Original Article

ANALYSIS OF MASTER SWIMMERS' SPORT PERFORMANCE FOR DIFFERENT FREESTYLE DISTANCES

ANÁLISE DO RESULTADO ESPORTIVO DE ATLETAS MÁSTER DE NATAÇÃO EM DIFERENTES DISTÂNCIAS DE NADO LIVRE

André Geraldo Brauer Júnior[1,2] e **Paulo Cesar Barauce Bento**[2]

[1]Centro Universitário Unibrasil, Curitiba-PR, Brasil.
[2]Universidade Federal do Paraná, Curitiba-PR, Brasil.

ABSTRACT

The aim of this study was to analyze the decline rate of master swimmers' world records compared to absolute world records, and sport performance decrease for both genders and different age groups (25 to 99 years old) in 50, 400 and 1500 meters freestyle swimming. The best performance for each distance and age group was collected from the official International Swimming Federation (FINA) website (www.fina.org). Group comparisons were made using One-Way ANOVAs followed by Dunett's post hoc test, with significance level set at $p \leq 0.05$. The decline rate of world records was greater in the 1500m distance in relation to the other distances analyzed for almost all age groups and both male and female swimmers. In addition, women showed a higher world record decline rate than men did for all race distances and almost all age groups. Both decline rate and sport performance decrease in the 1500 meters freestyle swimming seem to be more influenced by physiological changes derived from aging compared to the other race distances analyzed.
Keywords: Senior athlete. Aging. Sport performance.

RESUMO

O objetivo do estudo foi analisar a taxa de declínio dos recordes mundiais de nadadores máster em relação aos recordes mundiais absolutos e a redução do resultado esportivo em ambos os sexos em diferentes grupos etários (25 a 99 anos), nas distâncias de 50, 400 e 400 estilo livre. A coleta dos dados sobre os resultados esportivos dos nadadores foi realizada no site da Federação Internacional de Natação - FINA (www.fina.org). Para a análise estatística foi realizada a ANOVA - ONE WAY seguido de post hoc de Dunett com nível de significância de $p \leq 0.05$. A taxa de declínio dos recordes mundiais foi maior na prova de 1500m se comparado com as demais distâncias em praticamente todas as faixas etárias e em ambos os sexos. A taxa de declínio e a redução do desempenho esportivo é mais acentuada nas mulheres do que nos homens em todas as distâncias e em quase todas as faixas etárias. A taxa de declínio dos recordes mundiais e a redução do resultado esportivo na prova de 1500 metros nado livre parecem sofrer maior influência das alterações fisiológicas decorrentes do envelhecimento se comparadas às demais distâncias analisadas.
Palavras-chave: Atleta sênior. Envelhecimento. Desempenho esportivo.

Introduction

The total number of people over 65 years old is increasing every decade. Along with this trend of increasing life expectancy of the population, there has been a greater participation of people over 35 years in training programs with competitive purposes[1].

Competitions for athletes in master categories, organized by international/national/ regional confederations/federations or by athlete associations present a high technical level, and several athletes within age groups that participate in events of these categories remain competitive in some modalities, participating in absolute world championships and Olympic Games, with very expressive results[2].

In this sense, athletes in master categories offer an important source of data to determine physical decline rate associated with aging in physically fit men and women, with this population being considered a model for successful aging[3].

Thus, analyzing the sport performance of master athletes can contribute to understanding how systematized sports practice impacts the aging process. Bearing in mind their levels of physical activity and training routine, it is possible to assess the role of physical training within an irreversible biologically process.

Additionally, analysis of sport performance in swimming provides some advantages for ageing studies, since it is a sport modality of low joint impact and has a relatively low incidence of orthopedic injuries, even among older adults[4]. Moreover, unlike other sport events in which the number of male participants exceeds that of females, swimming attracts a similar number of male and female athletes in all age groups[1].

In this sense, some studies have sought to investigate sport performance decline in swimming during the aging process[5-7], as well as performance differences between genders[6,8]. However, the number of master athletes has been increasing steadily in the last decades and, consequently, there has been an improvement in age groups' records[9]. Therefore, it is necessary to update these data frequently, as it is not yet clear what the performance limit of these athletes is. Furthermore, analyzing results in races in which performance is determined by different conditioning factors (speed/strength, power or resistance) can contribute to the identification of aging effects on specific physical capacities.

Taking the above into account, the objective of this study was to analyze the decline rate of master swimmers' world records in relation to absolute world records, and sport performance reduction for both sexes and different age groups (25 to 99 years old) in the 50, 400 and 1500 meters freestyle races.

Methods

Participants

Documental data on the sport performance of the best swimmers in the world in each age group were collected from the FINA's public domain website (www.fina.org) in September 2015, and updated in February 2017.

Procedures

To assess age-related performance, the world records in the age groups were analyzed every five years, starting with the absolute world record for each race and continuing with the age groups (25-99 years old). For comparison between absolute world records and world records in age groups (decline rate), world records in Olympic pool (50m) were selected. As for analysis of sport performance reduction in the age groups, the ten best results of each age group and gender in the 50m, 400m and 1500m freestyle races were selected. Freestyle swimming events were chosen for attracting a higher number of athletes compared to other events.

The percentage difference to compare the world record with the records in the age groups was calculated using the formula below:

= [(age group's record – world record/world record) x 100]

The percentage difference to compare men and women was calculated using the formula below:

= [(women's record –men's record/men's record) × 100]

Statistical Analysis

Statistical analysis was performed initially by the *Kolmogorov-Smirnov* normality test. Once the normal distribution of data was obtained, the analysis of variance (one-way

ANOVA) was carried out, followed by Dunett's *post hoc* analysis, in which differences between the youngest master category (25-29 years old) and the others were considered. Data were expressed as mean ± standard deviation. In all calculations, a 5% significance level was set ($p < 0.05$). The software used for statistical tests was GraphPadPrism[5].

Results

Initially, world records were compared with the absolute world records of each age group to establish the sport performance decline rate. Besides, results were compared between genders (Table 1).

Table 1. World records, percentage differences between world records and age groups, and percentage differences between genders for each age group in the sprint, middle-distance and long-distance freestyle races (50m, 400m and 1500m)

AGE GROUPS (YEARS)

	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
50m –world record (s): 20.91 (men); 23.73 (women)															
Men's records (s)	22.34	22.13	22.76	23.31	23.98	24.08	25.01	25.23	26.33	28.35	30.28	31.96	33.94	40.72	47.43
Women's records (s)	25.42	25.74	25.98	26.44	26.59	28.22	28.69	29.31	31.35	33.57	34.85	37.61	44.70	49.68	64.52
Age difference (%)															
Men	6.8	5.8	8.8	11.5	14.7	15.2	19.6	20.7	25.9	35.6	44.8	52.8	62.3	94.7	126.8
Women	7.1	8.5	9.5	11.4	12.1	18.9	20.9	23.5	32.1	41.5	46.9	58.5	88.4	109.4	171.9
Gender difference (%)	13.8	16.3	14.1	13.4	10.9	17.2	14.7	16.2	19.1	18.4	15.1	17.7	31.7	22.0	36.0
400m –world record (s): 220.07 (men); 238.37 (women)															
Men's records (s)	241	238	246	247	251	257	262	280	296	312	318	352	422	482	691
Women's records (s)	259	259	266	263	276	281	290	300	328	355	372	400	486	545	647
Age difference (%)															
Men	9.5	8.3	11.7	12.1	14.1	16.6	19.3	27.2	34.7	41.8	44.4	60.1	91.9	118.8	213.8
Women	8.5	8.5	11.7	10.3	15.7	17.7	21.7	25.8	37.5	48.9	56.2	67.8	103.9	128.6	171.5
Gender difference (%)	7.32	8.48	8.24	6.54	9.87	9.37	10.5	7.08	10.6	13.8	17.1	13.5	15.1	13.2	-6.29
1500m –world record (s): 871.02 (men); 928.36 (women)															
Men's records (s)	974	926	960	997	999	1028	1043	1092	1173	1237	1263	1337	1715	1873	2850
Women's records (s)	995	1046	1047	1052	1076	1109	1155	1193	1349	1446	1482	1775	1931	2162	2500
Age difference (%)															
Men	11.8	6.3	10.2	14.5	14.7	18.1	19.7	25.4	34.7	42.0	45.0	53.5	96.9	115.0	227.2
Female	7.2	12.7	12.8	13.3	15.9	19.5	24.4	28.5	45.3	55.8	59.6	91.2	108.1	132.9	169.3
Gender difference (%)	2.17	13	9.09	5.48	7.71	7.87	10.8	9.23	14.9	17	17.3	32.8	12.6	15.5	-12.3

Source: The authors

The decline rate in men's 50 meters freestyle starts at 6.8% in relation to the absolute world record in the 25-29 years category, reaching 20.7% of variation in the 60-64 years age group. From this age group, rates rise more sharply (25.9%) to over 50% from 80 years. In women's, the initial variation is 7.1% (25-29 years), reaching 23.5% in the 60-64 years category. As of the age of 65, variation increases to 32.1%, reaching more than 50%, also from 80 years.

In the men's 400m freestyle race, the decline rate starts at 9.5% for 25-29 years, reaching 27.2% for 60-64 years. From then on, the decline rate begins to increase (34.7%), reaching values over 50% from the age of 80. For women, the initial variation is 8.5% (25-29 years) and reaches 25.8% for 60-64 years; from 65-69 years, the rate is 37.5%, reaching more than 50% from 75-79 years.

In the men's 1500m race, the decline rate starts at 11.8% for 25-29 years, reaching 25.4% for 60-64 years. From this age group, the rate raises to 34.7% and reaches values greater than 50% for 80-84 years. For women, the variation starts at 7.2% (25-29 years), reaching 28.5% for 60-64 years. From this age group, the decline raises to 45.3% and exceeds 50% already for 70-74 years.

As for gender comparison, it is possible to observe smaller differences in longer races (400m and 1500m versus 50m), for all age groups, with the exception ofthe 75-79 years group (15.1, 17.1 and 17.3% for the distances of 50m, 400m and 1500m, respectively) and 80-84 years (17.7, and 32.8% for the 50m and 1500m races, respectively). However, in more advanced age groups (95-99 years) and the distances of 400m and 1500m, women's performance is higher than men's – 6.29 and 12.3%, respectively.

Subsequently, sport performance decline was analyzed in the 50m, 400m and 1500m events (Figures 1 to 3). In the 50m race (Figures 1A and 1B), for both sexes, only from 60 years of age sport performance reduction becomes statistically significant ($p < 0.0001$).

Figures 2A and 2B display sport performance mean values in the 400m freestyle race, which begin to be significant for women aged 65 years and over, while for men this only happens after the age of 70 ($p < 0.0001$).

In the 1500m race (Figures 3A and 3B), there are significant reductions in performance for both sexes from 55 years of age ($p < 0.0001$).
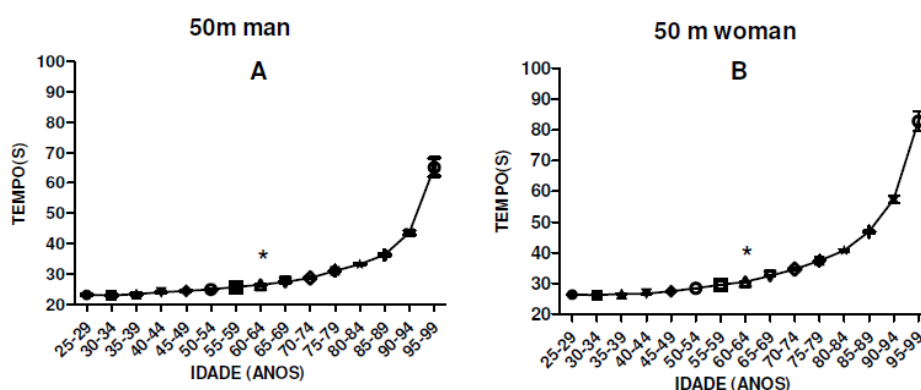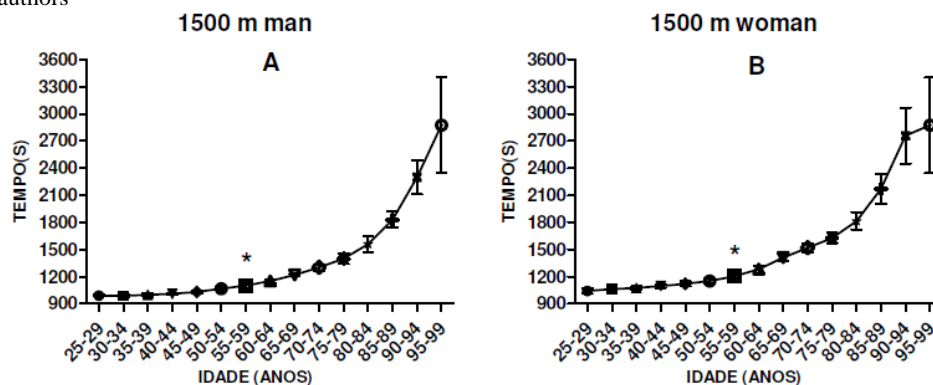

Figures 1A and 1B. Mean and standard deviation of the ten best sport performances of all time in men's and women's 50m freestyle

Source: The authors
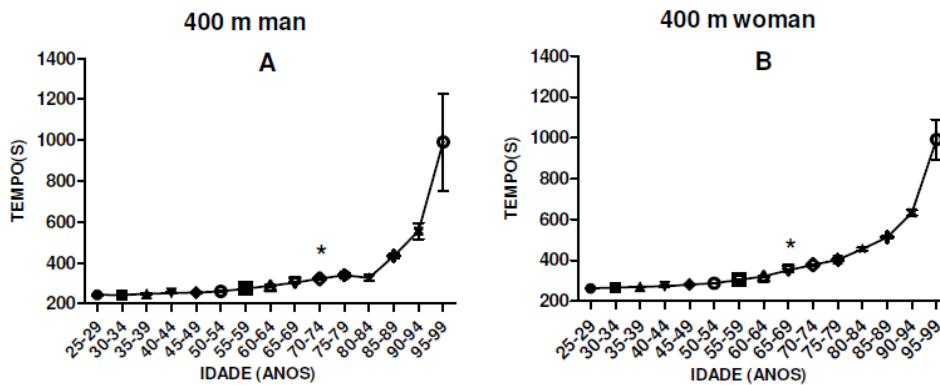
Figures 2A and 2B. Mean and standard deviation of the ten best performances of all time in men's and women's 400m freestyle

Source: The authors

Figures 3A and 3B. Mean and standard deviation of the ten best performances of all time in men's and women's 1500m freestyle

Source: The authors

Discussion

The objective of the present study was to analyze world record decline rates of master swimmers and sport performance reduction for both sexes and different age groups (25 to 99 years old) in the 50m, 400m and 1500m freestyle races. The main findings were: the highest decline rates of women's sport performance in relation to men's for all distances analyzed and in most age groups, as well as earlier reduction in sport performance. In addition, there were differences between swimming distances, with the longest one (1500m) presenting higher decline rates and earlier sport performance compared to shorter distances.

50m Freestyle Race

The 50m freestyle swimming is a sprint race, and performance is mainly related to alactacid anaerobic metabolism, where approximately 70% of the energy needed to sustain this work comes from this system of energy production[10] and muscle power, especially of the upper limbs[11].

The present study observed that the 50m race showed the lowest decline rates between age groups, whereas worsening of sport performance was slower compared to the 1500m race. The findings of the present study are corroborated by other investigations that sought to compare performance for different swimming distances during aging[1,8].

Due to changes that occur in aging, such as reduction and alterations in anaerobic enzymes, reduction of type 2 muscle fibers, decreased joint mobility and flexibility[5,12] and

increased tendon rigidity[13], it was to be expected that sport performance in this race would have a faster decline; therefore, other factors seem to intervene in this process. In a study conducted by Barbosa[14], who analyzed athletes participating in swimming events at the 2008 Olympics in Beijing, it was shown that swimmers in shorter races tend to be older than those in longer ones for both sexes, and male swimmers are older than female swimmers.

Although the decline rate of type II muscle fibers was more pronounced than those of type I, 50m race athletes presented decline rates lower than those in longer races. This can be explained by the fact that short-distance athletes reserve much of the training volume to high-intensity interval training methods, as well as strength training, according to previous studies[15]. This fact may interfere with the reduction in size and number of type II fibers and, therefore, delay age-related decline in anaerobic performance. Additionally, it is known that the strength and power of the upper limbs (fundamental for propulsion in this style of swimming) are less affected by aging than the lower limbs are[16].

In the present study, the age-related decline rate of anaerobic performance was similar for both sexes up to the 60-64 years age group, after which women's performance declines faster. In addition to the factors mentioned above, it can be seen that both the higher atrophy rate of type II fibers and hormonal changes can explain gender-related differences[17].

Regarding hormonal changes, it is known that estrogen levels connects with age-related decline in muscle mass, growth hormone (GH), insulin-like growth factor (IGF-I), and respective IGF32 binding proteins. Consequently, menopause-related reduction of estrogen levels has important implications on strength and sport performance[18].

400m Freestyle Race

The 400m freestyle swimming is a middle-distance race, and performance is related to both the aerobic energy production system and the glycolytic (lactacid anaerobic) system[19]. It is estimated that approximately 77% of the energy required for this swimming distance in males comes from the aerobic system and 23% from the anaerobic system[10]. In females, these values are 87% and 13% for the aerobic and anaerobic metabolism, respectively. The present study observed that the 400m race showed lower reduction rates than the 1500m race did in most of the analyzed age groups, whereas sport performance decline was the slowest among all races analyzed.

Thus, in addition to type I fibers, type IIa fibers also appear to be highly recruited in this race, as they show greater activity of glycolytic enzymes and produce more lactate than type I fibers do[20]. Therefore, age-related muscle mass reduction, and the transition to a more oxidative muscle profile, mediated by the atrophy of fast-twitch fibers, both in sedentary aging[21] and in master athletes[22,23], may explain age-related decreases in blood lactate production and, consequently, reduction in performance for this swimming distance.

Nevertheless, available data on blood lactate production during aging are limited and inconclusive. Some studies have suggested that both peak blood lactate and blood buffering capacity are compromised over the years[24,25]. However, other studies suggest that older swimmers are able to produce and remove blood lactate at the same rate as younger swimmers[5]. Therefore, the ability to produce and remove lactate might not fully explain performance reduction during races in which the glycolytic metabolism has a relevant contribution, as is the case of 400m freestyle.

Thus, both blood lactate production capacity and blood bufferingseem to relate to other factors such as changes in total muscle mass, reduction in the area of type II muscle fibers, reduction in strength, and changes in neuromuscular function, which is worth being further investigated for a better understanding of the problem.

1500m Freestyle Race

The 1500m freestyle swimming is a long-distance race, and performance is strictly related to maximum oxygen consumption and aerobic energy production system, which contribute significantly to success in this swimming distance[1].

The decline rates observed for this distance were higher than those of the 50m and 400m races in all age groups. In part, this can be explained by reductions in training load[12,26] (volume, intensity and frequency) observed in the master athletes due mainly to a greater need for longer recovery times between repetitions, as well as between training sessions training[6,27,28]. For Maglischo[15], long-distance swimmers present greater training volumes compared to sprinters and middle-distance ones, needing to spend more time on training.

Thus, performance decline in this swimming distance during aging may relate to several factors such as maximum heart rate, maximal oxygen consumption, ejection fraction, lactate threshold, movement economy and aerobic enzyme activity[12]. However, the influence of the above factors on performance reduction seems to be quite heterogeneous, where progressive reduction in maximal oxygen consumption appears to be a key physiological mechanism associated with endurance performance decline resulting from aging[7]. Despite this, previous studies have suggested that VO2max. decline rate in master long-distance swimmers is only half of that observed in sedentary individuals during aging[7].

Interpreting the above considerations, we must take into account some limitations of this study. One of them is the fact that we have assessed sport performance to infer about physiological mechanisms that may explain the aging process of master athletes. In addition, because it is a cross-sectional analysis, results may be different from those of longitudinal studies that explain sport performance reduction. Longitudinal investigations may provide a more detailed view on this issue. Furthermore, the smaller number of athletes in older age groups (95-99 years) limits statistical analyses in studies that use sport performance.

Conclusions

Based on the findings, it can be concluded that: (i) the decline rate of the world records and reduction in sport performance are higher in the 1500 meters freestyle swimming and seem to be influenced more by physiological changes from aging compared to the other distances analyzed; (ii) the decline rate of the world records and reduction in sport performance are more pronounced in women than in men for all swimming distances, and faster as of the 55-59 years age group.

Studies examining alterations in master athletes' training routines are necessary for a better understanding of age-related changes in performance.

References

1. Donato AJ, Tench K, Glueck DH, Seals DR, Eskurza I, Tanaka H. Declines in physiological functional capacity with age: a longitudinal study in peak swimming performance. J ApplPhysiol 2003;94(2):764-9. DOI:10.1152/japplphysiol.00438.2002.

2. Concannon LG, Grierson MJ, Harrast MA. Exercise in the older adult: From the sedentary elderly to the masters athlete. PMR 2012;4(11):833-839. Doi: 10.1016/j.pmrj.2012.08.007.

3. Heo J, Culp B, Yamada N, Won Y. Promoting Successful Aging Through Competitive Sports Participation: Insights From Older Adults. Qual Health Res 2012;23(1):105–13. DOI:10.1177/1049732312457247.

4. Rubin RT, Lin S, Curtis A, Auerbach D, Win C. Declines in swimming performance with age: a longitudinal study of Masters swimming champions. Open access J Sport Med 2013;4:63–70. DOI: 10.2147/OAJSM.S37718.

5. Reaburn P, Dascombe B. Anaerobic performance in masters athletes. Eur Rev Aging Phys Act 2009;6:39–53. DOI: 10.1007/s11556-008-0041-6.

6. Tanaka H, Seals DR. Age and gender interactions in physiological functional capacity: insight from swimming performance. J ApplPhysiol 1997;82(3):846–51. DOI: 10.1080/03610738008258376

7. Tanaka H, Seals DR. Endurance exercise performance in Masters athletes: age-associated changes and underlying physiological mechanisms. J Physiol 2008;586(1):55–63.

8. Ransdell LB, Vener J, Huberty J. Masters Athletes: An Analysis of Running, Swimming and Cycling Performance by Age and Gender. J ExercSci Fit 2009;7(2):S61–73. DOI: 10.1016/S1728-869X(09)60024-1

9. Akkari S, Machin D, Tanaka H. Greater progression of athletic performance in older Masters athletes. Age Ageing 2015;0:1–4. DOI: 10.1093/ageing/afv023

10. Richmond T, Buell J, Pfeil S, Crowder MW. Evidence-based recommendations for maximizing competitive swimming performance.J Swim Res 2015;23(1):1–14.

11. Garrido N, Marinho DA, Barbosa TM, Costa AM, Silva AJ, Pérez-turpin JA, et al. Relationships between dry land strength, power variables and short sprint performance in young competitive swimmers. J Hum Sport Exerc 2010;5(2):240–9. DOI: 10.4100/jhse.

12. Reaburn P, Dascombe B. Endurance Performance in mastersathetles. Eur Rev Aging Phys Act 2008;5(1):31–42.

13. Eyre DR. Cross-linking in collagen and elastin. Annu Rev Biochem 1984;53:717-48.DOI: 10.1146/annurev.bi.53.070184.003441

14. Barbosa TM, Costa MJ, Mejias E, Marinho DA, Louro H, Silva AJ. Pico da carreira desportiva em nadadores de nível mundial : análise das idades dos participantes nos Jogos Olímpicos de Pequim 2008 Peakcareer in world-rankedswimmers : age ' s analysisof 2008 Beijing Olympic Games participants. Motri2012;8(4):52–61. DOI: 10.6063/motricidade.8(4).1552

15. Maglischo EW. Part II : Training Fast Twitch Muscle Fibers : Why and How. J Swim Res 2012;19:1–18.DOI: 10.1519/JSC.0b013e318234eb6f

16. Candow DG, Chilibeck PD. Differences in Size , Strength , and Power of Upper and Lower Body Muscle Groups in Young and Older Men. J Gerontol 2005;60(2):148–56.

17. Varlamov O, Bethea CL, Jr CTR. Sex-specific differences in lipid and glucose metabolism. Front Endocrinol (Lausanne) 2015;5:1–7. DOI: 10.3389/fendo.2014.00241

18. Bortz WM, Bortz WM. How fast do we age? Exercise performance over time as a biomarker. J Gerontol A BiolSciMedSci 1996;51(5):M223–5.

19. Ribeiro JP, Cadavid E, Baena J, Monsalvete E, Barna A, Rose EH De. Metabolic predictors of middle-distance swimming performance. Br J Sp Med 1990;24(3):196–201.

20. Robergs RA, Ghiasvand F, Parker D, Robergs RA, Ghiasvand F, Parker D. Biochemistry of exercise-induced metabolic acidosis Biochemistry of exercise-induced metabolic acidosis. Am J Physiol - RegulIntegr Comp Physiol 2005;287:502–16. DOI: 10.1152/ajpregu.00114.2004

21. Jensen-urstad M, Svedenhag J, Sahlin K. Effect of muscle mass on lactate formation during exercise in humans. Eur J ApplPhysiolOccupPhysiol 1994;69:189–95. DOI: 10.1007/BF01094787

22. Nilwik R, Snijders T, Leenders M, Groen BBL, Kranenburg J Van, Verdijk LB, et al. The decline in skeletal muscle mass with aging is mainly attributed to a reduction in type II muscle fi ber size. ExpGerontol 2013;48(5):492-8. Doi: 10.1016/j.exger.2013.02.012

23. Korhonen MT, Cristea A, Ale M, Ha K, Sipila S, Mero A, et al. Aging , muscle fiber type , and contractile function in sprint-trained athletes. J ApplPhysiol 2006;101:906–17. DOI: 10.1152/japplphysiol.00299.2006

24. Mikkelsen UR, Nielsen RH, Mackey AL, Karlsen A, Coupp C. Differential satellite cell density of type I and II fibres with lifelong endurance running in old men. ActaPhysiol 2014;210:612–27. DOI:10.1111/apha.12195

25. Benelli P. Assessment of post-competition peak blood lactate in male and female master swimmers aged 40 – 79 years and its relationship with swimming performance. Eur J ApplPhysiol 2007;99:685–93. DOI: 10.1007/s00421-006-0334-2

26. Trappe S, Hayes E, Galpin A, Kaminsky L, Jemiolo B, Fink W, et al. New records in aerobic power among octogenarian lifelong endurance athletes. J ApplPhysiol 2013;114:3–10. DOI:10.1152/japplphysiol.01107.2012

27. Arampatzis A, Degens H, Baltzopoulos V. Why Do Older Sprinters Reach the Finish Line Later ? Exerc Sport Sci Rev 2011;39(1):18–22. DOI: 10.1097/JES.0b013e318201efe0

28. Borges N, Reaburn P, Driller M AC. Age-Related Changes in Performance and Recovery Kinetics in Masters Athletes: A Narrative Review. J Aging Phys Act 2015;21(4):149-157. DOI:10.1123/japa.2015-0021.

Author address: André Geraldo Brauer Júnior. Rua Coronel Alfredo Ferreira da Costa, 535, Bairro Jardim das Américas, Curitiba, PR, CEP 80540-. E-mail: brauerru@hotmail.com