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Performance trends in master freestyle swimmers aged 25–89 years at the FINA World Championships from 1986 to 2014

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Abstract Performance trends in elite freestyle swimmers are well known, but not for master freestyle swimmers. We investigated trends in participation, performance, and sex difference in performance of 65,584 freestyle master swimmers from 25–29 to 85–89 years competing in FINA World Masters Championships between 1986 and 2014. The men-to-women ratio was calculated for each age group, and the trend across age groups was analyzed using single linear regression analysis. Trends in performance changes were investigated using a mixed-effects regression model with sex, distance, and calendar year as fixed variables. Participation increased in women and men in older age groups (i.e., 40 years and older). Women and men improved race times across years in all age groups and distances. For age groups 25–29 to 75–79 years, women were slower than men, but not for age groups 80–84 to 85–89 years. In 50, 100, and 200 m, women reduced the sex difference from 1986 to 2014 in age groups 30–34 to 75–79 years. In 400 m, women reduced the gap to men across time in age groups 40–44, 45–49, and 55–59 years. In 800 m, sex difference became reduced across time in age groups 55–59 and 70–74 years. In summary, participation increased from 1986 to 2014 in women and men in older age groups, women and men improved across time performance in all distances, and women were not slower compared to men in age groups 80–84 to 85–89 years. We expect a continuous trend in increasing participation and improved performance in master freestyle swimmers.

Keywords Athlete · Master · Age group · Performance · Elderly people

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Introduction

Improvements in freestyle swimming performance in elite swimmers competing at a world-class level (e.g., World Championships, Olympic Games) are well investigated (König et al. 2014; Nevill et al. 2007; O'Connor and Vozenilek 2011; Stanula et al. 2012). Nevill et al. (2007) analyzed swimming speeds in 100-, 200-, and 400-m freestyle world record times since 1957 for men and women and found that swimming speeds showed a period of "accelerated improvement" during the 1960–1970 period, but were plateauing after 1970. Finalists competing in the World Championships 1994–2013 and Olympic Games 1992–2012 improved their performance in all freestyle swimming distances.

Although men are swimming faster than women (Senefeld et al. 2015), women were able to reduce the gap to men in elite freestyle pool swimming (Stanula et al. 2012). Stanula et al. (2012) showed that the difference between women and men was smaller the longer the freestyle swimming distances. For female and male gold medalists at the 2008 Olympic Games in Beijing, the sex differences were 11.47, 11.13, 10.33, 8.78, and 7.42 % for 50, 100, 200, 400, and 800 m, respectively.

Apart from elite freestyle swimmers, the performance of freestyle master swimmers has been investigated in recent years. It has been shown that freestyle swimming performance decreased with increasing age (Gatta et al. 2006, Rubin et al. 2013; Senefeld et al. 2015). However, performance trends in age group freestyle pool swimmers for distances from 100 to 800 m or longer are not well known (Akkari et al. 2015). Akkari et al. (2015) recently investigated changes in swimming performance in master athletes competing between 1975 and 2013 in 100-m freestyle, but not for longer freestyle distances. In 100-m freestyle swimming, the progressions were significant for all age groups and both sexes (Akkari et al. 2015). Athletes in older age groups demonstrated greater improvements in race times across years than younger athletes (Akkari et al. 2015).

The performances of freestyle race distances up to 1500 m were examined by Senefeld et al. (2015). These authors showed that female and male swimmers in age groups 25–29 and 30–34 years were the fastest. From age group 45–49 years and older, women and men became slower. The fastest swimmers in age group 85–89 years were ~60 and ~52 % slower than the fastest swimmers in age group 25–29 for men and women, respectively. From 25–29 to 85–89 years, the sex difference in freestyle swimming speed increased from 8.5 ± 2.9 to 20.3 ± 3.5 % (Senefeld et al. 2015).

Although trends in freestyle swimming performance for elite athletes are well investigated and performances of age groups of master freestyle swimmers were recently reported, we have no knowledge about participation and performance trends across calendar years in age groups of master freestyle swimmers. Such knowledge might have practical implications for both sports scientists and coaches working with master swimmers. Information about changes in performance and sex differences across years would help to design specific sex-tailored training programs. Since 1986, the Fédération Internationale de Natation (FINA) regularly holds World Masters Championships for freestyle pool swimming. Any swimmer older than 25 years, fulfilling the qualification time, and affiliated to an official swimming club can start in a FINA World Masters Championship (www.fina.org/discipline/masters).

The aim of the present study was to investigate participation and performance trends across calendar years in age group freestyle swimmers competing in the FINA World Masters Championships (50 to 800 m) held between 1986 and 2014 with the hypothesis that participation would have increased and performance would have improved during the last ~30 years as has been shown for age group marathoners (Ahmadyar et al. 2015; Jokl et al. 2004; Lepers and Cattagni 2012).

Materials and methods

Ethics

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.

Data sampling and data analysis

All data were obtained from the official and publicly accessible website of FINA (www.fina.org/content/fina-masters-world-championships-results-archive). FINA records all competitors in 5-year age groups from 25–29 to 105–109 years (www.fina.org). Master swimmers were defined by FINA as athletes equal or older than 25 years. All age group athletes competing in all FINA World Masters Championships between 1986 and 2014 were analyzed for trends in participation, performance, and sex difference in performance. For all athletes recorded in each age group, mean race time was calculated for each edition and for all freestyle swimming distances.

In FINA World Masters Championships, any athlete complying with the minimal age and affiliated to a club can participate. To be able to compete in a FINA World Masters Championship, each interested swimmer needs to meet the qualification time for his/her age group, discipline, and distance (http://finamasters2014.org/Montreal2014EntryBooklet.pdf), see the qualification times by sex, age group, discipline, and distance for the 2014 FINA World Masters Championship held in

Montreal, Canada, as an actual example (www.masterswim.org.tw/userfile/41606/Time-standards-Montreal-2014_2.pdf). All athletes who successfully finished their race are recorded with their age and race time in their specific age group (www.fina.org/content/fina-masters-world-championships-results-archive).

Statistical analysis

All successful female and male swimmers for all age groups in all years were included for data analysis in order to eliminate a selection bias (i.e., restriction to a limited number of top swimmers such as top three placed athletes or finalists). Due to the low participation in age groups 90 years and older, we excluded these athletes due to statistical reasons (i.e., individuals over 90 years were extremely underpowered relative to the other athletes and these data violate the assumptions of homoscedasticity used in regression analysis). Trends in participation were analyzed using single linear regression analysis. The men-to-women ratio was calculated with all men and all women for each age group, and the trend in the ratio across age groups was analyzed using single linear regression analysis. A mixed-effects regression model with finisher as random variable to consider finishers who completed several races was used to investigate changes in performance across calendar years. We included sex, race distance, and calendar year as fixed variables. We also considered interaction effects between sex and race distance, and the final model was selected by means of Akaike information criterion (AIC). The sex difference in race time was calculated using the equation ([race time in women] − [race time in men]/[race time in men] × 100). Sex difference is expressed in percent by using the mean of the absolute race times for each distance and age group. Trends in sex difference in race time were analyzed using single linear regression analysis. Statistical analyses were performed using IBM SPSS Statistics (Version 22, IBM SPSS, Chicago, IL, USA). Significance was accepted at $P < 0.05$.

Results

Participation trends

Between 1986 and 2014, a total of 65,584 freestyle swimmers (29,467 women and 36,117 men) were officially recorded. These were 8357, 7074, 5445, 4478, and 4113 women in 50, 100, 200, 400, and 800 m, respectively. For men, these were 10,900, 9978, 6327, 4740, and 4172 swimmers, respectively. Figure 1 presents the participation trends combined for all age groups from 25–29 to 85–89 years. In 1996, no 400-m freestyle race was held. Participation increased for women in all age groups except the following: 25–29 to 70–74 years in 50 m, 25–29 to 35–39 and 55–59 to 70–74 years in 100 m, 30–34 to 35–39 years in 200 m, 25–29 to 45–49 years and 55–59 to 65–69 years in 400 m, and 25–29 to 35–39 years in 800 m. Also for men, participation increased in all age groups with the exception of 25–29 to 35–39 years in 50, 100, and 200 m; 25–29 to 65–69 years in 400 m; and 25–29 to 45–49 years in 800 m.

Performance trends

Figure 2 presents the races times (expressed in s) combined for all age groups from 25–29 to 85–89 years. For age groups 25–29 to 85–89 years, male and female performance improved across years ($P < 0.0001$). For age groups 25–29 to 75–79 years, men were faster than women ($P < 0.0001$). For age groups 80–84 ($P = 0.274$) and 85–89 years ($P = 0.0116$), women were faster than men. Sex and distance showed a significant interaction in age groups 25–29 to 75–79 for all distances ($P < 0.0001$). Figure 3 shows that performance times were 1–1.5 larger in male than in female swimmers (i.e., up to 75–79 years of age) and that this difference tended to be larger in short distance races (i.e., 50 and 100 m) in young swimmers (i.e., 25–45 years) compared to the other distances and age groups.

We separately calculated the trend for the men-to-women ratio for age groups 25–29 to 75–79 years (i.e., where men were faster than women were) and 80–84 to 85–89 years (i.e., where women were faster than men were). The men-to-women ratio remained unchanged in age groups 25–29 to 75–79 years in 50, 100, and 400 m but increased in 200 and 800 m. For age groups 80–84 to 85–89 years, the men-to-women ratio remained unchanged in 50 and 100 m but decreased in 200 to 800 m.

Sex difference

Figure 4 shows that the % difference in performance (time, s) between male and female swimmers decreased across years. It also shows that this difference was larger

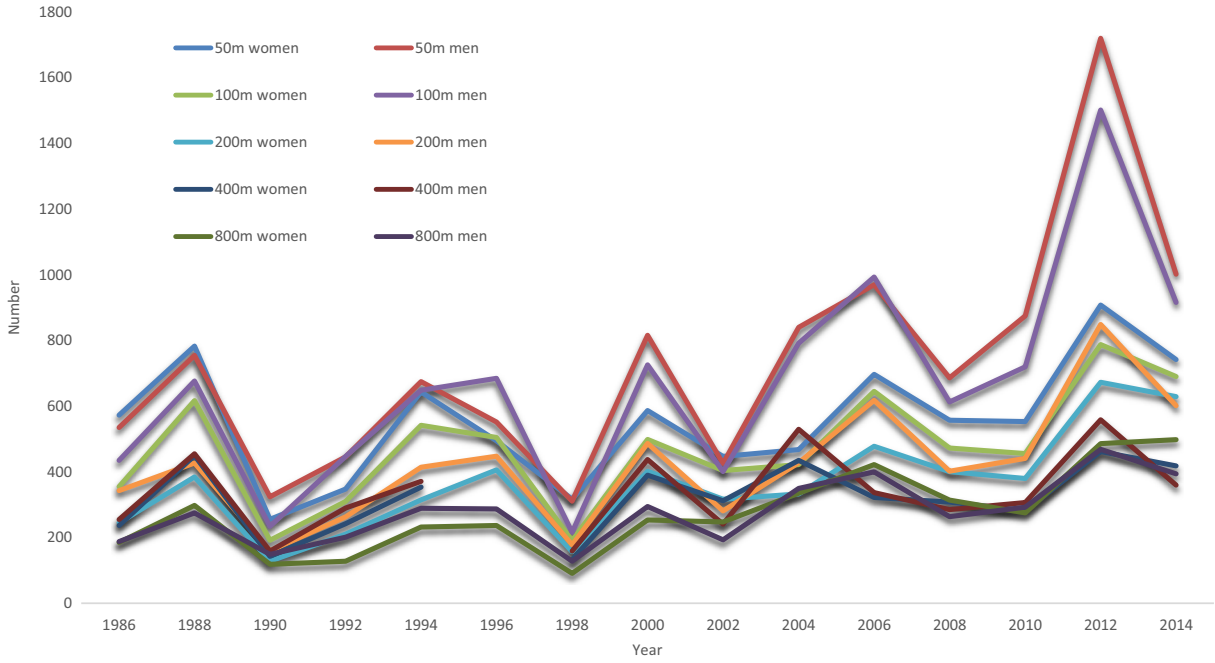

Fig. 1 Participation (number of swimmers) for master swimmers, combined for all age groups from 25–29 to 85–89 years. In 1996, no 400-m freestyle race was held

(1986–1992) for short distances (i.e., 50, 100, and 200 m), but now (2012–2014), it stabilized at around 17 % (on the average) over all distances. In 50, 100, and 200 m, women reduced the sex difference in age groups

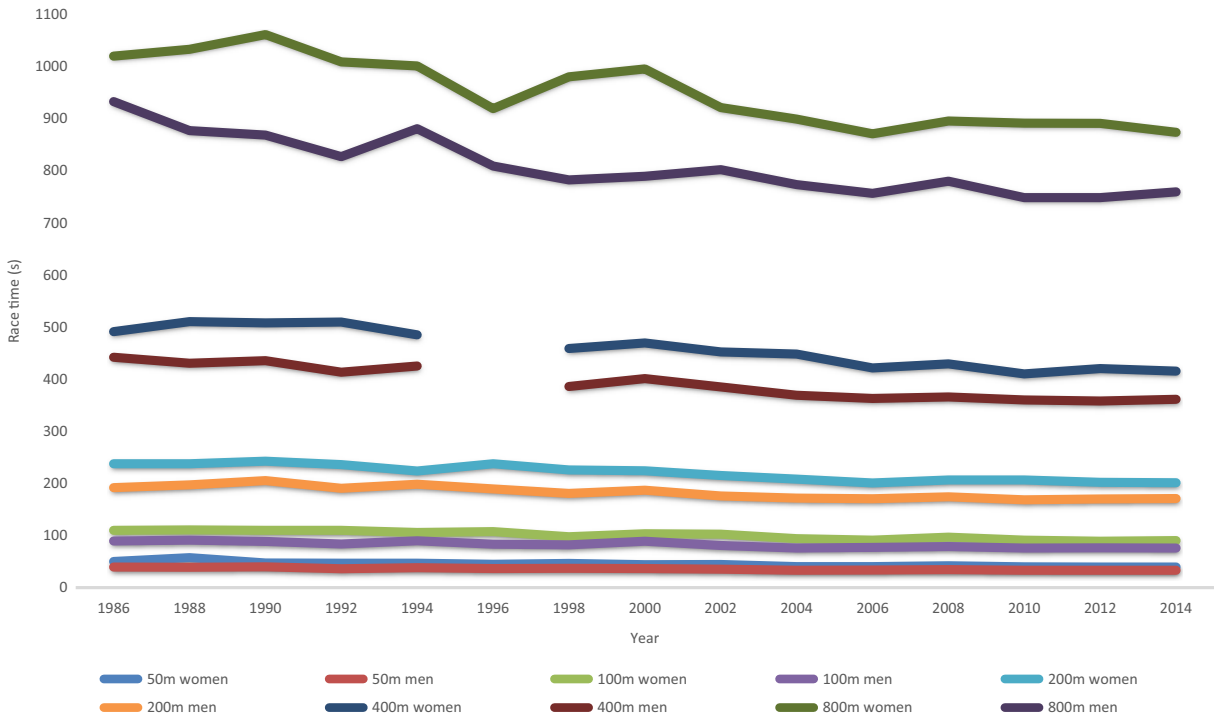

Fig. 2 Mean performance (race times, s) for master swimmers across years, combined for all age groups from 25–29 to 80–89 years. In 1996, no 400-m freestyle race was held

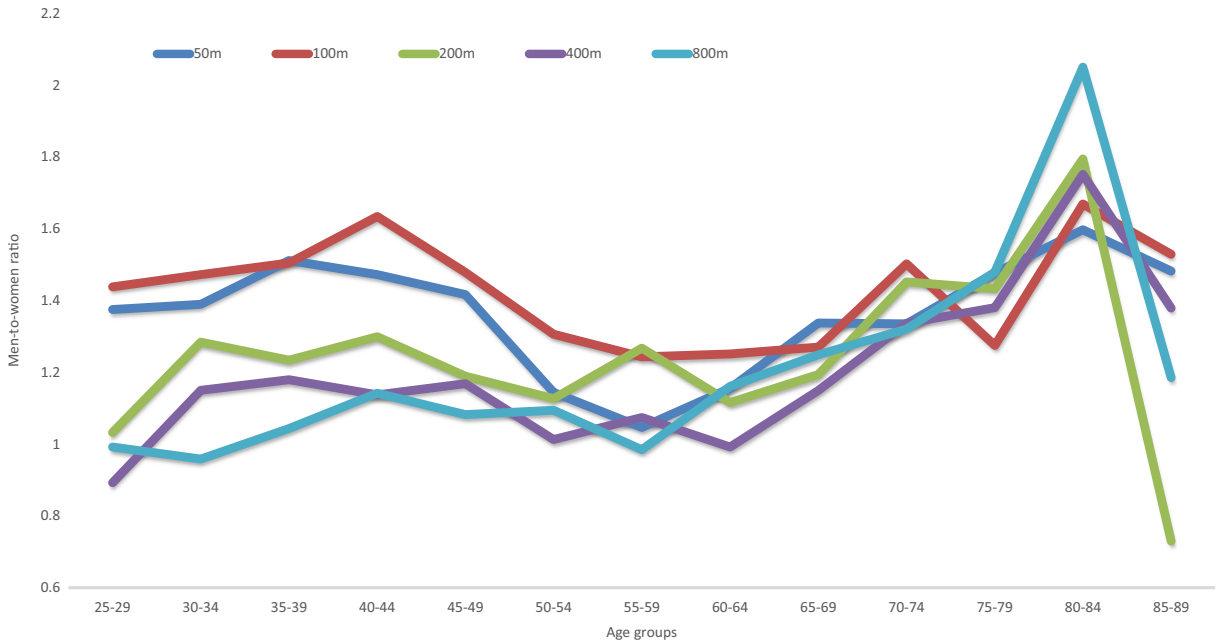

Fig. 3 The men-to-women ratio across age groups from 25–29 to 85–89 years

30–34 to 75–79 years ($P < 0.05$ to $P < 0.001$). In 400 m, women reduced the gap to men in age groups 40–44, 45–49, and 55–59 years ($P < 0.05$ to $P < 0.001$). In 800 m, the sex difference became reduced in age groups 55–59 and 70–74 years ($P < 0.05$ to $P < 0.001$).

Discussion

This study investigated participation and performance trends across calendar years in age group freestyle swimmers competing in the FINA World Masters Championships between 1986 and 2014. It was hypothesized that participation would increase and performance would improve. The most important findings were (i) participation increased across years in women and men, (ii) women and men improved performance in all distances from 1986 to 2014, and (iii) women were not slower compared to men in age groups 80–84 to 85–89 years.

Participation increased in women and men

A first important finding was that participation increased for both women and men mainly in swimmers competing in age groups older than ~40 years although the youngest age group in the FINA World Masters Championships was 25–29 years. A potential explanation for the findings for the unchanged participation in younger age groups (<40 years) could be the fact that the fastest freestyle swimmers in younger age groups still compete at world-class level races such as the World Championships and the Olympic Games (Allen et al. 2014; Allen and Hopkins 2015; König et al. 2014).

However, also, other reasons might explain this trend. In recent decades, there has been a continued increase in the number of master athletes in athletic events such as running, swimming, cycling, rowing, and weightlifting (Trappe 2001). Some of these master athletes may come from a background with years of training and competition experience, while others have only begun to compete as they approach middle-aged and older. Another explanation could be that older athletes change from other sports disciplines such as running to swimming. Excessive running may lead to overuse injuries of the lower limbs (Fredericson and Misra 2007; Rasmussen et al. 2013) and competitive athletes may then change to swimming in order to take care of their joints of the lower limbs. Age group athletes competing in short distance (Etter et al. 2013) and Ironman distance (Lepers et al. 2013, Stiefel et al. 2014) triathlon might also compete in swimming races at a high level in order to improve their swimming performance.

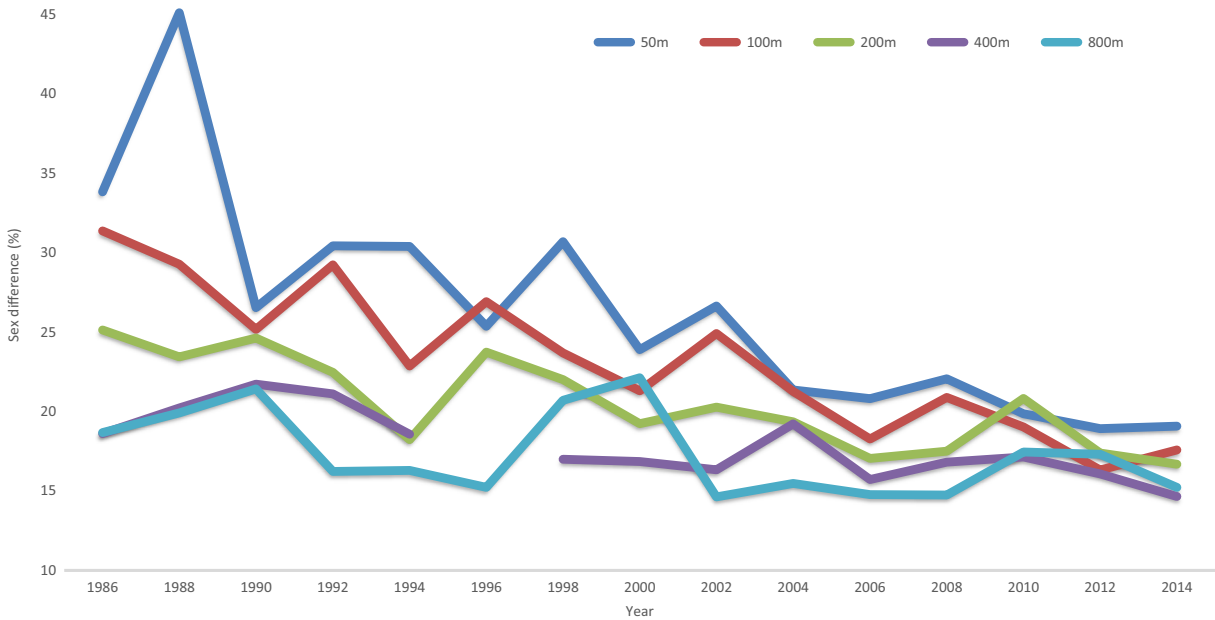

Fig. 4 Sex differences in performance times (%) across years for age group swimmers, combined for all age groups from 25–29 to 85–89 years. In 1996, no 400-m freestyle race was held

Women and men improved performance in all distances

A second important finding was that women and men improved freestyle swimming performance in all age groups and for all distances. This confirms previous findings for elderly athletes such as age group marathon runners (Ahmadyar et al. 2015; Lepers and Cattagni 2012) and age group swimmers (Akkari et al. 2015; Medic et al. 2009). A novel finding is, however, that female and male octogenarians improved their swimming performance. To date, Akkari et al. (2015) showed improvements in 100-m freestyle swimming in age groups 40–44 to 75–79 years. In their study, the slopes of improvements across calendar years were progressively greater in the older age groups with the greatest progression observed at the oldest age group of 75–79 years (Akkari et al. 2015).

The findings of an improved performance in master swimmers older than 80 years are different to findings for marathoners older than 75 years. In elderly marathoners older than 75 years competing during 2004–2011 in four races of the "World Marathon Majors" (i.e., Berlin, New York, Chicago, and Boston), the fastest women and men became slower across years (Ahmadyar et al. 2015). A potential explanation that elderly swimmers improved their performance could be their training. It has been shown for master athletes that chronic endurance training preserves muscle mass in aging athletes (Wroblewski et al. 2011). Master swimmers have a lower body mass index than untrained subjects of the sage age (Walsh et al. 2013). For master swimmers, training distance is an important factor for maintaining skeletal muscle mass and function in the aging process in swimmer aged 52–82 years (Abe et al. 2014).

Women were not slower than men in age groups 80–84 to 85–89 years

A third important finding was that men were faster than women from 25 to 79 years, but not from 80 to 89 years. The most likely explanation for this finding is the small number of women and men older than 80 years. The men-to-women ratio remained unchanged in age groups 25–29 to 75–79 years in 50, 100, and 400 m but increased in 200 and 800 m. For age groups 80–84 to 85–89 years, the men-to-women ratio remained unchanged in 50 and 100 m but decreased in 200 to 800 m.

Our findings differ from recent findings of Senefeld et al. (2015). These authors analyzed race times of the top ten female and male world record performances

from 1986 to 2011 in 13 5-year age groups between 25 and 89 years of age for 50- to 1500-m freestyle. The sex difference in swimming speed increased with increasing age from 8.5 ± 2.9 % (age group 25–29 years) to 20.3 ± 3.5 % (age group 85–89 years). The sex difference for age group 25–29 years was less than the sex difference in age groups 30–34 years and older to age group 85–89 years. The sex difference in swimming speed increased across age groups until the age of 60 years. After the age of 60 years, the sex difference increased more between age groups. The most likely explanation for the difference between our findings and the findings of Senefeld et al. (2015) is the difference in the investigated samples. While we considered all finishers at the FINA World Masters Championships until the age of 89 years without a selection of the top athletes, Senefeld et al. (2015) considered the top ten female and male world record performances until the age of 89 years.

The finding that women achieved a similar performance compared to men after the age of 80 years might be explained by anthropometric differences in elderly people. It has been shown that sarcopenia was higher in older men compared to older women. In people older than 80 years, the prevalence of sarcopenia was ~31 % in women and ~53 % in men (Iannuzzi-Sucich et al. 2002). An important aspect is the difference between women and men regarding an age-related loss in skeletal muscle mass. After the age of ~70 years, men lose significantly more fat free mass than women (Fantin et al. 2007). In women and men of the age of 68–78 years, the rate of loss in leg muscle mass was higher in men than in women (Zamboni et al. 2003).

A further explanation could be recent finding that women's age of peak performance increased in recent decades and they became similar to men's peak ages in many athletic events. In the last 20–30 years, the age of peak athletic performance increased in women but not in men (Elmenshawy et al. 2015). A further explanation could be training. Potdevin et al. (2015) showed for French master swimmers positive health outcomes in terms of body weight management, respiratory function, and vitality due to their race preparation where positive health outcomes were higher for female than for male master swimmers. These positive training effects might explain why women were not slower compared to men in age groups 80–84 to 85–89 years.

Factors influencing swimming performance in master swimmers

Also, swimming-specific factors should be considered. Different factors such as age, body height, hand grip strength (Zampagni et al. 2008), upper body strength, stroke frequency, and stroke length (Gatta et al. 2006) might have an effect on swimming performance in age group freestyle swimmers. The energy cost of swimming increases with age where the decrease in performance in master swimmers is due to both a decrease in the metabolic power available and to an increase in the energy cost of swimming (Zamparo et al. 2012b). Older master freestyle swimmers (60–80 years) swim at a significantly slower pace, with a lower propelling efficiency and a larger projected frontal area than younger master freestyle swimmers (30–60 years) (Zamparo et al. 2012a). In male athletes aged 50–90 years and participating in the World Master Championships in 200-m freestyle, the decline of stroke frequency was about 2.5 times steeper than that of stroke length across age groups (Gatta et al. 2006). In freestyle distances of 50, 100, 200, 400, and 800 m, age, body height, and hand grip strength were the best predictors in short-distance events, whereas age and body height were predictors in middle- and long-distance events (Zampagni et al. 2008). Differences between the sexes were found in 100 to 800 m, but not in 50 m.

Conclusion

In age group freestyle swimmers competing in the FINA World Masters Championships between 1986 and 2014 in age groups 25–29 to 85–89 years, participation increased in women and men preferably in the older age groups, women and men improved performance in all distances, women were not slower compared to men in age groups 80–84 to 85–89 years, and women reduced the gap to men until ~80 years, but not in older age groups. Due to these findings, we expect a continuous trend in increasing participation and improving performance in these master swimmers.

Compliance with ethical standards

Ethics 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.

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