



EFFECTS OF AGE AND GENDER IN PHYSIOLOGICAL RESPONSES, MECHANICS, AND PERFORMANCE OF MASTER SWIMMERS

original paper

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ABSTRACT

Purpose. The purpose of the study was to analyse the effects of age and gender in physiological responses, mechanics (stroke frequency, stroke length, stroke index), and performance time of master swimmers.

Methods. Overall, 34 male and 25 female master swimmers were divided into 2 age categories: (a) 30–39 years, (b) 40–49 years, and completed a 100-m freestyle swimming test with maximum intensity. Stroke mechanics and performance time were measured during the effort. Blood lactate concentration was determined after the test in the 3rd, 5th, and 10th minutes of passive recovery.

Results. Two-way ANOVA showed no interaction between gender and age category for any examined variable ($p > 0.05$). Maximum blood lactate was maintained in both genders despite ageing ($p > 0.05$) and was lower for females compared with males ($p < 0.001$). Higher values were observed for stroke frequency, stroke length, and stroke index for males ($p < 0.05$). For both genders, the 30–39 years category had significantly higher values for stroke length ($p = 0.020$) and lower for stroke frequency ($p = 0.014$), indicating that these swimmers can produce stronger strokes than those in the 40–49 years category. Performance time values were significantly lower for males compared with females ($p < 0.001$), but did not change with ageing ($p > 0.05$).

Conclusions. Despite ageing, swimmers are able to maintain all examined variables through a structured swimming training but with a possible decrease in stroke mechanics, independent of gender. Better values were observed for males compared with females probably owing to a greater muscle mass in the former.

Key words: master swimming, blood lactate, stroke, time performance

Introduction

A variety of sports, with running, cycling, and swimming most popular, are widespread among master athletes. As part of master sports, competitive or recreational swimming offers improvements in physical and mental health [1] independent of previous experience in the sport [2].

Ageing in sedentary population results in a decrement of HRpeak and oxygen consumption, high blood pressure, and failure to fulfil aerobic and anaerobic tasks [3]. Muscle mass and muscle fibre type and size

are strongly affected [4] and during ageing this population suffers from morbidity, mortality, lack of independence, and a decrease in the quality of life [5]. The previously sedentary population interested in master swimming should be investigated carefully, especially those wishing competitive participation, with the consideration of the fact that they were not formerly competitive athletes. A long term training plan for the abovementioned master swimmers should account for specific physiological and mechanical changes that occur with ageing [3].

Studies referring to maximum blood lactate con-

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centration (L_{Amax}) of master swimmers are scarce. Despite ageing, L_{Amax} remains stable in male subjects following high-intensity training [6], or it may decrease in both genders over a season of a structured swimming training combined with performance improvement [7]. However, differences of L_{Amax} between genders are not well studied. Time to reach L_{Amax} (tL_{Amax}) may not be related to the ageing process [6].

Previous findings claim that performance time increases with ageing [8–11]. After ca. 35–40 years of age, performance decrement is linear, about 1% per year, and becomes exponential after the age of 70 [8, 9]. The decrement is probably attributed to reductions of physiological functions or even psychological or social environment factors, injuries, or reduction of training load [8, 9]. On the other hand, most recent studies indicate that performance time can be maintained or even improved through structured training up to a certain age [7, 12–14]. Such training design refers to high-intensity or high-volume training. Gender differences reveal a similar rate of decline due to ageing but better performances for males compared with females of the same age categories, probably owing to a greater muscle mass in men [15].

Positive links between stroke characteristics improvement and performance time decrease have been reported by Ferreira et al. [16], who indicate that performance strongly connects to stroke mechanics [17]. As a result, possible strength and power losses owing to ageing might affect stroke mechanics and performance.

Obtaining information concerning blood lactate parameters, stroke mechanics, and performance time during ageing will provide significant data regarding the progress of the athlete, and possible decrements due to ageing, allowing to set goals and design an appropriate training plan.

The aim of the present study is to investigate physiological responses, mechanical swimming characteristics, and performance of maximal swimming effort in master swimmers of different age groups and genders.

Material and methods

Participants

The total of 59 healthy master swimmers were recruited from various athletic clubs of the same suburbs and volunteered to participate in the study. The swimmers were divided into 10-year-range age groups [6, 18]: (a) 30–39 years of age (females: $n = 13$, males: $n = 19$); (b) 40–49 years of age (females: $n = 12$, males: $n = 15$).

The subjects were non-smokers, had at least 1 year of swimming experience, and avoided any other physical activity for 6 months prior to participation. They were instructed to maintain their normal diet, avoid any strenuous exercises, and abstain from any alcohol consumption for 1 week prior to the test. The descriptive statistics for age, height, and body mass are presented in Table 1.

Design and procedures

The present study analysed the effects of ageing and gender on physiological responses, swimming stroke mechanics, and performance of master swimmers aged 30–49 years.

The training program logs, available from the coaches of the swimmers, presented that all swimmers were involved in a 60-min training program of 3 sessions per week the year before the measurement. Each swimming session was supervised by a swimming coach. Aerobic and anaerobic sets were involved in the training program as $63 \pm 3\%$ and $12 \pm 4\%$ of the training volume, respectively, and were calculated from the mean values of training program logs for each week of the year for all the participants. The other $25 \pm 2\%$ involved warm-up and recovery. Drill sets and swimming equipment (fins, paddles) were used in order to improve the technique parameters and muscular strength. The training volume and intensity were not characterized as high but medium, compared with other studies of master swimmers [12]. All swimmers were considered as fitness swimmers since some of them used to participate in local

Table 1. Mean \pm SD values regarding age, body height, and body mass in both genders and age categories

Anthropometric characteristics	Females		Males	
	30–39 years	40–49 years	30–39 years	40–49 years
Age (years)	34.7 \pm 2.5	44.7 \pm 3.6	33.5 \pm 2.9	45.1 \pm 2.5
Body height (cm)	165.5 \pm 7.3	164.9 \pm 6.7	182.8 \pm 7.6	177.1 \pm 8.1
Body mass (kg)	56.4 \pm 6.6	59.9 \pm 9.3	82.8 \pm 9.5	81.5 \pm 14.0

master swimming events once or twice per year and the general purpose of exercising was fitness and recreation as described by Lucero and Bleul-Gohlke [2].

Measurements

Measurements were conducted in an indoor 25-m swimming pool (26–27°C) during-afternoon hours. Before the test, anthropometric characteristics were obtained and the participants completed a questionnaire indicating previous training experience and competitive participation. Prior to the test, all swimmers performed a 15-min self-paced warm-up. After 10 minutes of rest, each individual was instructed to complete a 100-m freestyle swimming test with maximum intensity.

In order to eliminate the influence of the dive, a wall-push start and a wall-grab turn on the surface level were applied. All individuals managed to swim under the international swimming rules of the Fédération Internationale de Natation (FINA).

Performance time was determined for the whole distance (T100) with a stopwatch (Seiko S141; Japan) by 2 experienced researchers and the mean value was used for the analysis. Stroke frequency (SF) was measured by 2 experienced researchers with a crono-frequency meter (Golfinho Sports MC 815; Aveiro, Portugal) from 3 consecutive stroke cycles in the middle of each lap and the mean value of all laps was used for the analysis. One stroke cycle was defined as the full movement cycle of one arm. Stroke length (SL) was calculated as the quotient of speed vs. SF [19]. Stroke index (SI) as an indicator of swimming efficiency was established by the product of speed and SL as suggested by Costill et al. [20].

In order to determine swimming intensity, maximum heart rate (HR_{peak}) was measured with a Polar heart rate monitor (Polar S610 Electro; Kempele, Finland) placed on the sternum, immediately after the test. Estimated maximum heart rate (HR_{max}) was calculated in accordance with Tanaka et al. [21], with the following equation:

$$\text{HR}_{\text{max}} = 208 - 0.7 \cdot \text{age}$$

Lactate concentration measurement was conducted at the 3rd, 5th, and 10th minute of passive recovery [22] after the T100 while the individual was sitting on a comfortable chair out of the water. In each measurement, a blood sample was taken from the tip of the finger and analysed with a Lactate Scout analyser (SensLab, Germany). L_{Amax} was considered to be

the highest blood lactate concentration in post-exercise condition. After the measurements, tL_{Amax} was calculated.

Statistical analysis

Data are displayed as means \pm SD. All statistical tests were processed with the use of the SPSS statistical package (v. 25, IBM SPSS Inc.; Chicago, USA). The normality of the distributions was determined with the Shapiro-Wilk test. Standard statistical methods were used for the calculation of the means and standard deviations. Two-way analysis of variance (ANOVA) was applied in order to assess the effects of gender and age category (2 gender groups [males and females] \times 2 groups of age categories [30–39 and 40–49 years]) on the dependent variables of L_{Amax}, tL_{Amax}, SF, SL, SI, T100, and years of swimming experience. The difference between HR_{peak} and HR_{max} was analysed with a three-way repeated measures ANOVA (1st independent factor: age; 2nd independent factor: gender; 3rd repeated measures factor: heart rate [max vs. peak]). Eta squared (η^2) effect sizes were calculated as the sums of squares for the effect of interest divided by the total sums of squares [23]. The small, medium, and large effects were reflected in values greater than 0.01, 0.06, and 0.14, respectively [23]. Significance was accepted at the $p < 0.05$ level.

Ethical approval

The research related to human use has been complied with all the relevant national regulations and institutional policies, has followed the tenets of the Declaration of Helsinki, and has been approved by the authors' institutional review board.

Informed consent

Informed consent has been obtained from all individuals included in this study. The form involved information about the procedures of the experiment and the right to withdraw at any time.

Results

Years of swimming experience showed no interaction between the 2 examined factors of age category or gender ($F_{1,55} = 0.69$, $p = 0.409$). Moreover, no difference in years of swimming experience was observed between genders or age category (females: 4.5 ± 2.92 vs. males: 3.76 ± 3.41 years, $F_{1,55} = 0.77$, $p = 0.38$; 30–39 category: 3.52 ± 3.34 vs. 40–49 category: 4.74 ± 2.95 years, $F_{1,55} = 2.38$, $p = 0.13$).

Blood lactate

The results of the two-way ANOVA failed to reveal interaction between the 2 factors (gender and age category) for LAm_{ax} ($F_{1,55} = 2.07, p = 0.156$) or tLAm_{ax} ($F_{1,55} = 0.61, p = 0.439$). The results for LAm_{ax} and tLAm_{ax} for the independent variable of gender are presented in Table 2 and for age category in Table 3.

Mechanics

No significant interaction was detected between the 2 factors (gender or age category) for SF ($F_{1,55} = 0.11, p = 0.739$), SL ($F_{1,55} = 0.01, p = 0.930$), or SI ($F_{1,55} = 0.03, p = 0.854$). The results for SF, SL, and SI for the independent variable of gender are presented in Table 2 and for age category in Table 3.

Performance

No interaction between gender and age category could be demonstrated for the variable of T100 ($F_{1,55} = 0.32, p = 0.577$). The results for T100 for the independent variable of gender are presented in Table 2 and for age category in Table 3.

Heart rate

HR_{peak} was different from HR_{max} for the whole sample (172.88 ± 12.38 and 180.71 ± 4.32 beats/min, respectively, $F_{1,55} = 20.08, \eta^2 = 0.22$ [large effect], $p < 0.001$). HR_{peak} was different from HR_{max} for gender (females: 180.36 ± 4.14 and 178.32 ± 9.41 beats/min; males: 180.97 ± 4.49 and 168.8 ± 12.89 beats/min, $F_{1,55} = 10.27, \eta^2 = 0.11$ [medium effect], $p = 0.002$, respectively) and age category (30–39 category: 184.2 ± 1.95 and 173.25 ± 12.5 beats/min; 40–49 category: 176.58 ± 2.09 and 172.44 ± 12.41 beats/min,

Table 2. Mean \pm SD values, *F* results, *p* values, and effect sizes (η^2) for T100, SF, SL, SI, LAm_{ax}, and tLAm_{ax} in both genders

Variables	Females		Males		<i>F</i> _{1,55}	<i>p</i> value	η^2
	Mean	SD	Mean	SD			
T100 (s)	126.79	22.65	105.37	20.52	13.59	< 0.001*	0.20
SF (cycle · min ⁻¹)	28.14	4.77	30.51	4.70	4.13	0.047*	0.06
SL (m · cycle ⁻¹)	1.75	0.28	1.97	0.38	4.91	0.031*	0.07
SI [m ² · (cycle · s) ⁻¹]	1.45	0.46	1.98	0.72	9.90	< 0.001*	0.15
LAm _{ax} (mmol · l ⁻¹)	8.83	3.08	11.72	3.37	11.96	< 0.001*	0.17
tLAm _{ax} (s)	282.24	121.47	280.03	132.88	0.02	0.891	0.00

T100 – performance time for the 100-m distance, SF – stroke frequency, SL – stroke length, SI – stroke index, LAm_{ax} – maximum blood lactate concentration, tLAm_{ax} – time to reach LAm_{ax}

* *p* < 0.05 between the 2 genders

Table 3. Mean \pm SD values, *F* results, *p* values, and effect sizes (η^2) for T100, SF, SL, SI, LAm_{ax} and tLAm_{ax} in both age categories

Variables	30–39 years		40–49 years		<i>F</i> _{1,55}	<i>p</i> value	η^2
	Mean	SD	Mean	SD			
T100 (s)	114.33	27.09	114.59	19.68	0.03	0.858	0.00
SF (cycle · min ⁻¹)	28.18	4.35	31.08	4.99	6.42	0.014*	0.10
SL (m · cycle ⁻¹)	1.97	0.38	1.75	0.28	5.71	0.020*	0.09
SI [m ² · (cycle · s) ⁻¹]	1.87	0.72	1.61	0.59	2.14	0.149	0.03
LAm _{ax} (mmol · l ⁻¹)	10.64	3.45	10.33	3.67	0.20	0.658	0.00
tLAm _{ax} (s)	287.44	152.56	273.30	90.38	0.09	0.764	0.00

T100 – performance time for the 100-m distance, SF – stroke frequency, SL – stroke length, SI – stroke index, LAm_{ax} – maximum blood lactate concentration, tLAm_{ax} – time to reach LAm_{ax}

* *p* < 0.05 between the 2 age categories

$F_{1,55} = 4.33$, $\eta^2 = 0.073$ [medium effect], $p = 0.05$). No interaction was observed between the variables ($F_{1,55} = 0.89$, $p < 0.767$).

The results for the whole sample showed that all swimmers managed to swim at $95 \pm 6.3\%$ of their HRmax.

Discussion

The purpose of the present study was to analyse the physiological responses, mechanical characteristics, and performance of males and females of 30–39 and 40–49 years of age. Previous research involved measurements during national or international swimming events. The participants of the present study could not be compared with elite master swimmers and can be perfectly described as fitness swimmers [2]. The training goals for the participants in the present study included physical activity, recreation, and occasional competition in master swimming events. To the best of our knowledge, this is the first study referring to master swimmers with these specific characteristics, who, according to Lucero and Bleul-Gohlke [2], represent 70% of the master swimmers community. For this reason, the values obtained in the present study are not comparable with those of similar research [6, 18] but are closer to those observed by Ferreira et al. [7] owing to the same ability level of the subjects.

Regarding HRpeak, the participants performed in a near-maximum intensity, at $95 \pm 6.3\%$ of the estimated heart rate as calculated with the equation of Tanaka et al. [21]. Considering the fact that this result was not represented by elite swimmers, we can assume that this is acceptable for fitness swimmers.

The results of LAm_{ax} for males and females did not change with ageing. Therefore, it is possible to conclude that LAm_{ax} can be maintained despite ageing in healthy men and women. According to Benelli et al. [18], it is no longer certain that LAm_{ax} is reduced with ageing but it depends on experience and training. It is possible to maintain LAm_{ax} over years through high-intensity training [6]. The glycolytic mechanism and therefore LAm_{ax} depend on the muscle mass involved in the exercise [18, 24]. The non-statistically significant results of the present study are likely due to the maintenance of muscle mass in spite of ageing [25].

Ageing refers to a reduction in muscle mass, as well as in the number and size of muscle fibres type II [4], yet many master athletes adopt high-intensity parts in their training program that recruits muscle fibres type II. High-intensity training is able to maintain or delay the reduction in the size and distribu-

tion of muscle fibres of adult athletes as is with younger ones [6, 25]. At the same time, high-volume training can maintain muscle mass [26]. As described in the methods section, the participants of the present study followed a structured training program 3 times per week for more than 2 years so it is possible that they maintained their muscle mass.

Regarding gender, significantly lower values were observed for females compared with males. These results are consistent with the studies by Benelli et al. [18] and Ferreira et al. [7]. The glycolytic metabolism depends on muscle mass; therefore, higher lactic values were observed for males because of the greater muscle mass that they might have [15]. The analysis of tLAm_{ax} revealed that gender and age did not affect that variable.

Furthermore, the aim of the present study was to detect any differences in performance. Some previous research supports the reduction of performance with ageing [8] while others claim that there is an ability to maintain it through high-intensity and high-volume training [7]. In the present study, non-significant differences were observed with ageing. Performance time stayed stable through ageing probably because of training and the same swimming experience through each age category. With regard to gender, performance time values were lower for the whole sample of males compared with females.

Muscle strength and the ability to produce powerful and effective arm strokes in water are strongly connected to SF and SL [27]. Significantly higher values were observed for SF, SL, and SI in males, indicating their higher strength levels compared with females. As a result, we can claim that males have greater muscle strength than females, resulting in lower performance times and higher LAm_{ax} values [15].

Independent of gender, the 30–39 years age category had significantly higher values for SL and lower SF results, indicating that these swimmers can produce stronger arm strokes than those in the 40–49 years age category. Thus, we can conclude that there might be the beginning of a minor decrement in muscle strength with ageing that did not affect performance or lactate. Wider age category investigation could present more accurate results, probably indicating that training for older age categories should focus on maintenance of swimming stroke mechanics through strength training.

The measurements of the present study are able to verify the efficiency of a swimming training program and conclude possible necessities such as dry land training or better control of high-intensity and high-volume training. Furthermore, such tests offer

a health check for the master athlete. These considerations are fundamental for master athletes intending future participation in competitions but also for recreational swimmers seeking healthy exercise conditions. The results of the present study state the need to focus on technique and the fact that coaches should expect different results for females compared with males.

Nevertheless, some limitations should be mentioned, such as the low sample size, age range, and variety of swimming training distance. However, this is the first study that reports the effects of LAmax, swimming stroke mechanics, and performance in these age groups and between genders among fitness level master swimmers. Further research should focus on a wider range of age categories, distances, and compared variables, such as energetics and other physiological data.

Conclusions

The present data conclude that males and females aged 30–39 years compared with those aged 40–49 years are able to maintain all examined variables through a structured swimming training. Excluding the variable of gender, a minor decrement in mechanics as a result of ageing is observed. Better values were noted for males compared with females. Coaches should know that lower level master swimmers are able to maintain the examined variables with a possible minor decrement in mechanics, and consider the fact that males are better than females in 100-m freestyle.

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Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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