Original Article

Age of peak swim speed and sex difference in performance in medley and freestyle swimming – A comparison between 200 m and 400 m in Swiss elite swimmers

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ABSTRACT

Vaso, M., Knechtle, B., Rüst, C.A., Rosemann, T. & Lepers, R. (2013). Age of peak swim speed and sex difference in performance in medley and freestyle swimming – A comparison between 200 m and 400 m in Swiss elite swimmers. *J. Hum. Sport Exerc., 8*(3), pp.954-965. The aims of the present study were to examine (i) the age of peak swim speed and (ii) the sex difference in peak swim times in 200m and 400m medley versus freestyle. Swim times and ages of 5,524 swimmers (2,785 males and 2,739 females) from the Swiss high score list from 2006 to 2010 were analyzed using one-way analysis of variance (ANOVA). The age of peak swim speed was younger for females (~20-21 years) compared to males (~22-25 years) for both distances and both swimming styles. The sex differences in peak swim times for age group 10-39 years were 9.7% (SD=3.4) and 7.1% (SD=5.1) for 200m and 400m individual medley, and 10.1% (SD=5.0) and 6.1% (SD=4.0) for 200m and 400m freestyle, respectively. The sex differences were neither different between the two distances nor between the two disciplines ($p > .05$). There were no differences within each sex (i.e. females to females, and males to males) in the age of reaching peak swim speed in 200m and 400m individual medley and freestyle. However, females reached the peak swim speed at a younger age than males. The sex differences in peak swim times were similar for 200m than for 400m for both swim styles. To summarize, the present findings suggest no difference in the age of peak swim times in 200m and 400m individual medley and freestyle. However, females reached peak swim times earlier than males, which might be dependent on a different development of the genders in puberty and the related physiological and anthropometric factors. Sex differences in peak swim times were similar for 200m than for 400m for both swim styles. **Key words**: WOMAN, MAN, AQUATIC SPORT.

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INTRODUCTION

In swimming, several studies investigated the age-related decline in performance (Bongard, McDermott, Dallal, & Schaefer, 2007; Fairbrother, 2007a; Reaburn & Dascombe, 2008; Rubin & Rahe, 2010; Tanaka & Seals, 1997; Tanaka & Seals, 2008), the sex difference in performance (Ransdell, Vener, & Huberty, 2009; Rubin & Rahe, 2010; Tanaka & Seals, 1997) and the age of peak performance (Berthelot, Len, Hellard, Tafflet, Guillaume, Vollmer, et al., 2011; Fairbrother, 2007b; Schulz & Curnow, 1988; Tanaka & Seals, 1997). It should be noted, however, that these studies focused on freestyle swimming (Bongard, McDermott, Dallal, & Schaefer, 2007; Donato, Tench, Glueck, Seals, Eskurza, & Tanaka, 2003; Fairbrother, 2007a; Fairbrother, 2007b; Ransdell, Vener, & Huberty, 2009; Reaburn & Dascombe, 2008; Rubin & Rahe, 2010; Schulz & Curnow, 1988; Tanaka & Seals, 1997; Tanaka & Seals, 2003; Tanaka & Seals, 2007), and data on other swimming styles remains limited (Berthelot, Len, Hellard, Tafflet, Guillaume, Vollmer, et al., 2011; Craig & Pendergast, 1979; Saavedra, Escalante, Garcia-Hermoso, Arellano, & Navarro, 2012).

According to the rules of the 'Fédération Internationale de Natation' (FINA, www.fina.org), freestyle is an unregulated swimming style, and backstroke, breaststroke or butterfly are allowed (FINA Swimming rules, SW 5.1). Mostly, front crawl is used to swim freestyle due to it being the fastest swimming style according to the actual world records. Subject to swimming rule SW 9.1 (www.fina.org), individual medley is defined as follows: "In individual medley events, the swimmer covers the four swimming strokes in the following order: butterfly, backstroke, breaststroke and freestyle." Therefore, individual medley requires the training of four different swimming styles compared to only one, as in freestyle. Additionally, the turning technique required for each style must remain as described by the stroke rules of the style. Depending on the different swimming style, different stroke rates and speeds were found, showing the reliance on biomechanical techniques and skills in swimming (Bongard, McDermott, Dallal, & Schaefer, 2007; Craig & Pendergast, 1979). It can be assumed that training in four styles with different turning techniques requires more time and therefore swimmers may reach peak swim speed at older ages in medley compared to freestyle, which is in accordance with the age of the current male world record holders (i.e. 200m individual medley by Ryan Lochte at 26 years of age, 400m individual medley by Michael Phelps at 23 years of age; freestyle 200m and 400m by Paul Biedermann at 22 years of age).

The age of peak performance is a reliable factor to solidify if "hardware" skills such as biological and physiological development factors play a large role in defining the age of peak performance. When the peak performance remains stable over a long period of time, even if the training circumstances and used materials change, it shows that biological skills might have the bigger impact on performances of a certain type of sport rather than factors as training or personal circumstances. In literature, two groups of swimmers are generally distinguished; master swimmer (Baker & Tang, 2010) and elite swimmer (Nevill, Whyte, Holder, & Peyrebrune, 2007). An analysis from Schulz and Curnow (1988) of Olympic gold medal winners from 1896 to 1980 showed a noteworthy consistency in the age when peak performance was reached in most of the sports, although the performances increased during the investigated time period dramatically. Female swimmers were on average two years younger than male swimmers at the time when the peak swim times were achieved. Moreover, female peak performers were younger as swimming distances increased (Schulz & Curnow, 1988). For males a similar pattern was described, with a younger age of peak performance with increasing distances (Berthelot, Len, Hellard, Tafflet, Guillaume, Vollmer, et al., 2011; Schulz & Curnow, 1988).

Previous studies have found a sex difference in swimming speed of ~15-20 % for master swimmers (Baker & Tang, 2010) and ~10-12% for elite swimmers where males performed better than females (Nevill, Whyte, Holder, & Peyrebrune, 2007; Lepers, 2008; Lepers & Maffiuletti, 2010). The sex difference in performances seems to decrease as the swimming distances increase (Ransdell, Vener, & Huberty, 2009; Rubin & Rahe, 2010; Tanaka & Seals, 1997). Surprisingly, the sex spread for world record times remained unchanged from 1957 to 2007, i.e. in 100m, 200m, and 400m freestyle (Nevill, Whyte, Holder, & Peyrebrune, 2007).

The aims of the present study were to examine (i) the age of the peak swim speed and (ii) the sex differences in peak swim times in the 200m and 400m medley versus freestyle in elite swimmers at national level. According to previous literature, we hypothesized that (i) the peak swim times would be reached at an older age in individual medley compared to freestyle as more training time is required in order to develop the skills in the four various swimming styles (i.e. individual medley) compared to one (i.e. freestyle), (ii) the peak swim times would be achieved at younger ages for females than for males in both styles, and (iii) the sex differences in peak swim times would be greater in 200m compared to 400m for both styles.

METHODS

Sample

All individual medley and freestyle swimmers from the Swiss swimming high score list between 2006 and 2010 were analyzed regarding swim times, ages and sex. The data set from this study was obtained from the Swiss Swimming Federation (www.fsn.ch). The study was approved by the Institutional Review Board of St. Gallen, Switzerland, with waiver of the requirement for informed consent given that the study involved the analysis of publicly available data. The data set was obtained from the website of the Swiss Swimming Federation (http://rankings.fsn.ch/). Data from 1984-2005 were excluded due to the very low number of participants per age groups during these years.

From the five-year period between 2006 and 2010, data from 5,524 athletes, including 2,785 males and 2,739 females, were available. For the analysis of swim times, all athletes were separated by sex and then categorized by age groups as follows: 0-9 years, 10-19 years, 20-29 years, 30-39 years, 40-49 years, 50-59 years, 60-69 years, 70-79 years, 80-89 years, and 90-99 years, respectively. For each age group and sex, the three fastest swim times through the five years for both swimming distances (200m and 400m) in individual medley and freestyle were determined. When less than three participants were recorded within an age group the age group was excluded from data analysis. The following age groups had to be excluded from analysis due to low numbers of participants: for 200m medley 60-69 years and 70-79 years for females, for 400m medley 0-9 years females and males, 40-49 years females, 50-59 years and 60-69 years males and 60-69 years and 70-79 years females; and in 200m and 400m freestyle swimming 70-79 years females, respectively.

The results showed for each distances that the fastest swim times were achieved in the age groups 10-19 years or 20-29 years. Therefore, these two age groups were further divided into smaller age groups as follows: 10-11 years, 12-13 years, 14-15 years, 16-17 years, 18-19 years, 20-21 years, 22-23 years, 24-25 years, 26-27 years, and 28-29 years, respectively. For each age group, the top three swim times per distance were again determined through the five years, pooled and analyzed (n=3). The sex difference in performance was calculated as follows: ([performance in females] – [performance in males]) / [performance in males] x 100, whereas [performance in females] = mean swim times of the top three females and [performance in males] = mean swim times of the top three males. No athlete was included twice or several

times in the same year because Swiss Swimming Federation lists only the best swim time per year of an athlete in the same year.

Statistical analysis

In order to increase the reliability of data analyses, each set of data was tested for normal distribution and for homogeneity of variances prior to statistical analyses. Normal distribution was tested using a D'Agostino and Pearson omnibus normality test and homogeneity of variances was tested using a Levene's test in the case of two groups and with a Bartlett's test in the case of more than two groups. Performance of different age groups was compared using one-way analysis of variance (ANOVA) with Tukey-Kramer post-hoc test which was applied for both males and females. A one-way ANOVA with Tukey-Kramer post-hoc test was also used to compare sex difference across the swim styles and across the distances. Statistical analyses were performed using IBM SPSS Statistics (Version 19, IBM SPSS, IL, USA) and GraphPad Prism (Version 5, GraphPad Software, CA, USA). Significance was accepted at $p < .05$. Data in the text are given as mean ± standard deviation (SD).

RESULTS

Figure 1 shows the changes in swim times of the age groups classified by decades. In 200m individual medley (Panel A), the fastest swim times were achieved in the age groups 10-19 years and 20-29 years for both females and males. In 400m individual medley (Panel B), the fastest swim times were maintained within age groups 10-19 years and 30-39 years for females and within age groups 10-19 years and 20-29 years for males, respectively. For 200m freestyle, the fastest swim times were maintained within age groups 10-19 years and 40-49 years for females (Panel C) and within age groups 10-19 years and 20-29 years for males. For 400m freestyle (Panel D), peak swim time was maintained within age groups 10-19 years and 50-59 years for females, and within age groups 10-19 years and 20-29 years for males. The age groups mentioned above within the same panel were not significantly different.

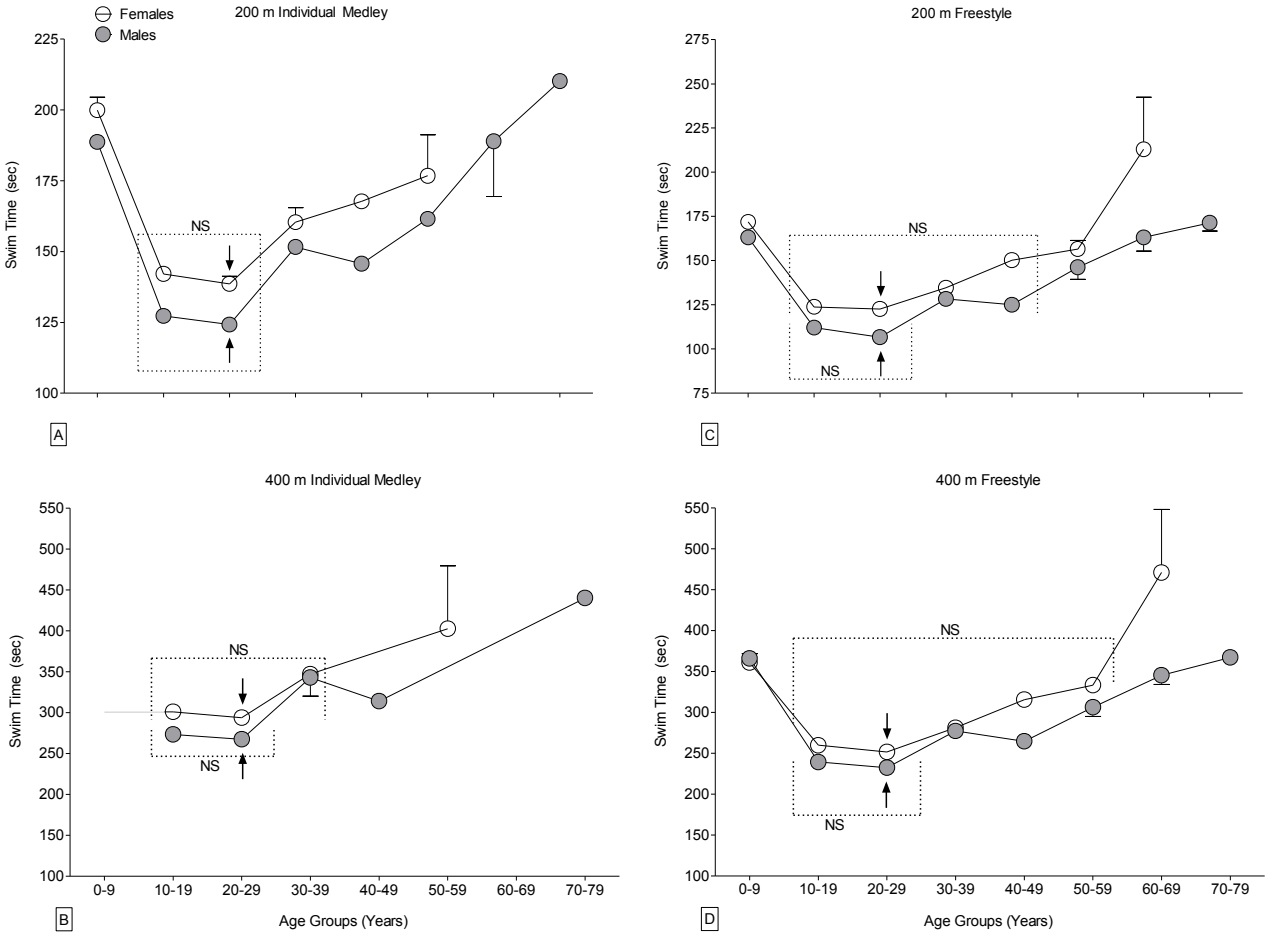

Figure 1. *Mean (± SD) swim times of the top three athletes per age group for males and females in 200m (Panel A) and 400m (Panel B) individual medley, and in 200m (Panel C) and 400m (Panel D) freestyle swimming. NS: no significantly different*

Figure 2 shows the changes in swim times for two-year age groups comprised between 10 and 29 years. For females, the fastest swim times were achieved at the age of 20-21 years for 200m individual medley (Panel A), 400m individual medley (Panel B), 200m freestyle (Panel C), and 400m freestyle (Panel D), respectively. For males, the fastest swim times were achieved at the age of 22-23 years for 200m individual medley (Panel A), 400m individual medley (Panel B), and 200m freestyle (Panel C). For 400m freestyle, the fastest swim times were obtained at the age of 24-25 years. For females, individual medley 200m and 400m the age groups from 12-25 years, for males in 200m the age groups from 16-25 years and in 400m the age groups from 14-29 years were not significantly different ($p > .05$). In freestyle, the fastest swim times in females in 200m were not significantly different at the age groups from 12-27 years and in 400m at 12-29 years ($p > .05$), while the fastest swim times in males showed no significant difference in 200m at the age groups from 18-23 years and in 400m at 16-27 years ($p > .05$).

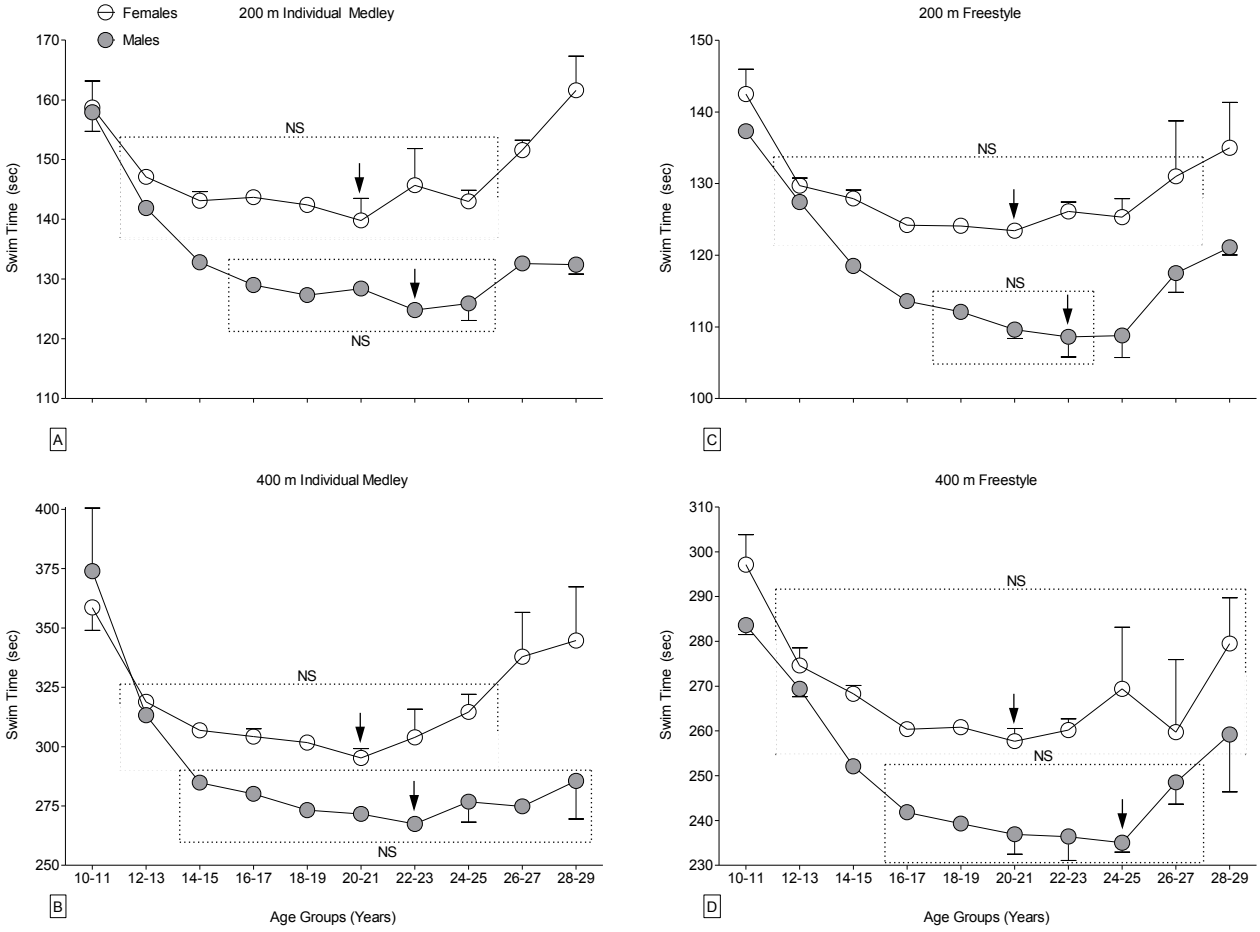

Figure 2. *Mean (± SD) swim times of the top three athletes of the 2-year age-groups comprised between 10-11 and 28-29 years in 200m (Panel A) and 400m (Panel B) individual medley, and in 200m (Panel C) and 400m (Panel D) freestyle swimming. An arrow indicates the fastest age group in males and females*

The sex differences for the fastest swim times for the 200m and 400m for 10-year age groups are presented in Table 1. The mean sex differences in the fastest swim times for the age groups comprised between 10 and 39 years were 9.7% (SD=3.4) for 200m individual medley, 7.1% (SD=5.1) for 400m individual medley, 10.1% (SD=5.0) for 200m freestyle and 6.1% (SD=4.0) for 400m freestyle, respectively. These sex differences were not different to each other ($p > .05$).

***Table 1**. Sex Difference (In Percentage) For 200m and 400m Individual Medley and Freestyle Swimming*
Note.- N.A. Not available

	Individual Medley		Freestyle	
Age Group (years)	**200m**	**400m**	**200m**	**400m**
0-9	5.9	N.A.	5.4	-1.4
10-19	11.7	10.2	10.4	8.6
20-29	11.6	9.9	14.9	8.3
30-39	5.8	1.2	4.9	1.5
40-49	15.1	N.A.	20.2	19.3
50-59	9.4	N.A.	7.1	8.9
60-69	N.A.	N.A.	30.6	36.4

Figure 3 shows the mean sex differences in the fastest swim times for the two-year age groups between 10 and 29 years old. The sex differences were not significant different between each other ($p > .05$): 11.1% (SD=6.3) for 200m individual medley, 11.3% (SD=6.7) for 400m individual medley, 10.1% (SD=4.6) for 200m freestyle and 7.6% (SD=3.5) for 400m freestyle, respectively.

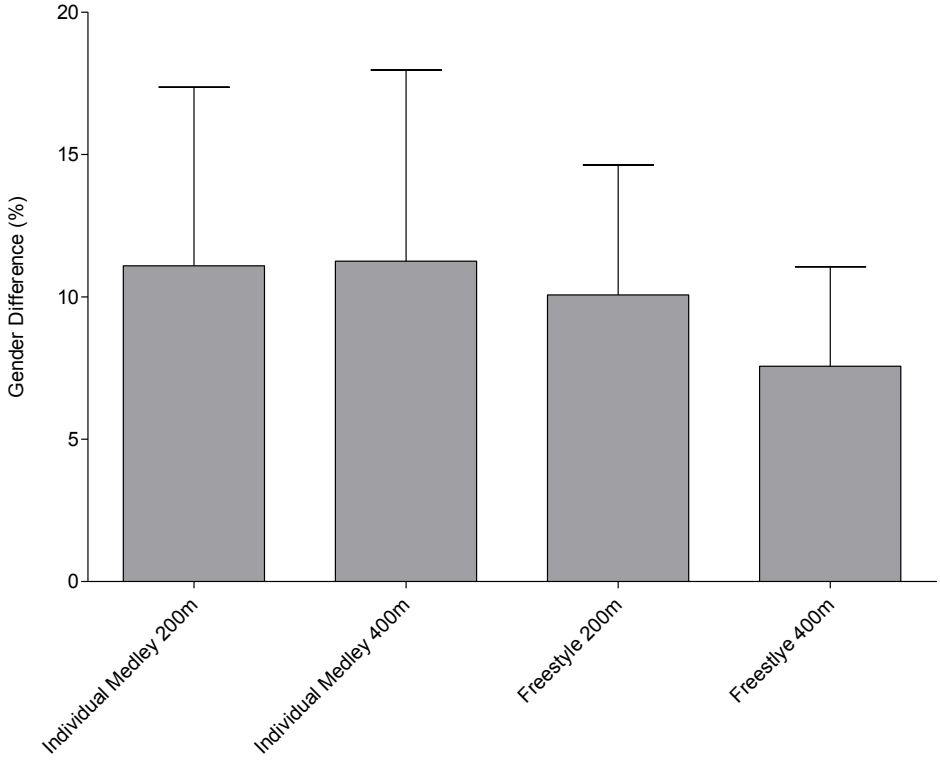

***Figure 3**. Sex difference of the top three athletes of the 2-year age-groups comprised between 10-29 years in 200m and 400m individual medley and in 200m and 400m freestyle swimming*

DISCUSSION

The present results showed, firstly, a similar age of the peak swim times for freestyle and individual medley for both females and males, where the age of peak swim times appeared ~1-5 years earlier for females (~20-21 years) than for males (~22-25 years). Secondly, the sex difference in peak swim times was similar for both distances (200m and 400m) and for both styles (individual medley and freestyle).

The age of peak swim times in individual medley and freestyle
For both swimming styles and both distances, females reached their peak swim times at the same age of ~20-21 years. In contrast, males were older than females when they reached their peak swim times. In males, the age of the peak swim times was 22-23 years for 200m and 400m individual medley and 200m freestyle, and 24-25 years for 400m freestyle, respectively.

Individual medley requires training of four different swimming styles as opposed to only one, as in freestyle. Accordingly, we assumed that it would take a longer time in life to achieve a high level of performance in medley compared to freestyle (Bongard, McDermott, Dallal, & Schaefer, 2007; Costa, Bragada, Marinho, Reis, Silva, & Barbosa, 2010; Craig & Pendergast, 1979; Schulz & Curnow, 1988; Zamparo, 2006). The present findings are not in accordance with our hypothesis. Previous findings in literature suggested that athletic tasks requiring strength, speed, and explosive power were reached in the early 20s, while those tasks requiring endurance, acquired skill and knowledge peaked in the late 20s and early 30s (Schulz & Curnow, 1988). Further, depending on the different swimming style, different stroke rates and speeds were found (Bongard, McDermott, Dallal, & Schaefer, 2007; Craig & Pendergast, 1979). Saavedra, Escalante, Garcia-Hermoso, Arellano, and Navarro (2012) showed that backstroke was the most important section of final performance in individual medley (200m and 400m) for males, while it was backstroke (200m) or freestyle (400m) for females. It was identified that an improvement of swimming techniques and constant training lead to faster swim times (Costa, Bragada, Marinho, Reis, Silva, & Barbosa, 2010; Zamparo, 2006).

A possible explanation for the same lifespan needed for reaching the peak swim speed might be that differences between the different swimming styles, according to the required skills to learn and effect them properly, are smaller than expected. A main factor of peak swim speed in swimming could be the natural anthropometric elements (Geladas, Nassis, & Pavlicevic, 2005). Pre-pubescent males and females showed no significant anthropometric differences (Schneider & Meyer, 2005), which was in accordance with our findings of there being no differences in swim times at the age of 10-13 years and the low percentage in sex difference varying from -1.4 to 5.9% at the age of 0-9 years. During puberty, the anthropometry of males and females was changing with increases in body height and body weight (Schneider & Meyer, 2005), which may explain our findings of faster swim times. The growth of the female body usually finishes earlier (~18 years) compared to males (~20 years), which might have a coherence of females reaching the peak swim time one to five years earlier than males in the present results. It seems that for reaching the peak swim times, it is necessary to have the anthropometric requirements of a finalized growth of the body. Apart from anthropometry, the developing physiological factors in adolescence also seem to have a main impact on the age of the peak swim time (Tanaka & Seals, 2003; Zamparo, 2006), such as the propelling efficiency, changes in muscle strength, biomechanical factors and bio-energetic values (Jürimäe, Haljaste, Cicchella, Lätt, Purge, Leppik, et al., 2007; Zamparo, 2006). These factors change during adolescence and are consistent with our results showing that the age of the peak swim time was higher than the age when body growth is usually finished.

The sex differences in the age of peak swim times

In accordance with Schulz and Curnow (1988), females in the present study achieved their peak swim speed earlier in life compared to males, although the average age of reaching peak swim times was older than in the comparable Olympic Games results. The reason that males were reaching their peak swim time one to five years later than females might be due to physiological and anthropometric factors. Swim time is effected by different factors such as body height (Geladas, Nassis, & Pavlicevic, 2005; Jagomägi & Jürimäe, 2005), fat mass (Tuuri, Loftin, & Oescher, 2002) and upper extremity length (Geladas, Nassis, & Pavlicevic, 2005). Females show a higher fat percentage and higher skinfold thicknesses than males (Schneider & Meyer, 2005). Additionally, shorter legs cause a more streamlined horizontal swimming position, and smaller body density and greater fat percentage also affects the better swim time of females (Tanaka & Seals, 1997; Tanaka & Seals, 2003). It is probable that the earlier onset of puberty in females compared to males with typical physiological and anthropometric changes of the body is the main reason for the earlier peaking of females. A possible explanation for the males peaking at the age of 22-25 years might be that the swim speed of males is more dependent on muscles compared to females. Muscle strength for males peaks at ~25 years of age (Shepard, 1998), which is close to our findings with a spread between 22 and 25 years.

It has been reported that the longer the swim distance, the younger the age of the swimmer would be (Berthelot, Len, Hellard, Tafflet, Guillaume, Vollmer, et al., 2011; Schulz & Curnow, 1988). Our findings showed no difference in age of the peak swim times for females. For males, with the exception of freestyle where the age for the 400m was older than in the 200m, there was also no age difference between the distances and styles. In literature, female peak performers were getting younger as swimming distances increased, i.e. the mean age of reaching the peak swim speed was 19.4 years in 100m freestyle, 17.6 years in 400m, and 16.0 years in 800m (Schulz & Curnow, 1988). For males, the mean age of Olympic gold medal winners showed a younger age of the peak swim speed in the 1,500m freestyle (20.35 years) than in the shorter 100m freestyle (21.42 years), but youngest mean age for males in 400m freestyle (19.94 years). Contrary to the latter, other literature reported for females and males master swimmers in 50m and 1,500m freestyle that with increasing distances, the age of peak swim speed holders also increased (Fairbrother, 2007b; Tanaka & Seals, 1997). However, these authors did not analyse data from swimmers below the age of 19 years and used the US Master Swimming as the database, whereas the other authors used a different database more focused on elite swimmers competing in the Olympics. An explanation for the differences from the literature to our results concerning the younger age could be that, although our swimmers were elite swimmers, there was a lack of outstanding swimmers coming close to the demands of a top Olympic swimmer in the age category of 16-21 years in our study. In contrast, the age difference in the distances at the Olympics were in accordance with our results, showing the age difference for the distances of 100m and 400m freestyle were at 1.48 years for males and at 1.8 years for females, thus within the spread of two years defined for the age groups in our results.

The sex differences in peak swim times

The present results showed a similar sex difference in the 200m and in 400m freestyle or medley. These findings are in contrast to the findings of Tanaka and Seals (1997), showing a larger significant sex difference in the 200m compared to the 400m freestyle. According to Tanaka and Seals (1997), in freestyle swimming females swimmers had lower oxygen costs with increasing distances than males (Tanaka & Seals, 2003). Males had significantly higher energy costs than females performing similar training programs. In swimming shorter distances (100 yards), females performed better with a higher fat-free body weight, lower body fatness and a greater height while standing, whereas males did not seem to be influenced by these factors (Siders, Lukaski, & Bolonchuk, 1993). For shorter anaerobic events of 10-100s,

a lower anaerobic capacity expressed to total body mass was shown, or the lower active muscle mass was a major cause in a lower performance for females (Reaburn & Dascombe, 2009). In swimming events of longer durations such as 1,500m, a faster swim time achieved by females and a lower sex difference in comparison to males was due to lower oxygen cost and a smaller body size, where the smaller body size may cause a smaller body drag (Tanaka & Seals, 1997; Tanaka & Seals, 2003). The reason for the larger sex differences in the 400m than in the 200m freestyle from the age of 50-69 years might be due to changing anthropometric factors i.e. increased fat proportions and decreased standing height of the female body. Further, the rate of decline in endurance performance (i.e. swimming) is greater in females than in males (Donato, Tench, Glueck, Seals, Eskurza, & Tanaka, 2003; Lepers & Maffiuletti, 2011). In contrast, females tend to lose more muscle strength and power than males (Tanaka & Seals, 2003) with advancing age, which would lead to a lower performance in sprint events as the 200m, and consecutive to a bigger sex difference in the 200m.

Limitations and implications for future research

Some interpretations of the present data are limited due to the small number of participants in older age groups. In addition, no data of training (Costa, Bragada, Marinho, Reis, Silva, & Barbosa, 2010; Issurin, Kaufman, Lustig, & Tenenbaum, 2008; Zamparo, 2006), anthropometry (Geladas, Nassis, & Pavlicevic, 2005; Jagomägi & Jürimäe, 2005; Siders, Lukaski, & Bolonchuk, 1993; Tuuri, Loftin, & Oescher, 2002; Zamparo, 2006), and physiology (Reaburn & Dascombe, 2008; Tanaka & Seals, 2003; Tanaka & Seals, 2008) of the swimmers were available, however attractive results were identified based on the high number of swimmers of young and middle age groups considering the two very different swimming styles. It must be taken into account also that different results in previous studies could be caused by a different selection of participants, i.e. Tanaka and Seals (1997) only used data from swimmers below the age of 19 years and from the US Master Swimming as the database, while other authors used a database more focused on elite swimmers, with the Olympics.

CONCLUSIONS

The present findings suggest no difference in the age of peak swim times in 200m and 400m individual medley and freestyle. However, females reached peak swim times earlier than males, which might be dependent on a different development of the genders in puberty and the related physiological and anthropometric factors. Sex differences in peak swim times were similar for 200m than for 400m for both swim styles. Further studies need to investigate which elements among anthropometric factors, physiological factors, acquired skills and techniques have the highest impact on the swim times for the distances of 200m and 400m.

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