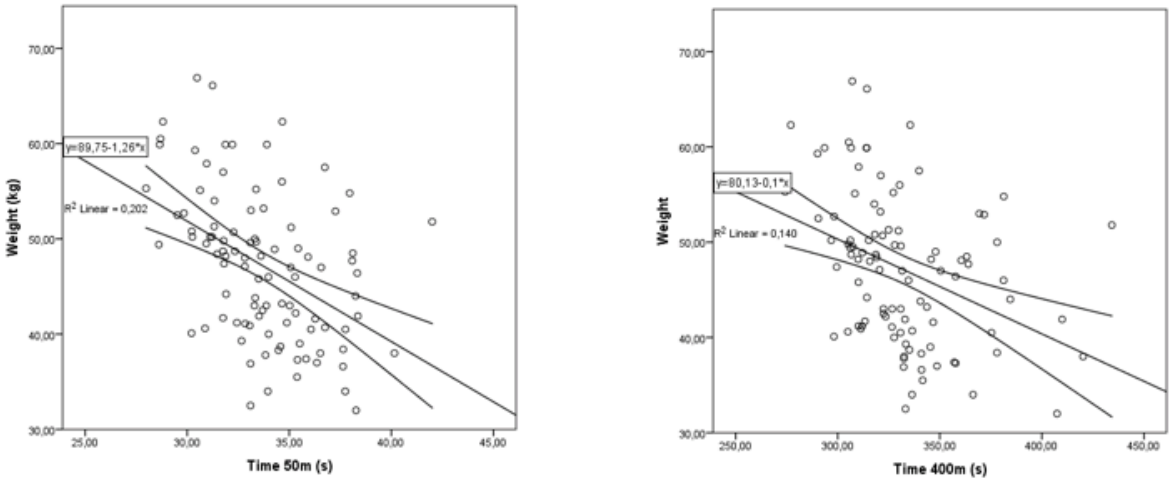

Figure 2. Graphical representation of the relationship between weight and 50m free time (left) or 400m free time (right).

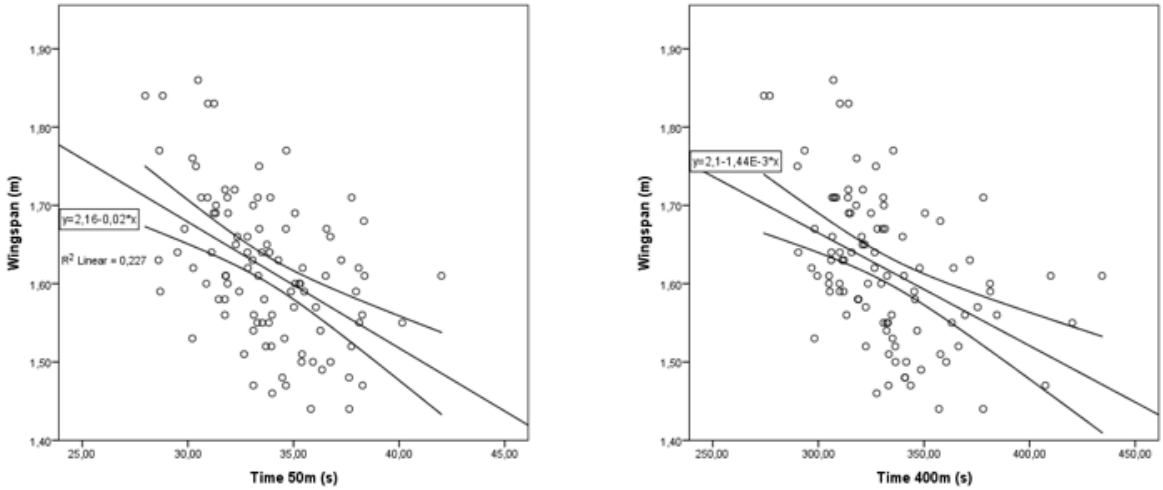

Figure 3. Graphical representation of the relationship between the wingspan and the 50m free time (left) or the 400m free time (right).

sports, female matches have been shown to elicit lower movement intensities than male matches (Bradley et al., 2014), which might have lower the "match pace" and restricted the total distance covered by male players during mixed-sex Ultimate Frisbee matches in our study. Nevertheless, the direct comparisons between sexes in the present study provide further insight into the precise demands encountered during Ultimate Frisbee competition.

The present study provides novel data directly comparing the external loads encountered during mixed-sex Ultimate Frisbee competition between males and females. Although small differences were observed in total distance covered between male and female players, males covered greater distances (large-moderate) working at higher intensities (i.e., high-intensity running, high-speed running, MACC, HACC, MDEC and HDEC) during official matches. These findings contrast those reported by Madueno et al. (2017) who observed similar total distance measures across sexes during separate male and female matches. However, the total distance data reported by Madueno et al. (2017) were indicative of shortened matches (2 x 18-min halves) and measurements were predicated on accelerometer-based estimates without the added provision of movement distances according to intensity.

This study is not exempt of limitations. For instance, only four matches were examined across a 2-day period in the study. The congested nature of the matches may have influenced the external loads performed players likely carrying residual levels of fatigue into subsequent matches. In this sense, it would be interesting to quantify temporal recovery responses in players 24-48 h following matches (Sparkes et al., 2018) as well as isolating the impact of competing under fatigue on external loads during Ultimate Frisbee (Coutinho et al., 2018). In addition, external demands were analysed using generic velocity threshold, obviating the individual velocity thresholds of each player. Finally, various contextual factors may have affected the match load encountered by players and have not been considered in this investigation, such as score line (Lago-Peñas, 2012), opposition quality (Castillo et al., 2018) or pitch surface (Pastore et al., 2017). Further research is encouraged examining the impact of these contextual match factors on the external loads of Ultimate Frisbee players, which may be analysed using the individual velocity thresholds for each player.

Supplementary Materials: The following are available online at www.jsc-cycling.com/xxx, Figure S1: title, Table S1: title, Video S1: title.

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