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The influence of sex on high intensity swimming test

Javier Moreno Lara[1], Inmaculada López-León[1], Luís Leitão[2], Sandro Fernandes da Silva[3,4], Antonio Jesús Sánchez-Oliver[1,4*], Raúl Domínguez[1,4]

[1] Department of Human Movement and Sports Performance, University of Seville, Spain.

[2] Sciences and Technology Department, Superior School of Education of Polytechnic Institute of Setubal, 2910-761 Setúbal, Portugal.

[3] Physical Education Department, University of Lavras. Lavras, Brazil.

[4] Studies Research Group in Neuromuscular Responses (GEPREN), University of Lavras, Lavras 37203-202, Brazil.

* Correspondence: Antonio Jesús Sánchez-Oliver; sanchezoliver@us.es

ABSTRACT

Differences based on sex have been reported in the energetic and mechanical demands of different exercise modalities; however, no studies have analyzed the influence of sex during high-intensity swimming. The aim of this study was to determine sex-based differences in the response to a high intensity swimming test on performance, fatigue, blood lactate concentrations (BLa) and rating of perceived exertion (RPE). A total of 23 competitive swimmers (11 males; 12 females) performed 8 sets of 50-m at maximum intensity with 2 minutes of recovery intra-sets. Pre- and post-exercise, BLa was analysed. In addition, RPE were administered at the end of each 50-m. Differences were detected in the high intensity swimming test on sex (η^2_p=0.566; p<0.001) and time (η^2_p=0.233; p<0.001), but not for the interaction time·sex (p>0.05). It was reported an effect for time on BLa (η^2_p=0.947; p<0.001) and RPE (η^2_p=0.559; p<0.001), but not for sex nor the interaction time·sex (p>0.05). Although males are faster, not differences were found in BLa, fatigue nor RPE between sexes. These results could be mediated by the all-out nature of the protocol and practical implications suggest that it is not necessary to adapt the training load in high intensity swimming session attending to the sex of the athletes.

KEYWORDS

Exercise; High Intensity Interval Training; Lactate; Metabolism; Physical Exertion

1. INTRODUCTION

Biological sex is a primary determinant of athletic performance based on differences in anatomy and physiology dictated by sex chromosomes, hormones, and non-physiological factors (Hunter et al., 2023). Anthropometric differences include height and a reduced percentage of fat mass in males (Gallagher, 1997) while at the histological level, females have a longer proportional area with the type I muscle fibers (Staron et al., 2000; Fournier et al., 2022). These histological differences increase mitochondrial content (Esbjornsson et al., 1993) and an enhanced ability to increase lipid metabolism (Sandbakk, 2018). Potentially, it could be attributed to a higher oxidative performance in females. Nevertheless, a higher muscle mass (Gallagher et al., 1997), proportion of type II muscle fibers (Staron et al., 2000; Fournier et al., 2022) induce to have larger, stronger, faster, and more powerful muscles in males (Miller et al., 1993). These histological differences allow males to produce higher torque in different sports activities such as swimming, jumping, and throwing actions (Hunter et al., 2023). Muscle differences are influenced by hormone levels as testosterone which presents important anabolic effects on muscle and bone mass and, haemoglobin concentrations (Handelsman et al., 2018; Notelovitz, 2002; Crewther et al., 2011). Differences in mass and muscle composition, hormones, and blood explain an increased maximal oxygen uptake (VO2max) in males (Hunter et al., 2023) and glycolytic non-oxidative metabolism (Maud & Shultz, 1986; Weber et al., 2006) which is mediated by type muscle composition.

Specifically in swimming no differences or a little trend to increase performance in the top girl swimmers (United States (US) top 5) have been observed along the pre-puberty period (Senefeld et al., 2019). During puberty, circulating testosterone levels are ~15 times (Handelsman et al., 2016) greater in men than women at any age (Senefeld et al., 2019). In the US top 100, from the age of 10 to 17, in all the Olympic free swim distances, male swimming velocity was faster than female (Senefeld et al., 2019). In general, it has been attributed and enhanced VO_2max (Lavoie & Montpetit, 1986), Maximal Aerobic Velocity (MAV) (Almedia et al., 2022) and non-oxidative swimming performance (Seiler, 2007) in males than female swimmers. Considering the differences on the world record swimming between male and female swimmers, it is shown an increased reduction of the magnitude along the distance (reduction from 13.2% in 50-m to 5.7% in 1500-m) (Hunter et al., 2023). This analysis based on the magnitude of difference across the different swimming distance suggest a possible interaction of the sex on swimming performance at longer distances. In female swimmers, factors as smaller body size, lower body density, lower torque, higher percentage of body fat and shorter legs; contributes to a more horizontal and streamlined body position (Pendergast et al., 1977), which reduce hydrodynamic resistance (Zamparo et al., 2020). These minor hydrodynamic resistances in combination with an increased lipid metabolism during prolonged swimming (Sandbakk et al., 2018) contribute to a higher economy (Tanaka & Seals, 1997). Economy is one of the limiting factors in swimming (Lavoie & Montpetit, 1986; Toussaint & Hollander, 1994). The gold standard for assessing economy is the reduction of VO_2 during submaximal intensities (Truijens et al., 2008), however indirectly it is estimated in the ratio VO_2:RPE (Coquart et al., 2014). By last, it is remarkable the social determinants such as lower incentives and access to training facilities that lead to lower participation of women compared to men. (Hunter et al., 2023).

Training programs in competitive swimmers are characterized by the inclusion of resistance training session, that enhances swimming performance (Herrera & López-Plaza, 2023). Regarding to swimming, although training volume is highly variable, either high volume or low volume training induced the same effects in highly trained (Faude et al., 2008), masters (Pugliese et al., 2015) or un-trained swimmers (Soultanakis et al., 2012). High intensity interval training (HIIT) is a fundamental method used in swimming to enhance performance (Karabiyik et al., 2023) in both low- and high-volume training programmes. Different studies have studied the influence of HIIT in swimmers (Kilen et al., 2014; Braun et al., 2016; Kabasakalis et al., 2020, 2022). Specifically, one study assessed the effect of 12 week of HIIT program for reducing swimming volume in a sample formed by 30 males and 11 female swimmers (Kilen et al., 2014), another research analysed the oxidative stress response to a high intensity swimming test in master swimmers (14 males and 10 females) (Braun et al., 2016) while other two studies analysed the acute response of blood biomarkers to these type of interval swimming tests in a sample formed by trained male and female swimmers (Kabasakalis et al., 2020, 2022). Because none of the studies focused in the analysis of HIIT or an acute high intensity swimming test in swimmers have analysed possible differences based on sex in trained swimmers (Kilen et al., 2014; Braun et al., 2016; Kabasakalis, A. 2020, 2022); the aims of this study were to determine sex-based differences in the response to a high intensity swimming test on performance, fatigue, blood lactate concentrations (BLa) and RPE. Based on previous studies that informed of an enhanced oxidative metabolism in women (Sandbakk, O. 2018) and powerful and glycolytic performance in males (Miller et al., 1993; Weber et al., 2006; Seiler, 2007), our hypothesis is that male swimmers will be faster and increase more BLa response after a high intensity swimming test in competitive swimmers while female swimmers will present a reduce fatigue and lower RPE during a high intensity swimming test.

2. METHODS

2.1. Design and Participants

In the present study, an experimental session that included a high intensity swimming test was held. As it can be seen in Figure 1, the assessment session started with an analysis of BLa before a standardized warm-up. After 5 minutes of finishing the warm-up, the participants carried out the high intensity swimming test consisting in 8x50 meters “all out” with 2 minutes of recovery between sets. Prior to the start of the test and after each repetition of the high intensity swimming test, the participants were given the Borg scale to determine RPE. In addition, after 3 minutes of rest, BLa were analysed a second time.

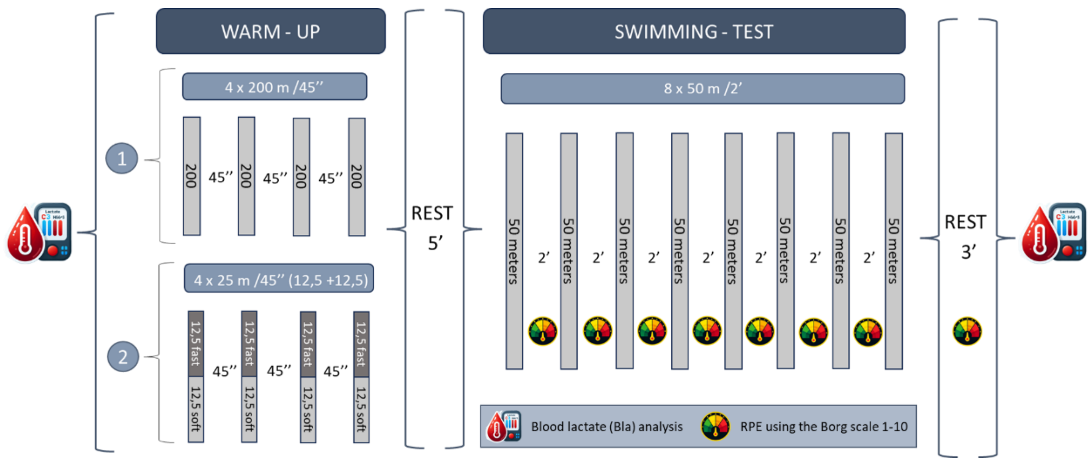

Figure 1. Experimental design of this study

The sample of the present study was formed by 23 competitive swimmers. A total of 23 swimmers of which 11 males (18.5 ± 3.14 years) and 12 females (16.9 ± 3.75 years index) from the team “Circulo Mercantil e Industrial de Sevilla” of Sevilla (8 males and 7 females) and “Clube de Nataçao do Fundao” of Fundao (3 males and 5 females). All the participants accredited the minimum mark for the Regional Absolute Championships of the current season. Other inclusion criteria were the next: i) to have at least 5 years of experience competing in swimming events; ii) train regularly (at least 5 days weekly) along the last year; iii) To include frequently high intensity swimming test in their training routines programs. The exclusion criteria included: i) to have some type of cardiovascular disease; ii) to take any medication; iii) to take any type of supplementation. All the participants were previously informed of the protocol to be followed for the study and signed a consent form to participate in the study. This study was approved by an Ethics Committee of the Polytechnic Institute of Setubal (code: PI26/2022).

2.2. Tests and Assessments

2.2.1. High intensity swimming test

The high intensity swimming test was preceded by a standardized warm-up in the water. Warm-up was composed by two parts. The first part consisted in 800-m front crowl (Zacca et al., 2019) divided into 4 sets of 200 metres (4 x 200-m) with a rest period of 45 seconds between sets. Indications to the participant were to carry out the series at "warm-up pace". The second part of the warm-up consisted in 4 sets of 25-m (4 x 25-m) of which 12.5-m were at maximum intensity and 12.5-m soft until the arrival to the wall.

Five minutes after the end of the warm-up, the test started. The high intensity swimming test consisted in 8 sets of 50-m with 2 minutes of recovery. Swimmers were instructed to perform all sets at maximum intensity, starting with the first set and not saving anything for later sets. The swimming test was performed using a push-off start from within the water with the front-crawl technique (Dalamitros et al., 2021). The test was completed in a 25-m six lane pool (Kilen et al., 2014). The times of each repetition was recorded by two different researchers using a Pulivia stopwatch (± 0.01s). The medium between the two researchers were considered for the analysis. In addition of the time for covering each set, it was analysed: the best and the worst 50-m, the medium time of the test and the average of the firsts and seconds four sets of 50-m. Also, it was calculated a fatigue index (FI) based on the magnitude of change between the time for covering the fastest and slowest 50-m, and a second FI based on the differences between the first and second 50-m partials (FI4x50).

2.2.2. Blood Lactate Concentrations (BLa) Assessment

BLa was analysed before performing the warm-up (BLA_{pre}) and three minutes after finishing the high intensity swimming test (BLA_{post}). A sample of 5 µl of blood was taken from the thumb of the index finger of the left hand. The assessment started cleaning the first drop of blood with alcohol and carefully drying before each sampling (Almeida, TAF. 2021). A Lactate Pro™ 2 LT-171 analyser system (Arkray Factory Inc., KDK Corporation, Shiga, Japan) was used.

2.2.3. Rating of Perceived Exertion (RPE)

RPE was analysed using a numerical scale from 0 to 10 (Modified Borg Scale, CR10). It consisted of a limited number range of 0 to 0.5 to 1 to 10, with numbers placed as positions so that a linear relation could be obtained (Borg, 1998). (The rating "0" is nothing at all and the rating 10 is extremely strong). This scale is administered after the warm-up and after each set in the intermittent test.

2.3. Statistical Analysis

All the results are depicted as mean (M) ± standard deviation (SD). The normal distribution of the data was verified through a Shapiro-Wilk test, while the equality of variances was confirmed using the Levene test. An analysis of variance with repeated measures (ANOVA-RM) was performed for the time factor in performance (the time covering each set), RPE and BLA assessment (BLA_{pre} and BLA_{post}); for the sex factor (male vs. female) and for the interaction time·sex. When it was detected statistical differences, a Post-Hoc Bonferroni was performed. Additionally, effect size (ES) was calculated by eta partial squared (η^2_p), considering small (<0.25), medium (0.26–0.63) and large (>0.63) ES (Richardson, 2011). Complementary for analysing possible differences between male and female fatigue levels, a non-related t-test was performed in FI and FI4x50. Statistical differences were fixed up $p<0.05$. All statistical processing was performed in the Jamovi software (version 2.3.28).

3. RESULTS

3.1. Swimming Performance

In the analysis of the high intensity swimming test, it was detected statistical differences between sexes ($F=27.40$; $\eta^2_p=0.566$; $p<0.001$). In fact, the post-hoc reported a faster time for covering each one of the 8 sets of 50-m in male swimmers ($p<0.001$). In the analysis of the time, it was detected a statistical effect with a progressively slowest time for covering each 50-m repetition ($F=18.57$; $\eta^2_p=0.233$; $p<0.001$) (see Figure 2). Nevertheless, it was not found any effect for the interaction time·sex ($F=5.73$; $\eta^2_p=0.086$; $p=0.062$). Complementary, it was not detected statistical differences between male and female swimmers in the FI ($t=1.46$; $p=0.160$) nor FI4x50 ($t=1.76$; $p=0.092$).

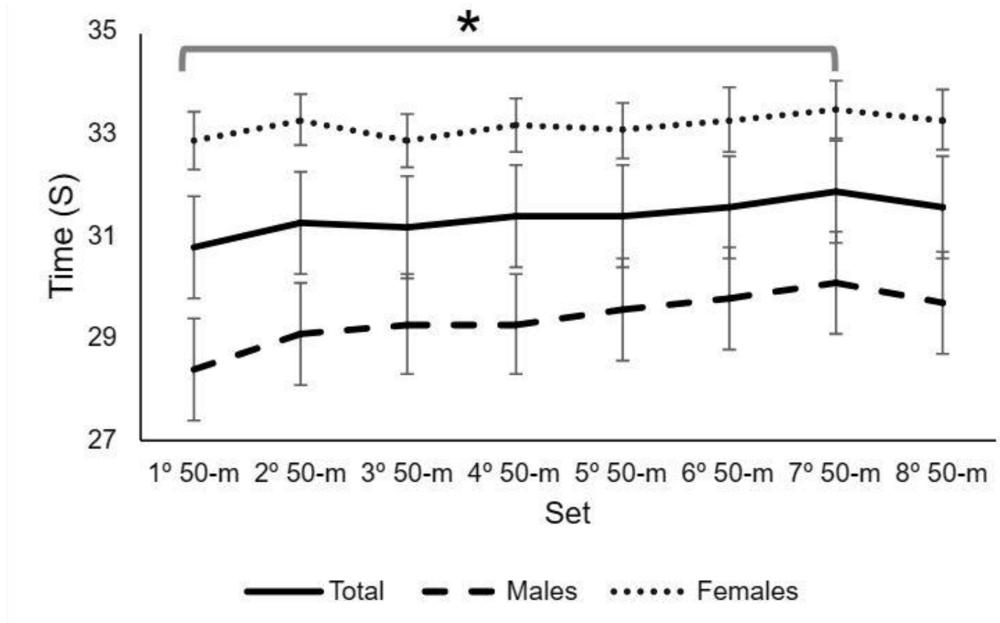

Figure 2. Time for covering each repetition of 50 m in males, females, and all participants
*Note. Data are given as mean ± standard deviation. *: statistical differences between the first and the seventh 50-m*

3.2. Blood Lactate Concentrations

BLa was significantly elevated after the high intensity swimming test in both males and females swimmers (F=375.02; η^2_p=0.947; p<0.001), however no effect was reported for sex (F=0.518; η^2_p=0.024; p=0.480) nor the interaction time·sex (F=1.09; η^2_p=0.050; p=0.308) (See Figure 3).

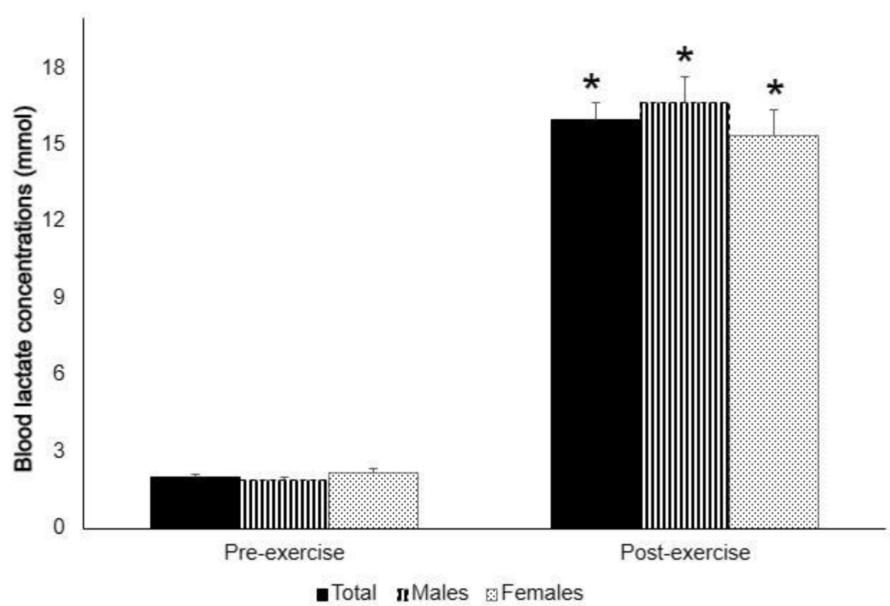

Figure 3. Blood lactate concentrations (BLa) before and after exercise for all participants and by sex
*Note. Data are given as mean ± standard deviation. *: statistical differences between the post- and the pre-exercise*

3.3. Rating of Perceived Exertion (RPE)

Regarding to RPE, it was detected a statistical effect for the time (F=26.348; η^2_p=0.559; p<0.001), but not for sex (F=0.122; η^2_p=0.006; p=0.730) nor the interaction time·sex (F=0.666; η^2_p=0.031; p=0.701). Therefore, it was observed an increased RPE since the third set of 50-m in comparison with the first 50-m (p<0.01) while the fourth set it was reported statistical difference with the second 50-m too (p<0.01). There were not statistically significant differences between the fifth, sixth and seventh 50-m (p>0.05), however RPE was significantly increased in the last 50-m in comparison with the fifth 50-m (p=0.006).

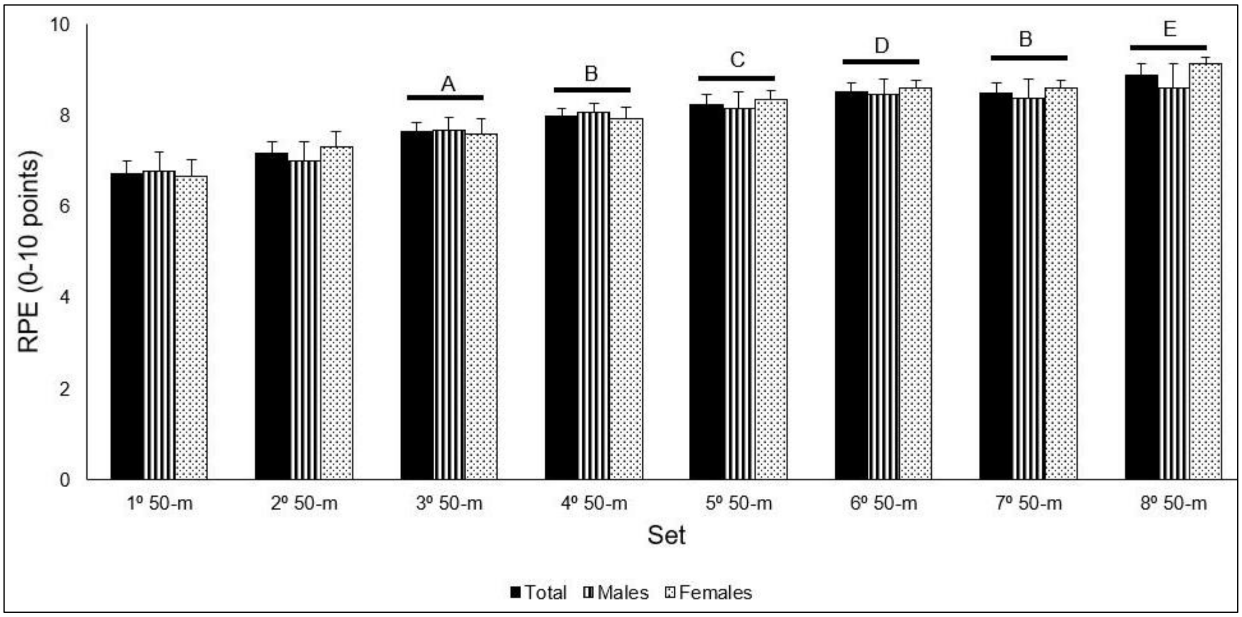

Figure 4. RPE values at the end of each 50-m repetition in males, females, and all participants

Note. Data are given as mean ± standard deviation. [A]: statistical differences with 1º 50-m; [B]: statistical differences with 1º and 2º 50-m; [C]: statistical differences with 1º, 2º and 3º 50-m; [D]: statistical differences with 1º, 2º, 3º and 4º 50-m; [E]: statistical differences with 1º, 2º, 3º, 4º and 5º 50-m.

4. DISCUSSION

The main findings of this study are the next: i) it exists a progressively fatigue, an increasement of BLa and RPE during a high intensity swimming test of 8x50-m; ii) male swimmers are faster than female swimmers; iii) it does not exist between male and female swimmers differences in the BLa and RPE response; iv) it does not exist a difference response in fatigue, BLa and RPE mediated by sex.

Differences based on sex have been reported previously in high intensive swimming performance in sets of 25-m (Kabasakalis et al., 2020, 2022; Papadimitriou et al., 2023) and 50-m (Kabasakalis et al., 2020, 2022; Terzi et al., 2021). These results in high intensive swimming are in line with sex-differences in VO_2max (Lavoie & Montpetit, 1986), MAV (Almedia et al., 2022) and non-oxidative swimming performance in trained athletes (Seiler et al., 2007). Physiological factors, including greater muscle mass, proportion of type II motor unit (Fournier et al., 2022), testosterone and heightened glycolytic metabolism (Weber et al., 2006) in men, collectively could explain these sex-related differences.

BLa is assessed along the high interval intensity test because it is considered an indicator of the contribution of glycolytic activity to the energy metabolism along physical activity (Goodwin et al., 2007). Our results suggest a similar non-oxidative metabolism in swimmers independently of the sex. These findings are opposed to other studies performed in swimmers (Kabasakalis et al., 2020, 2022; Cuenca-Fernandez et al., 2023). In two different studies, it was identified a higher BLa response in males in a 4x50-m (Kabasakalis et al., 2022) and 8x50-m test (Kabasakalis et al., 2020), however these two studies used a ratio work-to-rest of 1:1 while our study used a ratio ~1:4. These differences based on sex were similar in the study of Cuenca-Fernández et al. (2023) who found differences using 10x100-m and 20x50-m with a ratio work-to-rest of 1:1. A decreasement in the ratio work-to-rest induce to an increasement of the oxidative metabolism (La Monica et al., 2019). An increased lipid contribution to energy metabolism during swimming (Sandbakk et al., 2018) and enhanced economy (Tanaka et al., 1997) could explain the lower BLa response to interval swimming in studies with a ratio of work-to-rest 1:1 (Kabasakalis, 2020, 2022; Cuenca-Fernandez et al., 2023). In fact, BLa concentrations were lower in males (11.3-14.2 mmol) and females (7.7-13.4 mmol) in comparison with our study (~16 mmol for both, male and female swimmers). These differences in BLa could be attributed because the present study presented the characteristics of an “all out” effort with a very high glycolytic demands which is the most predominant energy metabolism. Moreover, in agreement with the results reported by us, other studies that have used a recovery of 2 minutes in 4x50-m (Terzi et al., 2021) and 3 minutes in a 5x50-m swimming test (Papadimitriou et al., 2023) found similar BLa and no differences based on sex. Therefore, at difference of submaximal interval swimming procedures with a higher glycolytic response between sexes (Kabasakalis et al., 2020, 2022; Cuenca-Fernandez et al., 2023), the results of the present study reflexed a similar BLa response in all out high intensity swimming tests with increased work-to-rest ratio. These results are in line with a meta-analysis which concluded that do not exist a sex·HIIT interactions on BLa (Lock et al., 2024).

Results in the analysis of the fatigue are in line with BLa response. Therefore, it was reported an effect of time, but not for sex nor interaction sex time in time for covering 50-m and differences mediated by sex in FI and FI4x50. These results could be attributed partially to the characteristics of the effort and the swimming pacing strategy. Pacing strategy is defined as the distribution of exercise intensity during any kind of a race (Moser et al., 2020). In this study, it was used an all-out pacing strategy, which is the most used in 50-m events, because swimmers should combine to provide maximum velocity and try to maintain it (Maglischo, 2002). In a recent systematic review (McGibbon et al., 2018) and a study with master swimmers (Moser et al., 2020) focused in the pacing strategies, it was not reported a different pacing strategy based on sex in distances of 50-m and 100-m; but it was reported an effect for longer distance (i.e., 400-m) with a more stabilization swimming velocity in female swimmers (McGibbon et al., 2018; Moser et al., 2020). At difference of other swimming distance that include another pacing strategy as even pacing strategy (400-m) (McGibbon et al., 2018) an increased oxidative metabolism could reduce H^+ concentrations (Kelly et al., 1992) in females who could maintain a more constant and efficient race pace. Nevertheless, the results of the present study suggest that in swimming events characterized by an all-out pacing strategy there are not influence of the sex.

Previously, it has been speculated that female swimmers could reduce RPE response based in a hypothetical lower glycolytic input during intensive swimming (Massini et al., 2021). The results of the present study reported a similar glycolytic demand and the absence of difference on RPE response. In this way, the similar response between males and female swimmers on RPE was found after 4 x 25-m (Kabasakalis et al., 2022), 4 x 50-m (Kabasakalis et al., 2022) 5x50-m (Papadimitriou et al., 2023). The similar pattern of RPE along all-out swimming protocols are in line with other type of exercises as cycling (Karayigit et al., 2022; Astorino & Sheard, 2019; Magal et al., 2020) and running (Laurent et al., 2010) following all-out pacing strategies along high intensity interval protocols. Even this RPE response in males and females are in line with time-to-exhaustion test (Garcin et al., 2005). RPE is closely linked to essential physiological variables such as heart rate, VO_2 and BLa in the context of swimming performance (Ueda et al., 1995). Considering the very high demands imposed by the all-out nature of the swimming test, swimmers experimented increased BLa values and VO2 slow component that induce fatigue reflected by a RPE response similar in males and females with values near to the maximum.

The main practical applications of this research study lie in the finding that there are no differences in fatigue, BLa, or RPE based on sex. These findings, suggest that it is not necessary to adjust the volume or recovery periods between sets in HIIT based on the sex of the swimmers. Additionally, this study intended to raise awareness about the importance and the need of analysing sex differences in sports, leading to a better understanding of sex-specific characteristics.

This study presents various limitations that must be considered. Firstly, a biomechanical parameters analysis has not been carried out. The stroke length, stroke cycle frequency, and stroke index are some of the most determining biomechanical variables that could affect to swimming performance (Marinho et al., 2020). It would be interesting to consider the analysis of these biomechanical variables for future researches, to observe possible differences and interactions according to sex. Secondly, the moment of the menstrual cycle of each female swimmer was not controlled. It could be considered that hormonal fluctuations along the different phases of the menstrual cycle (follicular, ovulatory, and luteal phases) influence in the responses to exercise (Forouzandeh Shahraki et al., 2020). For example, strogen levels are elevated during the ovulatory phase with implications in the anabolic muscle metabolism, increasing glycogen storage capacity (McNulty et al., 2020). Additionally, during the luteal phase, there is an increase in ventilatory response and heart rate during high-intensity efforts (Rael et al., 2021). Therefore, it would be relevant to analyse the performance, fatigue, metabolic and RPE response during high intensity swimming test in competitive female swimmers along the different phases of the menstrual cycle.

5. CONCLUSIONS

In this study it has been examined the existence of sex-based differences in the response to a high intensity swimming test on performance, fatigue, blood lactate concentrations (BLa) and RPE.

The results of the present study concluded that male swimmers are faster during a high intensity swimming test with a similar response of fatigue indicators, BLa and RPE. At difference of other swimming procedures, with a higher oxidative demand reflected in an even swimming pacing strategies, that informed of a possible advantage for female swimmers; the short distance (50-m), increased work-to-rest ratio and all-out pacing strategy induce to a necessarily progressive fatigue and RPE in swimmers of both sexes. Therefore, in high intensity swimming using short distances (50-m) and a moderate completed recovery (2 minutes) it does not exist an interaction of sex on fatigue, glycolytic metabolism and RPE. Practical implications of these results are important because, at difference of other type of swimming training sessions, it is not necessary to adapt the training load in high intensity swimming session attending to the sex of the athletes.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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