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Force production and symmetry in water fitness exercises: a gender comparison

Catarina Costa Santos[1,2,3*], Mário Jorge Costa[3,4], Raul Filipe Bartolomeu[3,5,6], Tiago Manuel Barbosa[3,6], Luís Manuel Rama[1,7]

ABSTRACT

The aim of this study was to analyse and compare propulsive forces, relative force production and symmetry between genders during water fitness exercises. Eighteen participants (women, *n*= 9; age: 20.67± 0.87 years; body mass: 58.18± 4.97 kg; height: 159.19± 5.85 cm; and men, *n*= 9; age: 22.11± 1.76 years; body mass: 72.93± 7.00 kg; height: 170.83± 5.57 cm) underwent two incremental protocols performing horizontal adduction (HA) and the rocking horse (RH_{add}) exercises, from 105 to 150 bpm. Propulsive peak force of dominant (PF_D) and non-dominant upper-limbs (PF_{ND}) was assessed by a differential pressure system. An isokinetic dynamometer was used to collect the dry-land isometric peak strength of the dominant upper-limb. Significant differences between genders were found for most of the music cadences in HA and RH_{add}. Men were able to produce higher propulsive force values for both upper-limbs during the overall incremental protocol, whereas women reached a higher relative force production. However, no significant differences were found between both genders at the same music cadence. Most actions were asymmetric in women, whereas men showed a symmetric pattern. The cadence of 135 bpm elicits a symmetric motion in both genders while exercising water fitness exercises.

KEYWORDS: Aquatic Exercise, Propulsive Force, Isometric Strength, Cadence, Sex.

INTRODUCTION

Water fitness programmes often include muscular conditioning as some part of the sessions. It aims to improve participants' strength and conditioning (e.g., Reichert et al., 2019), as well as to enhance sports performance and/or help in the rehabilitation from an injury episode (e.g., Robinson, Devor, Merrick, & Buckworth, 2004; Psycharakis, Coleman, Linton, Kaliarntas, & Valentin, 2019). Thus, participants from different age groups, fitness levels, and genders participate in those sessions (Colado et al., 2013; Santos, Barbosa, & Costa, 2020).

Several studies carried out gender comparisons on strength production in a broad range of exercise modalities on land (e.g., Nelson, Thomas, & Nelson, 1991; Van den Tillaar & Ettema, 2004; Rice et al., 2017). There is solid evidence that men produce a greater amount of strength than women (Stoll, Huber, Seifert, Michel, & Stucki, 2000; Hunter & Enoka, 2001; Sinaki, Nwaogwugwu, Phillips, & Mokri, 2001). The lean body weight (LBW) and the muscle distribution in body segments are underlying factors that explain those differences (Heyward, Johannes-Ellis, & Romer, 1986). This seems to be genetically determined and greater in men when assessing the upper body strength (Miller, MacDougall, Tarnopolsky, & Sale, 1993). Although gender differences are obvious on land, the comparison of force production between women and men within the water fitness background is unclear. To the best of our knowledge, at least one study was

[1]Faculty of Sport Sciences and Physical Education, University of Coimbra, Coimbra, Portugal. [2]Department of Sport Sciences, University of Beira Interior, Covilhã, Portugal.
[3]Research Center in Sports Sciences, Health and Human Development, Vila Real, Portugal.
[4]Department of Sport Sciences, Polytechnic Institute of Guarda, Guarda, Portugal.
[5]Department of Sport, Exercise and Health Sciences, University of Trás-os-Montes e Alto Douro, Vila Real, Portugal.
[6]Department of Sport Sciences, Instituto Politécnico de Bragança, Bragança, Portugal.
[7]Research Unit for Sport and Physical Activity, Coimbra, Portugal.
*Corresponding author: Universidade da Beira Interior, Rua Marquês de Ávila e Bolama – 6201-001 – Covilhã, Portugal. E-mail: catarina.costa.santos@ubi.pt

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conducted recruiting competitive swimmers, reporting that men had higher propulsive forces than women due to higher velocity and strength levels (Morouço, Marinho, Izquierdo, Neiva, & Marques, 2015).

Another point of interest is the amount of force that can be transferred between land and water environments. Santos, Rama, Marinho, Barbosa, and Costa (2019) verified that young health participants are able to reach ~68% of total dry-land strength at a cadence of 150 beats per minute (bpm) during water fitness exercises. Although the literature is limited about this topic, one may wonder if this can be a gender factor. For instance, men can produce a greater force production in water but exhibit similar or lower transfer than women when considering force production on land. This is a brand new topic and will allow us to clarify the real force transfer to water by both genders. Plus, it will allow getting further adjustments in exercise prescription and planning.

The force data acquisition may also provide new insights into critical aspects of the motion, such as force-production coordination (Santos, Marinho, Faíl, Neiva, & Costa, 2021). The lateralisation phenomenon that characterises symmetry can be established early in human life (Carpes, Mota, & Faria, 2010). Accordingly, laterality plays an important role when asymmetries arise in any exercise mode. Gender differences seem unclear when assessing coordination from propulsive force production. Women are more prone to produce forces asymmetrically than men during some land tasks (Bailey, Sato, Burnett, & Stone, 2015). In water, the front-crawl stroke coordination seems not to be influenced by gender (Formosa, Sayers, & Burkett, 2013). Whether such a gender gap is noticeable in water fitness exercises and at various levels of intensity remains to be examined. It will allow detecting a possible gender-effect in symmetry for strength/conditioning purposes and injury prevention.

The aim of this study was threefold:

- to analyse and compare propulsive forces between genders during two water fitness exercises;
- to compare the relative force production from both genders considering dry-land data;
- to assess and compare the symmetry at different levels of intensity.

It was hypothesised that:

- men would show higher propulsive force values than women;
- the relative force production would be similar for both cohorts;
- women would be more susceptible to show asymmetries while exercising.

METHODS

Participants

Eighteen participants, 9 women (age: 20.67± 0.87 years; body mass: 58.18± 4.97 kg; height: 159.19± 5.85 cm; body mass index: 23.12± 3.49 kg/m^2) and 9 men (age: 22.11± 1.76 years; body mass: 72.93± 7.00 kg; height: 170.83± 5.57 cm; body mass index: 24.99± 2.18 kg/m^2), apparently healthy, physically active and having at least one year of experience in water fitness programs volunteered to participate in this study. They reported no previous history of musculoskeletal or neurologic injury, conditions or syndromes diagnosed in the past six months. Participants of both genders were recruited among those enrolled in a Sports Science degree and taking an elective module in Water fitness (two sessions a week). They were advised to keep their normal daily routine. All participants were informed of the benefits and experimental risks prior to signing an informed consent document. All procedures were in accordance with the Declaration of Helsinki in respect to human research and approved by the Ethics Committee (code: CE/FCDEF-UC/00362019).

Procedures

The data collection was held in a 25-m indoor swimming pool with a mean water temperature of 29.5°C. Participants were randomly assigned to perform in different days the following water fitness exercises (Figure 1):

- horizontal upper-limbs adduction (HA);
- the rocking horse with horizontal upper-limbs adduction (RH_{Add}).

The two exercises were performed as reported elsewhere (Barbosa et al., 2010; Costa, Cruz, Simão, & Barbosa, 2019; Santos et al., 2019). The water surface level was set at near xiphoid process, as previously described (Barbosa, Garrido, & Bragada, 2007).

All selected exercises are prescribed on a regular basis in water fitness programmes. Each exercise was performed over an incremental protocol, with 4 music cadences, starting at 105 bpm and increasing every 30 seconds by 15 bpm, up to 150 bpm. The music cadence was controlled by a metronome (Korg, MA-30, Tokyo, Japan) plugged-in into a sound system. Both exercises were performed at "water tempo", where the countdown of only one beat in every two beats (Kinder & See, 1992) allows the synchronisation with the specific movement. Verbal and visual cues were given to participants during the protocol. The test ended when the participant decreased the range of motion, failed

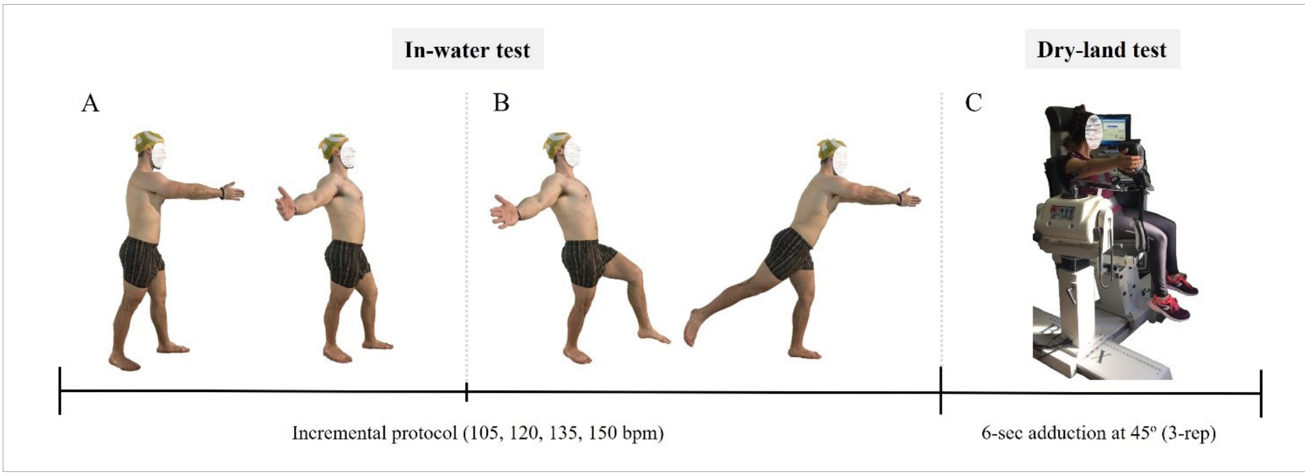

Figure 1. In-water and dry-land testing procedures. (A) Horizontal adduction; (B) rocking horse; (C) isometric adduction of dominant upper-limb.

to maintain the desired cadence or when the 30-sec trial was completed. Accordingly, all women and men were able to finish the incremental protocol successfully, i.e. without failure.

Measures

Propulsive forces were assessed with a differential pressure system (Havriluk, 1988). The system is composed of two independent pressure sensors that were positioned between phalanges of middle and ring fingers of both hands and allowed to assess the peak force of dominant (PF_D) and non-dominant (PF_{ND}) upper-limbs, respectively, in Newton (N). A 0.2% measurement error was reported using this system (Havriluk, 1988). A signal-processor (AcqKnowledge v.3.7.3, Biopac Systems, Santa Barbara, USA) was used to export data with a 5Hz cut-off low-pass 4th order Butterworth filter upon residual analysis. Symmetry Index (SI, %) was estimated as proposed by Robinson, Herzog, & Nigg (1987) (Equation 1):

$$\text{SI (\%)} = \frac{2(x_d - x_{nd})}{(x_d + x_{nd})} \times 100 \quad (1)$$

Where:
x_d = the force produced by the dominant upper-limb;
x_{nd} = the force produced by non-dominant upper-limb.

Symmetry data was interpreted as suggested by the same authors, where: if SI= 0%, perfect symmetry; if 0%> SI< 10%, symmetric motion; and if SI≥ 10%, asymmetric motion.

The isometric strength production was retrieved using an isokinetic dynamometer (Biodex Multi-joint System 3 Pro, Shirley, USA) as a dry-land strength measure (Figure 1). Two groups performed a 3-minute warm-up on a stable upper body ergometer (Monark 891E, Vansbro, Sweden). Cadence was set between 70 and 80 rpm. Participants were strapped with two bands across the chest and one across the pelvis while adopting a sitting position. The limb-support pad was positioned on the dominant upper-limb (i.e., palm hand). A 2-repetition trial was conducted before each test for familiarisation purposes (Meeteren, Roebroeck, & Stam, 2002). Immediately, a 3-repetition protocol with dominant upper-limb in adduction at 45º was performed during 6-sec of maximal isometric strength and the 15-sec interval between sets (Harbo, Brincks, & Andersen, 2012).

The isometric peak strength of the dominant upper-limb (IPF_D) was considered at the best repetition and was expressed in Newton (N). The relative force production for dominant upper-limb (RF_D) was considered as following (Equation 2):

$$\frac{100 \times PF_D}{IPF_D} \quad (2)$$

Statistical analysis

Exploratory data analysis was used to identify potential outliers. The normality of distribution and homogeneity were checked with Shapiro-Wilk and Levene's tests, respectively. Since the assumptions failed, non-parametric procedures were adopted. Descriptive statistics (mean and standard deviation) are reported. Mann-Whitney U test was used to compare the variables between genders. The significance level was set at $p \leq 0.05$. Additionally, effect size (ES) was calculated with the Equation 3 (Fritz, Morris, &

Richler, 2012) and interpreted based on Cohen's guidelines (Coolican, 2009):

- small (0.20);
- moderate (0.30);
- large (0.50).

$$r = Z/\sqrt{N} \tag{3}$$

RESULTS

Data of the propulsive peak force for the dominant (PF_D) and the non-dominant (PF_{ND}) upper-limbs between women and men are present in Table 1. The observed trend was of larger values in PF_D and PF_{ND} for men over the incremental protocol. Significant differences between genders were found for PF_D at cadence 120, 135 and 150 bpm. Differences in PF_{ND} were also found for HA_{135}, HA_{150} and RH_{add} during the incremental protocol. No differences were noted in PF_D for HA_{105}, RH_{105} and PF_{ND} for HA_{105} and HA_{120}. However, PF_{ND} for HA_{105} showed a value close to the significance. A large ES was found for cadence 135 and 150 bpm in both limbs on HA and also for cadence 120, 135 and 150 bpm on RH_{add}.

Table 2 depicts the relative force production of women and men for dominant upper-limb (RF_D) considering the dry-land strength. In both groups, the values seem to have a trend to increase with increasing cadence. Women showed to elicit a higher percentage of force than men regarding maximal strength delivered on dry-land. The values of RF_D ranged from ~47 (105 bpm) to ~74% (150 bpm) for women and from ~33 to ~62% for men. However, no significant differences were noted between genders at the same music cadence. A small ES was noted in most music cadences in the two fitness exercises.

Table 3 shows the symmetry index in both exercises at different cadences. A symmetric motion was found for women

Table 1. Comparison (Mean±SD) of the propulsive peak force for dominant and non-dominant upper-limbs in two water fitness exercises in different genders and at different music cadences (*n*= 18)

		Cadence (bpm)											
		105	*p*	ES	120	*p*	ES	135	*p*	ES	150	*p*	ES
HA													
PF_D (N)[a]	Women	25.15± 4.69	0.173	0.32	29.04± 4.08	0.051	0.46	32.08± 4.93	0.011	0.60	35.41± 4.46	0.011	0.60
	Men	36.43± 15.89			41.73± 17.68			50.40± 14.59			56.20± 12.12		
PF_{ND} (N)[a]	Women	24.34± 3.90	0.066	0.43	28.27± 4.69	0.110	0.38	32.35± 4.01	0.015	0.57	37.23± 5.95	0.008	0.63
	Men	34.05± 11.73			40.33± 14.57			48.32± 12.30			57.30± 7.20		
RH_{add}													
PF_D (N)[a]	Women	22.18± 5.01	0.086	0.40	26.29± 4.85	0.028	0.52	29.80± 4.18	0.008	0.63	35.97± 7.04	0.008	0.63
	Men	29.69± 9.27			38.41± 10.59			50.34± 10.85			56.38± 10.65		
PF_{ND} (N)[a]	Women	20.59± 6.92	0.051	0.46	25.61± 2.71	0.028	0.52	27.99± 4.16	0.008	0.63	32.96± 6.46	0.011	0.60
	Men	30.32± 7.36			36.25± 8.46			50.09± 8.92			55.51± 16.92		

[a]Data are presented as mean± SD; bpm: beats per minute; ES: effect size; HA: horizontal adduction; *n*: total of the sample; PF_D: peak force of dominant upper-limb; PF_{ND}: peak force of non-dominant upper-limb; RH_{add}: rocking horse horizontal adduction.

Table 2. Comparison (Mean± SD) of the differences in the relative peak of force production between genders during two water fitness exercises at different cadences (*n*= 18)

		Cadence (bpm)											
		105	*p*	ES	120	*p*	ES	135	*p*	ES	150	*p*	ES
HA													
RF_D (%)[a]	Women	51.79± 12.71	0.374	0.21	60.16± 15.46	0.374	0.21	67.21± 21.44	0.214	0.29	73.90± 21.48	0.314	0.23
	Men	40.92± 21.18			46.28± 22.30			55.69± 20.78			62.41± 21.51		
RH_{add}													
RF_D (%)[a]	Women	46.71± 17.03	0.110	0.38	53.96± 12.35	0.314	0.24	62.38± 18.67	0.374	0.21	76.27± 29.50	0.314	0.24
	Men	33.07± 14.08			43.39± 18.25			54.77± 15.66			61.69± 16.82		

[a]Data are presented as mean± SD; bpm: beats per minute; ES: effect size; HA: horizontal adduction; *n*: total of the sample; RF_D: rate force production for dominant upper-limb; RH_{add}: rocking horse horizontal adduction.

Table 3. Statistic (Mean± SD) of the symmetry index (SI) in both genders (*n*= 18)

Cadences (bpm)	Variable	HA				RH_{add}			
		Women	Men	*p*	ES	Women	Men	*p*	ES
105	SI (%)[a]	11.18± 7.52[b]	9.41± 7.52[a]	0.453	0.17	19.48± 13.52[b]	12.03± 6.93[b]	0.310	0.24
120	SI (%)[a]	7.81± 6.65[a]	10.71± 4.44[a]	0.085	0.40	17.76± 9.51[b]	14.10± 11.61[b]	0.566	0.14
135	SI (%)[a]	9.03± 4.75[a]	9.30± 6.01[a]	0.895	0.03	16.97± 8.86[b]	9.17± 6.57[a]	0.038	0.49
150	SI (%)[a]	12.94± 4.27[b]	10.70± 7.34[a]	0.233	0.28	20.80± 14.42[b]	12.65± 6.84[b]	0.566	0.14

[a]Data are presented as mean± SD; [a]symmetric motion; [b]asymmetric motion; bpm: beats per minute; ES: effect size; HA: horizontal adduction; *n*: total of the sample; RH_{add}: rocking horse horizontal; SI: symmetry index.

during HA at cadences 120 and 135 bpm, while for men, all music cadences elicited a value below the 10% cut-off value. However, RH_{add} elicited an asymmetric motion in women. The trend was also noted for men, except during the cadence of 135 bpm that produced a symmetric motion. No differences between genders were found for most music cadences in both exercises, except for RH_{add} at 135 bpm.

DISCUSSION

The aim of this study was to compare propulsive force production and symmetry between genders in two water fitness exercises. Although men were able to produce larger force values than women, those represented a lower relative force considering the total strength value obtained in dry-land testing. Moreover, men seemed to perform more symmetrical exercises than women at the various cadences in both water fitness exercises.

This is the first study reporting propulsive force values between genders in the aquatic environment. As expected, men showed greater propulsive force values than women in both exercises. Moreover, those were obvious at faster cadences. It is well documented that men show a greater amount of strength than women in different land and water exercises (e.g., Stoll et al., 2000; Morouço et al., 2015). The main differences are explained by the large skeletal muscle mass (Welle, Tawil, & Thornton, 2008), the higher levels of circulating testosterone in men (Dreyer et al., 2010) and the relative distribution of the LBW (Hoffman, Stauffer, & Jackson, 1979; Heyward et al., 1986), compared to the women. At some point, gene expression has been considered the likely potential factor of these differences (Haizlip, Harrison, & Leinwand, 2015). The muscle fibre type composition is also related to gender. Specifically, a prevalence of slower type-I fibres was detected in women, compared to the higher percentage of fast type-II fibres (-IIa and -IIx) in men (Simoneau et al., 1985; Miller et al., 1993; Staron et al., 2000). Since type-I fibres are characterised with slow muscle contractile function, whereas the opposite happens with type-II fibres (i.e., faster muscle contractile), the highest propulsive force that we found for men can be associated with the muscle fibre-type composition that leads to higher power output (Bottinelli, Canepari, Pellegrino, & Reggiani, 1996). Gender-related differences in maximal strength tend to be more pronounced in the upper-limbs muscles (Wilmore, 1974; Hosler & Morrow Jr., 1982; Miller et al., 1993; Kanehisa, Ikegawa, Tsunoda, & Fukunaga, 1994). Schantz, Randall-Fox, Hutchison, Tydén, and Åstrand (1983) showed differences in some muscle fibres CSA of the arms, despite the similar number of fibres for both genders. So, this can explain this trend of behaviour in the water for the two exercises analysed.

Interestingly, our second hypothesis was not confirmed. The women showed a greater ability to transfer force from land to water than men. The women cohort was able to reach 73-76% of the total strength value obtained on land, while men remained at 62%. Thus, it can be speculated that men present an improved technique quality for this motion pattern, which induce a lower relative force production.

Men showed to be more symmetrical than women over most music cadences selected, regarding the SI cut-off value. This is in tandem with available reports in the literature, where men tend to perform a symmetric motion during different activities. Bailey et al. (2015) found that women were more likely to asymmetries in force-production during a squat jump and countermovement jump height. Moreover, Jaszczak (2008) reported that women were less able to coordinate pattern adjustment at higher velocities during breaststroke simulation, which is in line with our findings. The symmetric motion was seen in both groups at a cadence of 135 bpm, except for women in RH_{add}. This finding is in agreement with previous research in water fitness exercises. Santos et al. (2019) reported that the cadence of 135 bpm seemed to be appropriate to minimise asymmetries during water fitness exercises. Maybe, cadences slower or faster than 135 bpm may impose some motor control constraints and/or elicit exhaustion/fatigue that will impair the performer to reach the motion symmetry. However, the HA promotes higher SI values compared to RH_{add}. Notwithstanding, an alternative segmental action (i.e., RH_{add}) may lead to a desynchronisation of the motor units (Enoka & Laidlaw, 1998) compared to a simultaneous segmental action (i.e., HA) for both groups. It should be noted that RH_{add} requires an optimal level of coordination between limbs, as reported elsewhere (Santos et al., 2019).

Water fitness professionals should consider the correct use of the music cadence in an attempt to get the desired effort and conditioning through their sessions. They should be aware of the differences between genders regarding strength and muscular conditioning. The cadence of 135 bpm seems the most appropriate to get an optimal stimulus for strength development while maintaining the range of motion. Plus, it seems the best way to increase the force transfer from land to the water environment (i.e., relative force production) in both genders. Finally, the exercises that involve an alternative segmental action should be discarded to reduce potential asymmetries' when trying to work strength.

Some limitations can be addressed to this piece of research:

- the uncontrolled effect of kinematic variables;
- the recruitment of young healthy subjects.

CONCLUSIONS

Men are able to produce a larger force than women performing water fitness exercises. Despite that, women were able to reach a higher relative force production considering the total strength value obtained in dry-land. Men are also able to deliver more symmetrical upper-limbs actions than women exercising at a wide range of cadences.

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