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"Young" masters vs. elite swimmers: Comparison of performance, energetics, kinematics and efficiency

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Abstract

Background: Competition in masters swimming is getting tougher. Athletes are dedicating more time and effort to excel in masters competitions than they use to. **Research question:** What are the factors associated with masters and elite swimmers performance? **Type of study**: A cohort group comparison (young master versus elite swimmers) and a correlational study (association between selected variables and performance) were conducted. **Purpose**: The aim was to identify the energetics, kinematics and efficiency variables associated with young masters (former elite) and elite swimmers performance as well as compare it between both cohort groups. **Methods**: Twenty male swimmers (masters: N=8, 29.75±3.80-y; elite: N=12, 20.41±3.20-yld) performed a 7x200m freestyle swim. The performance (200m freestyle at official competition), velocity at which the 4 $mmol.l^{-1}$ of blood lactate was assessed (*V4*), peak blood lactate concentrations (La_{peak}), peak oxygen up-take (VO_{2peak}), minimum velocity to elicited VO_{2peak} (vVO_{2peak}), total energy expenditure ($\dot{E}_{tot}$), stroke frequency (SF), stroke length (SL), mean swimming velocity (v), energy cost (C), stroke index (SI) and propelling efficiency (ηp) to check whether this was achieved. **Results**: Elite swimmers presented a better performance. *V4*, VO_{2peak}, vVO_{2peak}, $\dot{E}_{tot}$, *SF, v* and *SI* were significantly higher in elite swimmers. For both groups performance was associated with the *V4*, vVO_{2peak} and *v*. In addition, elite swimmers' performance was impaired with regard to the La_{peak}. **Conclusions**: Young masters swimmers presented impairment in performance related to a decrease in the energetics profile and biomechanical behaviour. Nevertheless, their previous background as elite swimmers allowed them to maintain high swimming efficiency. **Keywords**: freestyle swim, energy expenditure, stroke kinematics, energy cost

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Introduction

Masters swimming competitions have existed for a long time. However, it is becoming increasingly popular and the numbers of athletes have increased substantially over the last few years. Nowadays, competition is tougher than it used to be (at national level in some countries, continental and world championships). Masters competitions are no longer an extension of recreational sports as in the past. Athletes dedicate much time and effort to excel in masters events, as happens in elite sports. In fact, some of the competitive masters swimmers nowadays are former elite athletes. Swimming is a notably appropriate sport to provide insight into the transition between elite and masters careers. Most of the scientific community focuses on adult/elite swimmers and a few to their younger counterparts (i.e. children). In comparison to these two main categories, research on masters swimmers is scarce. To the best of these authors' knowledge, little research has been conducted on the transition from elite to masters careers, or the main differences between elite and "young" masters swimmers.

Masters peak performance occurs during their late '20s to early '30s, after which there is a progressive downturn[1]. There is a non-linear decline or impairment on performance with increasing age[2-4]. Swimming performance is related to energetics and biomechanics[5-6]. The interaction between energetics and biomechanics has as its main aim the enhancement of swimming efficiency and thereby performance. Cross-sectional and longitudinal data report relationships between performance decline or impairment, with total energy expenditure ($\dot{E}_{tot}$)[4,7], peak blood lactate

(La_{peak})[8,9], peak oxygen up-take (VO_{2peak})[8,9] and lactate threshold (or similar concepts, such as *V4*)[3] decreases. It seems that nothing has been reported in the literature concerning the minimum velocity to elicit the VO_{2peak} (vVO_{2peak}) of masters swimmers.

With increasing age, there is a trend towards decreases in swimming velocity (*v*) and stroke length (*SL*)[4]. No differences were reported for the stroke frequency (*SF*)[4]. A cross-sectional study with masters swimmers participating at the World Masters Championships showed significant declines in *v*, *SL*, and *SF* across the seven competition age-groups, the decline of *SF* being about 2.5 times steeper than that of *SL* in the 200-m freestyle event[10]. However, it seems that systematic evidence for masters swimming kinematics is scarce, at least in comparison to their younger aged and adult/elite counterparts.

Some authors have reported a decrease in propelling efficiency (ηp) and energy cost (C) with increasing age[4,11], while it is suggested that a masters swimmer's overall efficiency does change[3,4]. Even so, the body of knowledge about masters efficiency is scarce. Also, it seems that there are no data reporting *SI* (considered as another efficiency parameter or at least an overall technical ability estimator) for these athletes.

Data reported previously have been mainly for "old" masters (i.e. 35-years or older). Most of those masters have a recreational background in the sport when they were younger. In addition, as masters, they have a recreational and/or fitness-oriented approach to the sport. Little scientific evidence exists for masters subjects and even less for young competitive masters who were formerly elite athletes.

The aim in this research study was to identify the energetics, kinematics and efficiency variables associated with young masters (former elite) and elite swimmers' performance, as well as, comparisons between both cohort groups. It was hypothesised that masters swimmers would have a lower performance, energetics and swimming efficiency than their elite counterparts. Also, performance decline or impairment would be related to the change in the biomechanical and energetics profiles.

Methods

Subjects

Twenty masters and elite male swimmers volunteered to serve as subjects. Masters swimmers (N=8; 29.75±3.80-y; 1.78±0.04-m in height; 79.63±8.60-kg body mass and 1.81±0.04-m arm span; 6.31±1.5 training sessions/wk.; 2.7±1.5 km/session; 491.82±79.70 FINA points of personal best) were defined as former elite swimmers that at the time of data collection regularly participated in national and/or international masters championships. Elite level swimmers (N=12; 20.41±3.20-y; 1.79±0.06-m of height; 72.83±6.44-kg of body mass; 1.85±0.06-m of arm span; 10.3±1.5 training sessions/wk.; 4.4±1.7 km/session; 682.89±51.87 FINA points of personal best) were considered as those regularly participating in national championships and/or international meetings and representing the National Swimming Team. All the procedures described below were approved by the Institutional Ethics Committee and followed the Helsinki Declaration regarding human experiments.

Design

The present study analysed whether masters swimmers show differences in performance, energetics, kinematics and swimming efficiency compared to their adult/elite counterparts. The study included an experimental design comparing the two cohort groups (masters vs. elite swimmers). A correlational research design was also implemented to assess the association between selected variables (from the energetics, kinematics and efficiency domains), including performance in each cohort group.

Methodology

Protocol

Swimmers performed an intermittent set of 7x200-m front crawl[12], this being an adaptation of another protocol[13]. Velocities increased by 0.05 $m \cdot s^{-1}$ so that swimmers would attain their best performance on the last part of the protocol. Underwater pacemaker lights (GBK-Pacer, GBK Electronics, Aveiro, Portugal), placed on the bottom of a 25-m swimming pool, were used to control swimming velocity and help swimmers maintain an even pace for each lap. A 30-sec resting period was given between steps to collect blood samples and oxygen uptake for further energetics analysis.

Performance data collection

Swimming performance was assessed based on times for the 200-m freestyle races at official short (local, regional, national and/or international) competitions. The time gap between energetic plus biomechanical assessment and swimming performance took less than two weeks[14].

Energetics data collection

To determine the *V4* and La_{peak}, capillary blood samples were collected from the ear lobe. Thereafter blood lactate concentrations were obtained using an auto-analyser (YSI 1500 l, Yellow Springs, Ohio, USA). Data collection occurred during the 30-sec rest period immediately following and in the 3rd, 5th, and 7th min after the intermittent protocol. Individual *V4* (in $m \cdot s^{-1}$) was obtained interpolating the average lactate value (i.e., 4 $mmol \cdot l^{-1}$) with the exponential curve of lactate/velocity. La_{peak} (in $mmol \cdot l^{-1}$) was considered to be the highest blood lactate concentration in the post exercise condition[15,16].

Oxygen uptake was measured immediately after each trial with a portable gas analyser (Cortex, Model MetaLyzer 3B, Leipzig, Germany) based on the backward extrapolation method. Backward extrapolation methods have been shown to be valid procedures for VO_{2peak} measurement and are used on a regular basis in the aquatic environment[4,14,17-19]. More details about this procedure can be found elsewhere[14]. VO_2 (in $ml \cdot kg^{-1} \cdot min^{-1}$) reached during each step of the protocol was estimated using the backward extrapolation of the oxygen recovery curve[19]. The VO_{2peak} was considered to be the mean value in the 6-sec after the VO_2 detection during the recovery period[19]. The vVO_{2peak} (in $m \cdot s^{-1}$) was also computed and considered as being the swimming velocity corresponding to the first stage that elicited the VO_{2peak}[20].

Total energy expenditure ($\dot{E}_{tot}$, in $ml \cdot kg^{-1} \cdot min^{-1}$) was calculated during the last 200-m of the incremental protocol, corresponding to the swimmer's maximal effort[12]:

$$\dot{E}_{tot} = VO_2 net + (\alpha \cdot \delta^{-1}) \cdot \left[La^-\right] net \qquad (1)$$

where $\dot{E}_{tot}$ represents maximal total energy expenditure corrected for body mass, $VO_2 net$ the net oxygen uptake corrected for body mass, $\alpha.\delta^{-1}$ constant value to convert lactate units in oxygen uptake units ($\alpha.\delta^{-1}$ = 2.7 $mlO_2 \cdot kg^{-1} \cdot mmol^{-1}$) and $[La^-]net$ the blood lactate net corrected for body mass.

Kinematics data collection

For the kinematical assessment both SF and SL at maximal performance were measured. Kinematic variables were measured for each 25-m lap and averaged for the last 200-m. The *v* was obtained from the lap distances and the 25-m split times measured with a stopwatch by an expert evaluator. The *SF* was obtained with a chronometer (Golfinho Sports MC 815, Aveiro, Portugal) from three consecutive stroke cycles, in the mid-15-m of each lap by two expert evaluators and converted to SI units (in Hz). The *SL* (in m) was estimated[21]:

$$SL = \frac{\bar{v}}{SF} \qquad (2)$$

where *SL* represents stroke length, *v* swimming velocity and the *SF* stroke frequency.

Efficiency estimation

To estimate the swimming efficiency, the *C, SI* and η*p* were computed for the last 200-m. *C* was calculated as[22,23]:

$$C = \frac{\dot{E}_{tot}}{\bar{v}} \qquad (3)$$

where *C* represents energy cost after its conversion to SI units (in $J \cdot kg^{-1} \cdot m^{-1}$) considering that 1 mlO_2 is equivalent to 20.9 J, $\dot{E}_{tot}$ total energy expenditure and *v* swimming velocity. The *SI* (in $m^2 \cdot s^{-1}$), considered as one of the swimming stroke efficiency indexes, or at least an estimation of the overall technical ability, was calculated as[24]:

$$SI = SL \cdot \bar{v} \qquad (4)$$

where *SI* represents stroke index, the *SL* stroke length and *v* swimming velocity. The η*p* (in %) was also estimated as another stroke efficiency index[25]:

$$\eta_p = \left[\left(\frac{v \cdot 0.9}{2\pi \, . \cdot SF \cdot l}\right) \cdot \frac{2}{\pi}\right] \cdot 100 \qquad (5)$$

where *v* represents swimming velocity, *SF* stroke frequency, and *l* distance between shoulder and hand during the insweep phase (in m). The *l* was computed trigonometrically measuring the arm's length and considering the average elbow angles during the insweep as reported in the literature[11].

Statistical analysis

The normality of the distributions was assessed with the Shapiro-Wilk test. Parametric and non-parametric statistics were selected accordingly. Data variation was analysed with ANOVA one-way (masters vs. elite swimmers) measures ($P \leq 0.05$). All assumptions to calculate the ANOVA analysis were considered (i.e. independence, normality and homoscedasticity). Effect size was calculated with eta squared (η^2) and as rule of thumb interpreted as follows[26]: (i) without effect if $0<\eta^2\leq 0.04$; (ii) minimum if $0.04<\eta^2\leq 0.25$; (iii) moderate if $0.25<\eta^2<0.64$ and; (iv) strong if $\eta^2>0.64$.

Spearman correlation coefficients were computed between performances and remain selected variables for each cohort group ($P\leq 0.05$) considering a[26]: (i) small effect size if $0\leq|r|\leq 0.2$; (ii) moderate if $0.2<|r|\leq 0.5$ and; (iii) strong if $|r|>0.5$.

Results

Performance

Significant performance variations were verified between elite and masters swimmers [$F(1,18)=42.272$, $P<0.001$, $\eta^2=0.70$] (Figure 1). Elite swimmers gave a better performance than their masters counterparts in the 200-m freestyle race.

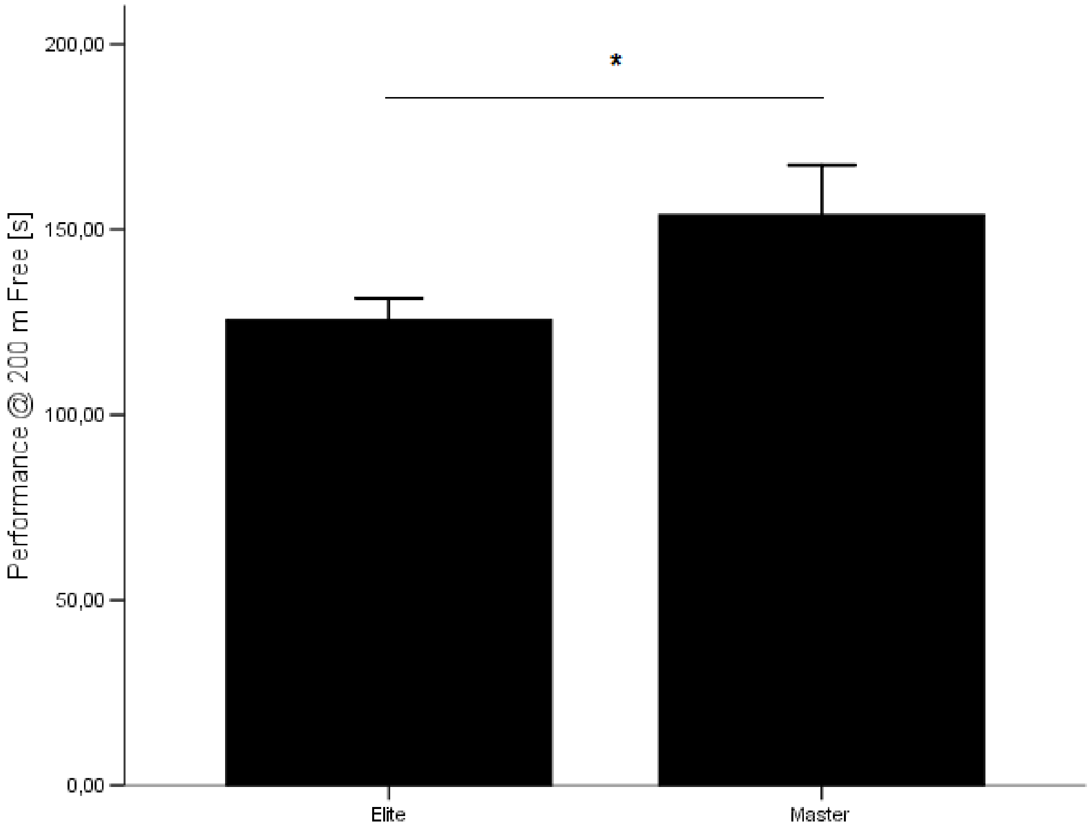

Figure 1: Comparison of the 200-m freestyle race performance between masters and elite swimmers (p ≤ 0.05)*

Energetics

Most of the energetics variables presented significant variations with moderate-strong effects between elite and masters swimmers (Figure 2). *V4* [$F(1,18)=73.541$, $P<0.001$, $\eta^2=0.81$], VO_{2peak} [$F(1,18)=6.886$, $P=0.02$, $\eta^2=0.28$], vVO_{2peak} [$F(1,18)=29.364$, $P<0.001$, $\eta^2=0.63$] and $\dot{E}_{tot}$ [$F(1,18)=5.069$, $P=0.04$, $\eta^2=0.23$] were significantly higher for the elite than masters swimmers. The La_{peak} showed no difference between groups [$F(1,18)=1.832$, $P=0.19$, $\eta^2=0.10$]. Hence, an impairment or decline of the masters swimmers energetics profile exists.

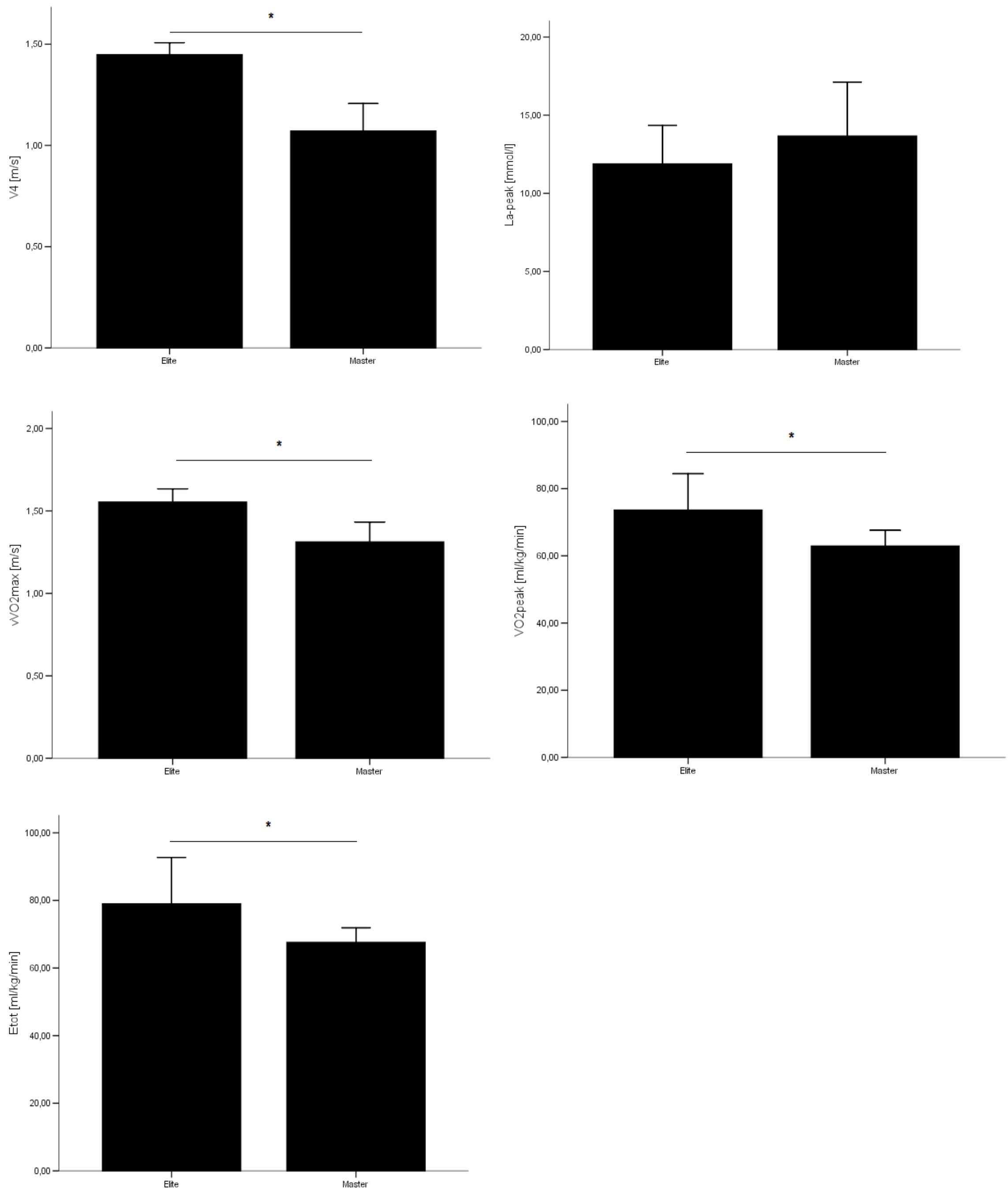

Figure 2: Comparison of the velocity at 4 mmol l^{-1} (V4), maximal blood lactate (La_{peak}), peak oxygen up-take (VO_{2peak}), total energy expenditure ($\dot{E}_{tot}$) and minimum velocity to achieve VO_{2peak} (vVO_{2peak}) between masters and elite swimmers ($p \leq 0.05$).*

Kinematics

Regarding the stroke kinematic variables (Figure 3), there were significant variations in the *SF* [$F(1,18)=16.406$, $P=0.001$, $\eta^2=0.49$] and the *v* [$F(1,18)=52.690$, $P<0.001$, $\eta^2=0.075$], but not for the *SL* [$F(1,18)=0.568$, $P=0.46$, $\eta^2=0.03$]. Variables with significant statistical meaning ranged from moderate to strong effects. Therefore, *v* changes seem to be mainly related to *SF* variations and to a lesser extent, to *SL*.

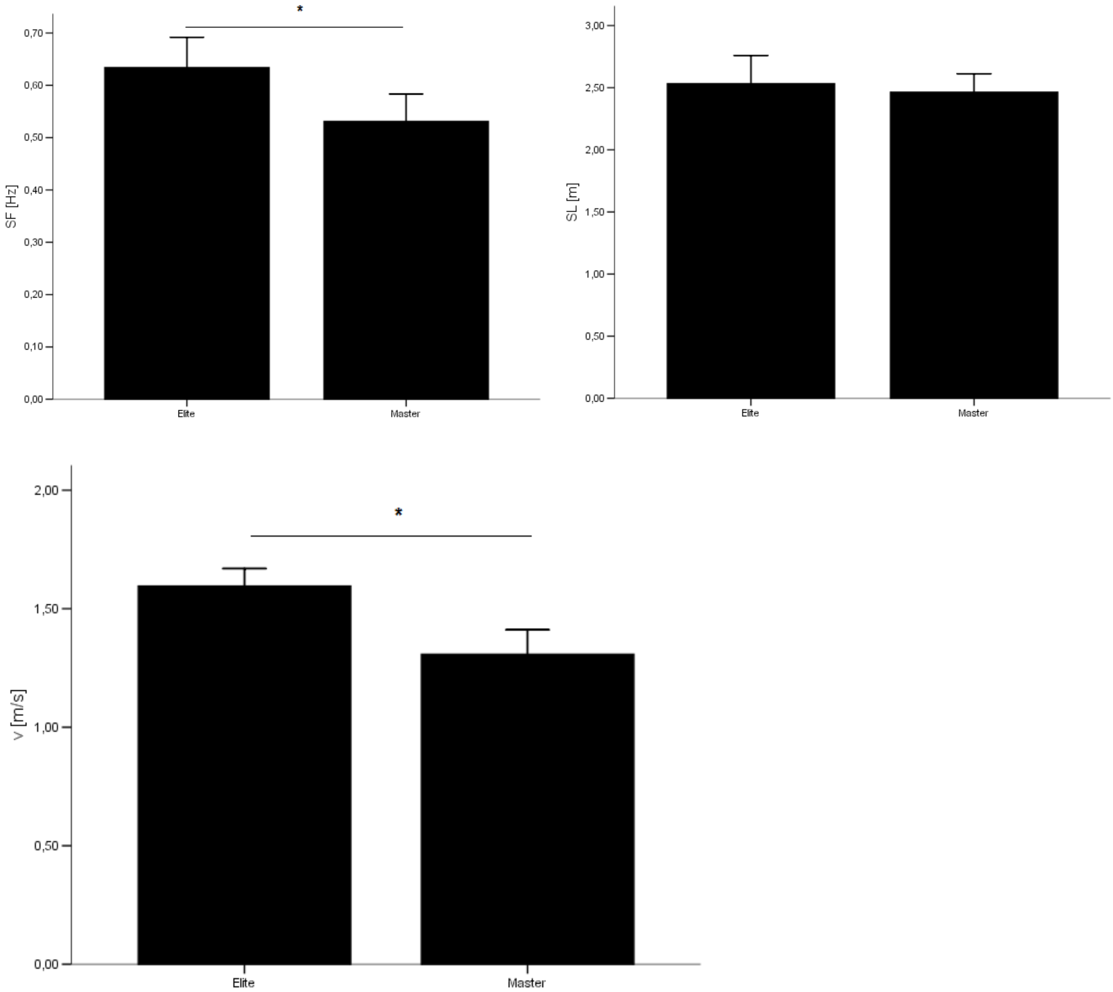

Figure 3: Comparison of the stroke frequency (SF), stroke length (SL) and swimming velocity (v) between masters and elite swimmers ($p \leq 0.05$).*

Efficiency

Of the three variables selected to estimate swimming efficiency (Figure 4), only the *SI* was significantly higher in the elite than the masters swimmers, but showed a moderate effect [F(1,18)=19.274, P<0.001, η^2=0.53]. There were no significant variations in the ηp [F(1,18)=0.099, P=0.76, η^2=0.01] and *C* [F(1,18)=0.382, P=0.54, η^2=0.02]. So, one might say that swimming efficiency is surprisingly stable for young masters athletes than for their former top competitors.

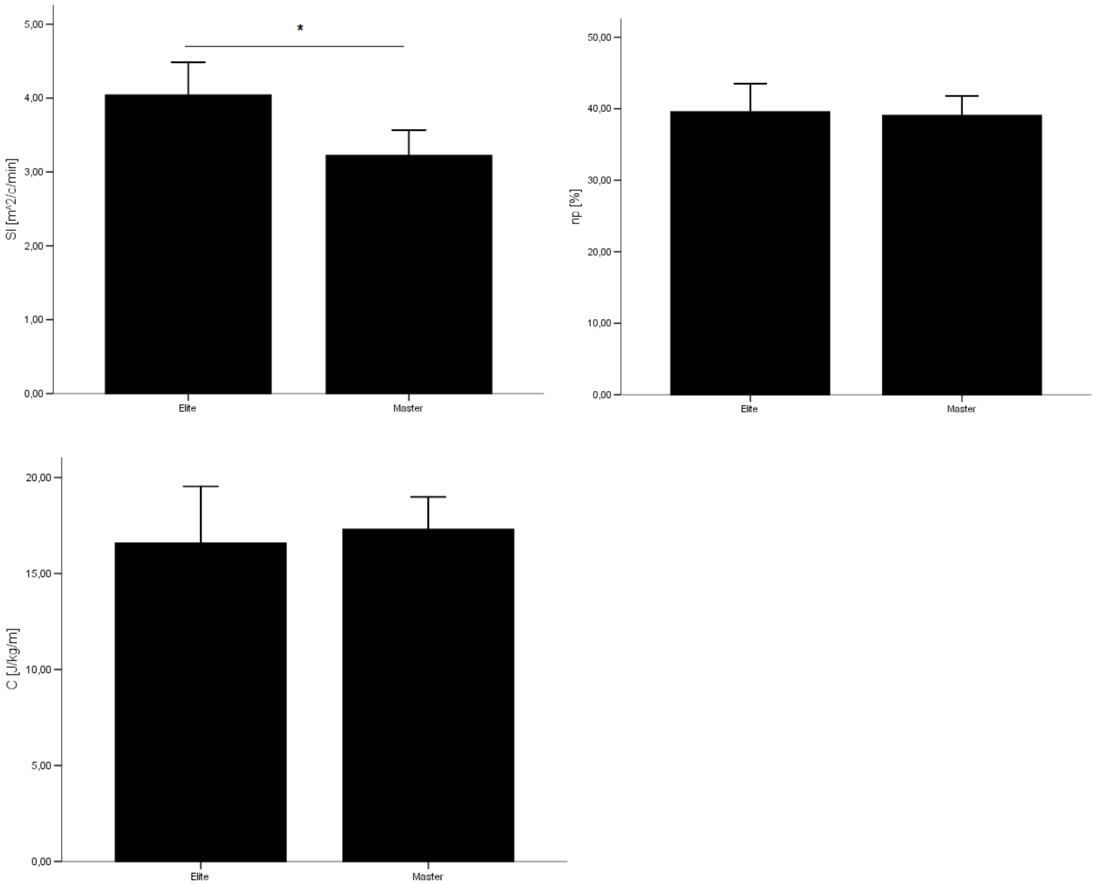

Figure 4: Comparison of the stroke index (SI), propelling efficiency (ηp) and energy cost (C) between masters and elite swimmers ($p \leq 0.05$).*

Associations between performance and remaining variables

For both cohort groups performance was associated (Table 1) with strong effect sizes to the *V4* (elite: r_s=-0.79, P=0.01; masters: r_s=-0.79, P=0.01), vVO_{2peak} (elite: r_s=-0.98, P<0.001; masters: r_s=-0.97, P<0.001) and *v* (elite: r_s=-0.97, P=0.01; masters: r_s=-0.98, P=0.01). Elite swimmers performance was also associated to the La_{peak}, which was not the case for the masters swimmers (elite: r_s=-0.71, P=0.01; masters: r_s=-0.21, P=0.61). Hence, performance impairment of masters swimmers is related to a decrease in energetics and biomechanics, but with no change in efficiency.

Table 1: Spearman correlation coefficients between swimming performance and remaining selected variables for masters and elite swimmers cohort groups

	Elite swimmers' performance	**Masters swimmers' performance**
V4	-0.79 (P = 0.01)	-0.79 (P = 0.02)
La_{peak}	-0.71 (P = 0.01)	-0.21 (P = 0.61)
VO_{2peak}	-0.37 (P = 0.24)	0.01 (P = 0.99)
$\dot{E}_{tot}$	-0.27 (P = 0.40)	-0.21 (P = 0.61)
vVO_{2peak}	-0.98 (P < 0.001)	-0.97 (P < 0.001)
SF	-0.22 (P = 0.50)	-0.54 (P = 0.16)
SL	-0.21 (P = 0.51)	-0.20 (P 0.62)
v	-0.97 (P < 0.001)	-0.98 (P < 0.001)
SI	-0.73 (P = 0.01)	-0.68 (P = 0.06)
ηp	-0.27 (P = 0.40)	-0.07 (P = 0.86)
C	-0.09 (P = 0.79)	- 0.33 (P = 0.42)

V4 - velocity at which the 4 $mmol.l^{-1}$ of blood lactate is achieved (*V4*); La_{peak} - peak blood lactate concentrations, VO_{2peak} - peak oxygen up-take, vVO_{2peak} - minimum velocity to elicited VO_{2peak}, $\dot{E}_{tot}$ - total energy expenditure, SF - stroke frequency, SL - stroke length, v- mean swimming velocity, C - energy cost, SI - stroke index, ηp - propelling efficiency

Discussion

The aim of this study was to identify the energetics, kinematics and efficiency variables related to young masters (former elite) and elite swimmers' performance. Main findings were that young masters swimmers showed a decline in performance compared with elite swimmers. This is mainly related to a decreased energetic profile and biomechanical behaviour with no change in swimming efficiency.

Performance

The goal of competitive swimming is to cover the event's distance at the maximal velocity, as performance is assessed from the time taken to complete the distance:

$$t(v1,v2)_{min} = \frac{r(t2)-r(t1)}{v(t2)-v(t1)} \qquad (6)$$

where *t* is the time, *v* is the swimming velocity, *r* is the position. Thus performance can be assessed based on the time spent or in the velocity achieved during a race.

Elite swimmers gave a better performance than the masters in the 200-m freestyle race. In masters athletes, performance can be used to estimate the physiological functional capacity[2]. Several other papers have already reported an age-related decline in performance (i.e. physiological functional capacity)[2-5]. In comparison to other sports, swimming performance is reasonably well sustained[27]. However, these data were collected from middle-aged to older masters and recreational swimmers as opposed to younger competitive masters swimmers. Some deterministic models suggest that energetics and biomechanics are the main performance-determinant domains[6]. Thus, to obtain a deeper insight into the changes that take place in young masters swimmers, an assessment of the energetics and biomechanics were carried out.

Energetics

An energetics assessment includes the analysis of all energetics pathways contributing to $\dot{E}_{tot}$:

$$\dot{E}_{tot} = \sum_{i=1}^{3} A_i \qquad (7)$$

where $\dot{E}_{tot}$ represents total energy expenditure, A_i a given energetic pathway. The A_i includes the aerobic, anaerobic lactic and anaerobic alactic pathways:

$$\dot{E}_{tot} = Aer + An_{lac} + An_{alac} \quad (8)$$

where $\dot{E}_{tot}$ represents total energy expenditure, *Aer* aerobic contribution, An_{lac} anaerobic lactic contribution and the An_{alac} anaerobic alactic contribution. So an energetics assessment should include these pathways, although An_{alac} can be considered negligible in trials or steps with approximately 2-min duration or longer[12].

There are differences in aerobic capacity (i.e. *V4*) and aerobic power (i.e. VO_{2peak}, vVO_{2peak}, $\dot{E}_{tot}$) when comparing elite with young masters competitive swimmers. The literature reported the same trend[3,4,7]. Decreased aerobic capacity and aerobic power may be related to: (i) decline of physiologic systems throughout the life span, understood to start approximately in the 30s; (ii) the lower training volume, intensity and energetic zones practiced. Aerobic capacity and power are dependent on a high volume (number of training sessions and total distance covered per session) at a moderate-hard pace. Although strongly engaged in training, masters swimmers have a reduced training volume and do not achieve the same volumes of training sets at moderate-hard intensities as their elite counterparts.

La_{peak} presented a non-significant variation. Two papers have suggested that La_{peak} decreases with age in masters athletes[9], including swimmers[8]. Anaerobic capacity depends on gender, muscle mass, muscle fibre type and size, muscle architecture and strength, substrate availability, efficiency of metabolic pathways, accumulation of reaction products, aerobic energy system contribution, heredity and physical training[9]. However, a sharp decrease occurs at around 30-35-years-old[9]. In this research, young masters swimmers (up to their middle 30s) were assessed. Changes in anaerobic capacity are not so evident in this sample.

Kinematics

Linear velocity of cyclic or periodic movements, just like swimming, can be measured as:

$$\bar{v} = 2 \cdot \pi \cdot r \cdot \frac{1}{P} \quad (9)$$

where *v* represents mean linear velocity, *r* the radius and *P* the period (time spent to make a full revolution). The inverse of the period (i.e. 1/P) is known as frequency. For competitive swimming this is considered to be the *SF*. The remaining part (i.e. 2.π.r) is related to the SL. Indeed, *v*, *SF* and *SL* are often assessed in swimming kinematics.

There were moderate-strong variations in the *v* and the *SF* with no changes for the *SL*. As there is a decline or impairment in performance, it becomes obvious that the *v* will decrease. Based on Equation 2, the question to be raised is whether the *v* decrease takes place due to a shift in the *SF*, in the *SL*, or both. In one paper, the *v* decreased due to a decline in the *SL*, with no changes in the *SF*[4]. In contrast, in this research, *v* decreased due to a decreased SF and unchanged *SL*. Each swimmer has an individual strategy, combining *SF* and *SL* to achieve a given *v*. However, elite swimmers maintain the *SL* as high and constant as possible, manipulating the *SF* whenever they want to change the *v*[23]. Young masters assessed in this research are former elite swimmers that finished their career at the top-level. Eventually they become aware of the importance of maintaining the *SL* as high and constant as possible. On the other hand, their *SF* decreased, which can be related to lower mechanical power and muscle strength.

Efficiency

One approach to enhance performance (i.e. the *v*) is to maximise the energetics profile and improve the technical/biomechanics behaviour. In Equation 3, moving v to the left side of the equation, it becomes:

$$v_{\max} = \frac{\dot{E}_{tot\text{-}\max}}{C} \quad (10)$$

$\dot{E}_{tot\text{-}max}$ represents the energetics profile and *C* the technical/biomechanical behaviour (i.e. efficiency) since it is related to mechanical efficiency and mechanical work:

$$C = \frac{w_{tot}}{\eta_o} \quad (11)$$

where *C* represents energy cost, w_{tot} total mechanical work per unit of distance and η_o overall efficiency. Meanwhile, ηp is based on a ratio between the swimmer's body velocity (related to the mechanical work to overcome drag) and his linear hand plus arm's velocity (related to the mechanical work to transfer kinetic energy to water):

$$\eta_p = \frac{W_d}{W_d + W_k} \qquad (12)$$

where ηp represents the propelling efficiency, W_d the mechanical work to overcome drag and W_k the mechanical work to transfer kinetic energy to the water ($W_{total} = W_d + W_d$). Hence, the estimation of *C, ηp* and *SI*, are comprehensive and feasible ways of gaining insights about swimming efficiency.

Only the *SI* presented higher values for the elite swimmers in comparison to the masters swimmers. Previous reports for masters swimming found a *C* and η*p* decrease with age[7]. However, it should be highlighted that these data refer to submaximal exercise, including recreational and fitness-oriented swimmers, in a higher age-range (i.e. from their 30s up to the 80s). At least young masters competitive swimmers finishing their top-level career recently seem to maintain a fairly good technique and swimming efficient. According to Equation 3, masters swimmers efficiency is similar to that of elite swimmers because they decrease $\dot{E}tot$ and *v*, as discussed in the energetics and kinematics sub-sections. The same reasoning can be exercised for the η*p*. Masters swimmers present a lower *v* and *SF*. So according to Equation 5, η*p* is kept constant.

Associations

The variables having the strongest association with performance were, respectively, the vVO_{2peak}, *v*, *V4* for both groups; adding the La_{peak} in the elite swimmers' group. The data confirm that the 200-m freestyle is a race determined by the swimmers energetics and biomechanics[6]. Furthermore, regarding energetics, aerobic and anaerobic pathways play a major role[28,29]. The ratio between the aerobic-anaerobic contributions ranges roughly between 60-40% respectively[28-30]. The La_{peak} showed a small and non-significant association with masters performance. One of the points that discriminate elite from masters swimmers is the anaerobic contribution. Masters training is mainly characterised by lower volumes and intensity than for their elite counterparts. The number of training sessions and the volume per session in this study's cohort groups (masters vs. elite) as reported in the subjects sub-section was also different. This is due to: (i) logistical reasons (i.e. masters swimmers are no longer totally focused on their sporting careers, having fewer training sessions because of professional commitments); (ii) physiological reasons (i.e. a decline of physiological systems related to anaerobic pathways throughout the life span); (iii) swim career planning (i.e. higher intensity sets and bouts increases the odds of a skeletal muscle injury).

Practical applications

Masters (formerly elite) swimmers show performance impairment due to a decrease of their physiological functional capacity (i.e. energetics profile). Masters athletes present a high swimming efficiency which might be related to their past experience as elite swimmers. Masters seem to be able to keep a fairly good or constant technique (i.e. stroke kinematics), possibly due to a better proprioceptive or "sensibility to water" (as it is called among the swimming community). The energetics might be the domain with a higher potential for improvement. To excel, masters swimmers should engage in a greater number of sessions and/or volume per training session so as to exercise other energetic regimes, which are elicited during short-distance swim races. With this performance will eventually enhance. On the other hand, high-intensity sets might increase the odds of skeletal muscle injuries. Besides that, training sessions will become more time-consuming (i.e. the need of more sessions per week and/or the duration of each session) which is quite challenging for people that are no longer full-time athletes and only have a couple of hours per day to practice. A good way to accommodate sporting and professional careers would be to do more than one session per day over weekends, holidays and/or vacations. However, further research should be conducted to have a deep insight about the chances of getting skeletal muscle and other types of injuries as a result of these types of high-intensity programmes. Whenever possible, dry-land training sessions should be incorporated in masters training programmes. Strength power training would be most useful to increase *SF* and therefore *v*.

Limitations

Main limitations may be listed as follows: (i) the young masters (former elite swimmers) assessed were all strongly engaged in competitions at national and international level. Hence, data reported in this research are not representative of fitness-oriented, middle-aged, or older swimmers; (ii) motor control (e.g. inter-limb coordination, EMG) and/or muscle strength assessments could give some insights about the kinematic behaviour.

Conclusions

Young masters swimmers suffer from a performance decline or impairment, which is related to decreases in their physiological functional capacity and biomechanical behaviour. Their background as elite swimmers allows them to maintain high swimming efficiency. Masters swimmers engaged in top-level competitions should include training sets and energetic regimes that are elicited during short-distance swim races.

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