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Research article

Relative Age Affects Marathon Performance in Male and Female Athletes

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Abstract
Marathon runners are ranked in 5-year age groups. However the extent to which 5-year groupings facilitates equitable competition has not been evaluated. The aim of this study was to evaluate the effect of relative age in male and female marathon running. Marathon finishing times for the top ten male (aged 20-69 years) and female athletes (aged 20-64 years) were obtained from the 2013 New York and Chicago marathons. Intra-class and inter-class validity were evaluated by comparing performances within (intra-class) and between (inter-class) the 5-year age groups. Results showed intra-class effects in all male age groups over 50 years, in all female age groups over 40 years, and in male and female 20-24 age groups ($p < 0.05$). Inter-class differences existed between the 20-24 and 25-29 age groups in both males and females, between all male age groups over 50 years, and between all female age groups over 40 years ($p < 0.05$). This study provided the first evaluation of the effects of relative age in male and female marathon running. The results provide preliminary but compelling evidence that the relatively older male athletes in age groups over 50 years and the relatively older females in age groups over 40 years are competitively disadvantaged compared to the younger athletes in these age groups.

Key words: Aging, endurance, age classification, competition, exercise

Introduction

Competition is a defining feature of sport and is known to be a potent social motivator for sports participation. When competition is one-sided, the motivation to participate in sport is reduced, especially in unsuccessful participants. Classification in sport reduces the likelihood of one-sided competition thereby promoting participation (Tweedy and Vanlandewijck, 2011). Age is a common unit of classification in sport, and the effect of an age classification system is to control for the influence of aging on the outcome of competition to increase the likelihood that successful athletes are those that have the most advantageous combination of physiological and psychological attributes and have enhanced them to best effect (Tweedy et al., 2014; Tweedy and Vanlandewijck, 2011).

A relative age effect, defined as a "difference in age between individuals within each age group" that "may result in significant difference in performance" (Helsen et al., 2005; Medic et al., 2007), has been shown in youth and masters sports settings. For example, in masters swimming the younger athletes in each class are more likely to break National and World records and be selected for National competitions (Medic et al., 2007). In marathon running, age is classified using 5-year age groups (e.g. 20-24 years, 25-29 years)(Chicago Marathon, 2013; New York Marathon, 2013) so that athletes can achieve competitive success across the age span. However, previous studies have shown that the effect of aging on marathon performance varies considerably. Specifically, marathon times decrease with maturation until the age of optimal performance which is believed to occur in the 25-29 age group (Lara et al., 2014). Then, in masters athletes (>35 years), marathon times increase and the relationship between age and marathon running performance is characterised by a curvilinear relationship. The extent to which marathon performance is affected by aging is at first relatively small then accelerates in runners who are aged over 50 years (Lara et al., 2014; Leyk et al., 2009). Hence it is likely that a relatively small age effect exists in some age groups (e.g. 35-39 years) compared to others (e.g. 60-64 years) which increases the possibility that in some age groups the relatively older masters athletes are competitively disadvantaged.

A valid age classification system should promote participation by encouraging close competition, and classifying age according to the extent to which it impacts marathon performance. In such a system, age groups should comprise the maximum number of consecutive ages which have a similar impact on marathon running performance to ensure they are as competitive and equitable as possible. While a systematic 5-year age group structure is relatively easy to administer and makes it relatively easy to recognise class boundaries, this structure potentially creates a relative age effect in the masters age groups with a bias in favour of relatively younger athletes. However, because the literature currently lacks a class-by-class evaluation, the age effect within and between each 5-year age grouping is not known. The aims of this study were to quantify the relationship between age and marathon performance, and to evaluate the intra-class and inter-class effect of age on marathon running performance in males and females. We hypothesised that there would be inter-class and intra-class effects in masters athletes aged over 50 years.

Methods

The marathon finishing times for the top ten male and female athletes were obtained from publicly accessible online databases containing results from the 2013 editions of the New York and Chicago marathons (Chicago Marathon, 2013; New York Marathon, 2013). These marathons were selected because they are major world marathons and therefore are likely to have a high level of participation and attract fast athletes in each age group. In

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addition, the full results of these marathons were available on publicly-accessible online databases. The fastest ten athletes were extracted because successful marathon running requires consistent training, and an appropriate lifestyle which is lacking factors such as smoking and sedentary behaviour which negatively impact on performance (Leyk et al., 2009). Consequently the best marathon performances in each age group (e.g. the top ten) provide the ideal dataset to minimise potentially confounding lifestyle factors (Lara et al., 2014). Finishing times for males aged 20-69 years and females aged between 20-64 years in 1-year intervals were downloaded from each database and combined to produce a final dataset comprising twenty finishing times (10 for Chicago and 10 for New York) for each of 50 (males) and 45 (females) 1-year age groups which led to 10 (males) and 9 (females) five-year age groups. Insufficient data in age groups >70 years in males and >65 years in females precluded useful analysis and results from these age groups were excluded from the study.

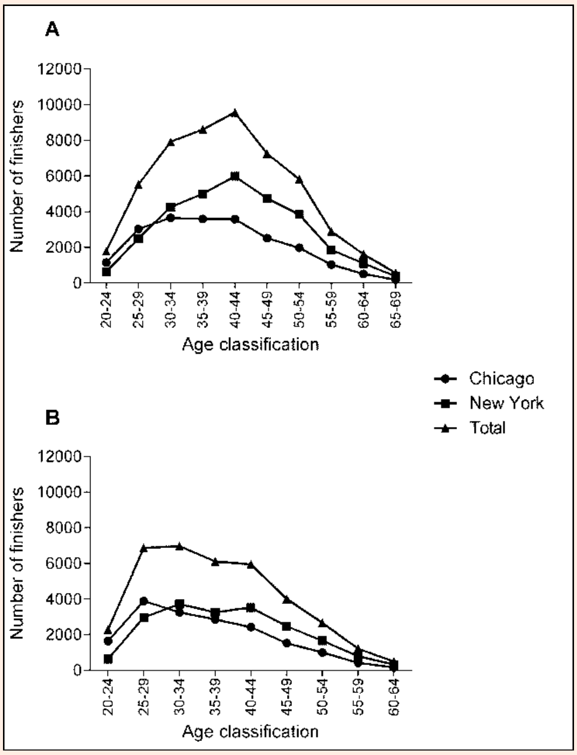

Figure 1. The number of finishers in each age group for males (A) and females (B). Overall, male participation was greatest in the 40-44 age class and female participation was greatest in the 30-34 age class.

Statistical analyses

Mean and standard deviation for male and female marathon times were calculated for each age in 1-year intervals. The relationship between age (in 1-year intervals) and marathon time was modelled using a quadratic regression analysis (Lara et al., 2014). The mean finishing times for the two youngest ages and the two oldest ages in each 5-year age group were calculated and extracted for further analyses. Independent t-tests with Bonferroni corrections for multiple comparisons were used to evaluate intra-class validity by comparing the mean finishing times in the two youngest ages to the two oldest ages within each class. One-way ANOVA with Bonferroni corrections for multiple comparisons was used to evaluate inter-class validity by comparing the mean finishing times of consecutive age groups. Effect sizes were calculated using Cohen's d which standardises the difference between the means by the standard deviation (Cohen, 1988). Effect sizes were interpreted as follows: 0.80 was a large effect size, 0.50 was a medium effect size, and 0.20 was a small effect size (Cohen, 1988).

Results

In 2013 there were 39,122 finishers in the Chicago Marathon and 50,304 finishers in New York. The number of finishers in each age group for males and females is presented in Figure 1. Overall the 40-44 age class and 30-34 age class provided the largest contribution of male and female finishers respectively.

Figure 2 shows the intra-class participation difference between the two youngest and oldest ages in all male and female age groups. Intra-class participation consistently decreased with in all age groups over 40 years in males and females.

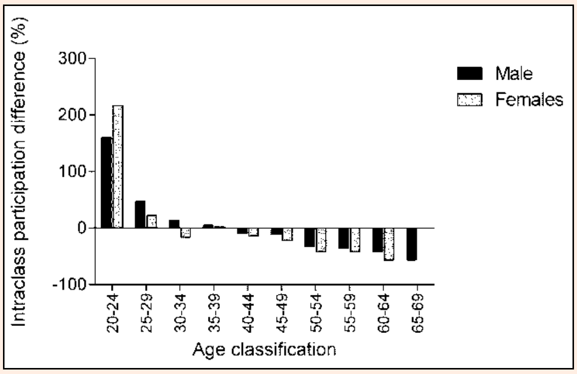

Figure 2. The intra-class participation difference between the two youngest and oldest ages in all male and female age groups. A positive difference means that participation increased from the younger ages to the older ages in a given age group. Note that there were insufficient data in the female 65-69 year age group.

The relationship between 1-year age intervals and marathon finishing time was significant and U-shaped for both males (R^2 = 0.83; y = 0.07517x2 – 5.084x + 242.1; p <0.05) and females (R^2 = 0.75; y = 0.09997x2 – 6.840x + 300.3; p<0.05) (Figure 3). The fastest average time ± S.D. in our male sample was 146 ± 11minutes in the 29 year old sample. In females, the fastest average time ± S.D. was 169 ± 15 minutes in the 26 year old sample.

Results of the intra-class age group comparisons are presented in Figure 4 and the intra-class effect sizes are presented in Table 1. There was a significant main intra-class effect of age on marathon running performance. In the youngest age group (20-24 years) an age effect was detected for both males and females (p < 0.05). The mean difference between the oldest athletes in the class (aged 23-24 years) and the youngest athletes in the class (aged 20-21 years) was 18.3 minutes for males and 28.6 minutes for females.

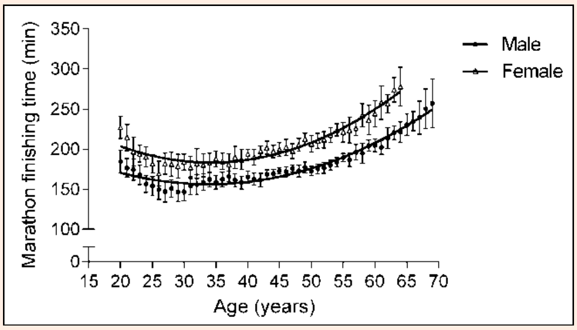

Figure 3. The model of the relationship between 1-year age intervals and marathon finishing time. The relationship was U-shaped for both males and females. In masters athletes (>35 years), the deterioration in marathon times was curvilinear.

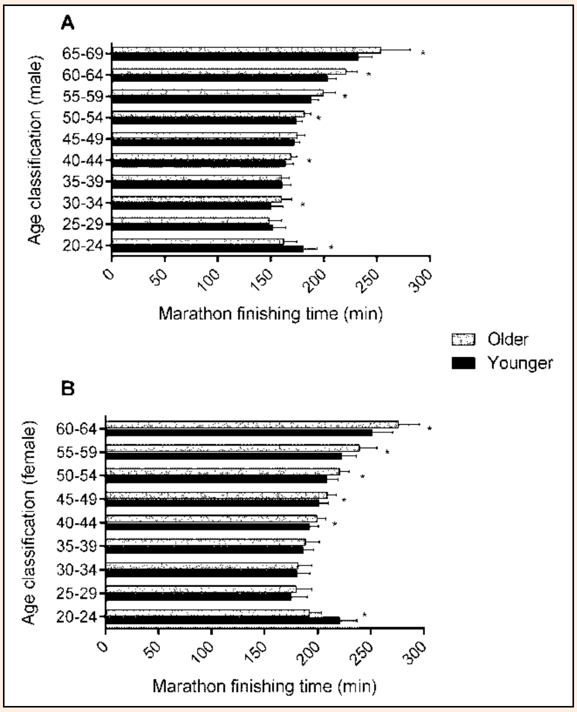

Figure 4. Results of the intra-class analysis. In males, significant effects of age were found in the 20-24 class, 30-34 class, 40-44 class, and all age groups over 50 years. In females, significant effects of age were found in the 20-24 class, and all age groups over 40 years. * indicates significant intra-class effect.

In males, relatively younger athletes outperformed the relatively older athletes in the following age groups: 30-34 yrs (10 minutes), 40-44 yrs (5.2 minutes), 50-54 yrs (7.8 minutes), 55-59 yrs (11.5 minutes), 60-64 yrs (17.4 minutes), and 65-69 yrs (21.2 minutes) ($p < 0.05$; Figure 4). In females, relatively younger athletes outperformed relatively older athletes in the following age groups: 40-44 yrs (7.3 minutes), 45-49 yrs (8.1 minutes), 50-54 yrs (12.1 minutes), 55-59 yrs (16.9 minutes), and 60-64 yrs (25 minutes) (Figure 4). In the age groups where significant effects were observed the effect sizes were large, many with a Cohen's d over 1 (Table 1).

Results of the inter-class age group comparisons are presented in Figure 5 and the inter-class effect sizes are shown in Table 2. There was a significant main inter-class effect of age on performance ($p < 0.05$). Males and females aged 25-29 years ran faster than athletes aged 20-24 years ($p < 0.05$). In males the difference was 21 minutes and in females the difference was 29 minutes indicating an effect of maturation ($p < 0.05$).

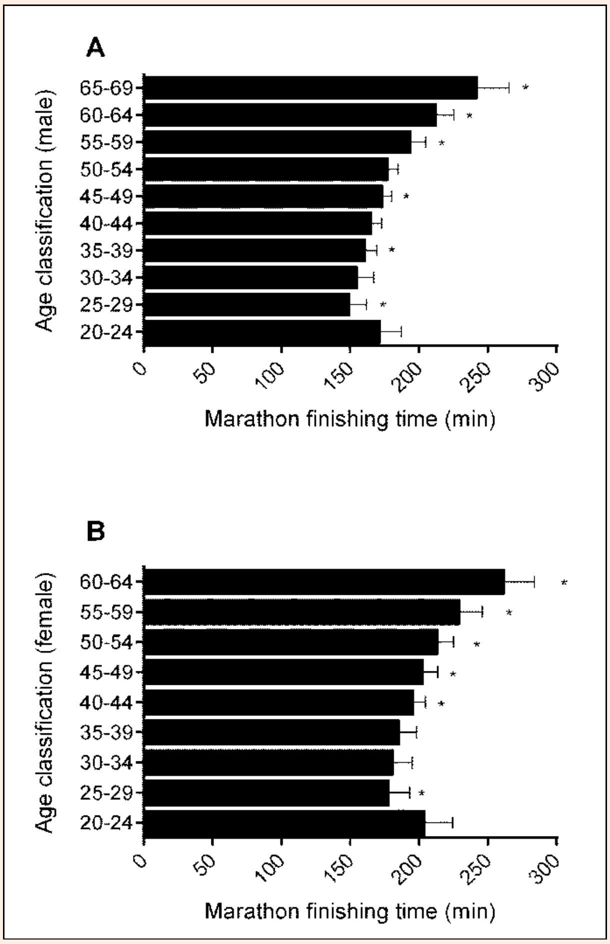

Figure 5. Results of the inter-class analysis. In males, there were significant inter-class effects between the 20-24 age group and the 25-29 age group, the 30-34 and the 35-39 age groups, the 40-44 and the 45-49 age group, and all age groups over 50 years. In females, significant inter-class effects were found between the 20-24 and the 25-29 age groups, and all age groups over 35 years. * indicates a significant difference from the preceding (i.e. younger) class.

Table 1. The effect sizes (Cohen's d statistic) for intra-class comparisons in males and females.

	Age Classification									
	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69
Male	1.4	.3	.9	.1	.8	.4	1.3	1.3	1.8	1.0
Female	2.0	.3	.1	.2	.9	.9	1.2	1.1	1.3	N/A

Large effect size ≥ 0.80, medium effect size ≥ 0.50, small effect size ≥ 0.20. There was insufficient data in the female 65-69 age class preventing analysis. N/A indicates that insufficient data were available.

Table 2. The effect sizes (Cohen's d statistic) for inter-class comparisons in males and females.

	Age Classification Comparison								
	20-24 vs. 25-29	25-29 vs. 30-34	30-34 vs. 35-39	35-39 vs. 40-44	40-44 vs. 45-49	45-49 vs. 50-54	50-54 vs. 55-59	55-59 vs. 60-64	60-64 vs. 65-69
Male	1.6	.5	.6	.5	1.2	.5	1.9	1.6	1.6
Female	1.5	.2	.4	1.0	.8	1.0	1.2	1.7	N/A

Large effect size ≥ 0.80, medium effect size ≥ 0.50, small effect size ≥ 0.20. There was insufficient data in the female 65-69 age class preventing analysis. N/A indicates that insufficient data were available.

Similarly, significant inter-class effects were observed in masters athletes: male athletes aged 35-39 years were slower than athletes aged 30-34; male athletes aged 45-49 years were slower than those aged 40-44 years (7.1 minutes); and the male age groups 55 years and over were slower than the corresponding younger age group (Figure 5, $p < 0.05$). In addition, all female age groups aged 40 years and over were slower than the corresponding younger age group (Figure 5, $p < 0.05$).

Discussion

Age classification is an important feature of modern sport and is implemented with the intended effect of increasing sport participation by reducing the impact of aging on the outcome of competition. Marathon athletes compete in 5-year age groups and this study provided the first empirical evaluation of the relative age effects in male and female marathon athletes. The findings from this study are summarised as follows: 1) significant intra-class effects were observed within the male 20-24 age group, 30-34 age group, 40-44 age group and all age groups over 50 years, 2) significant intra-class effects were observed within the female 20-24 age group and all age groups over 40 years, 3) significant inter-class effects were found in males between the 20-24 and 25-29 age groups, the 30-34 and 35-39 age groups, and between all age groups over 50 years, and 4) significant inter-class effects were found in females between the 20-24 and 25-29 age groups and all age groups over 35 years.

The significant and large intra-class effects observed in all male age groups over 50 years and all female age groups over 40 years were the key findings of the current study. These results indicated that relatively older athletes in these age groups were significantly slower compared to their younger counterparts. These results were most likely due to the accelerated impact of aging on marathon running performance in older athletes which is thought to be caused by a progressive decline in VO_2max and strength, secondary to reduced active muscle mass (Faulkner et al., 2008; Reaburn and Dascombe, 2008; Tanaka and Seals, 2008). The regression model shown in Figure 3 and the regression models in previous studies were in agreement that a curvilinear relationship exists between age and marathon performance with a more pronounced deterioration in older athletes (Lara et al., 2014; Leyk et al., 2009). In support of the model, the results of the current study showed larger effects of aging on marathon performance in older athletes compared to those in middle-age. For example, the average male marathon time increased by 9% between 35-50 years, a change of less than 1% per year. However, there was a 33% increase between 50-65 years which corresponded to a change of more than 2% per year. These results provided preliminary but robust evidence that relatively older male athletes in age groups over 50 years and relatively older females in age groups over 40 years are competitively disadvantaged compared to relatively younger athletes. One practical approach to address this issue is to increase the number of age groups (Medic et al., 2009), however further research would be required to determine the optimal class configuration.

The results of the current study showed an inter-class and intra-class deterioration in marathon participation with aging which corresponded to the deterioration in marathon performance. In order to finish in the top ten of an age group, a marathon athlete requires a lifestyle which is lacking factors that negatively impact running performance and permits consistent athletic training over many years (Leyk et al., 2009). It is likely that a combination of many external lifestyle factors such as increased work commitments and family responsibilities (Caspersen et al., 2000), physiological decline as a result of the aging process and injury are responsible for the reduced participation with aging. An intra-class decline in participation within masters age groups indicates an unequal distribution of participants which could be a contributory factor toward the intra-class performance effects we observed in the current study. For this reason a previous study controlled for participation frequency to avoid making a type I error (Medic et al., 2009). However, in the current study we decided against controlling for participation frequency for two main reasons. First it was not possible to determine causation between participation and performance outcomes from our results. While it is possible that an unequal distribution of participants within a class directly affected marathon performance between constituent ages, the prospect of close competition is a motivator for taking part in sport (Vallerand and Rousseau, 2001) and, given that masters athletes are aware of the inherent advantages conferred to younger athletes (Medic et al., 2013), it remains a possibility that marathon athletes withdraw from competition as they become relatively older in their age group because they become unable to achieve a satisfactory finishing time or a high finishing position in their class. Consequently intrinsic motivation, perceived competence and task goal motivation are reduced (Medic et al., 2007) which decreases the prospect of training and competitive racing in the future. On this basis, controlling for participation would increase the probability of failing to detect a true effect (i.e. a type II error). Second, the possibility that reduced participation is a major contributory factor toward the decline in masters athletic performance has previously been explored but results from a study that controlled for participation frequencies were similar to those from a study that did not control for participation frequency (Medic et al., 2007; 2009). In both studies the likelihood of setting a track and field record was higher for the relatively younger athletes in each class.

Significant and large intra-class effects were observed in the 20-24 age class in males and females showing that the younger athletes in this class were slower compared to the relatively older athletes. Moreover, the 20-24 age class was significantly slower than the 25-29 age class which was the fastest class in both males and females. These results are most likely due to the effects of prolonged physical training on marathon running in young athletes up to the age of peak performance. Initially young athletes tend to show a strong VO_2max response to aerobic training which tends to stabilise at approximately 20 years (Mikulic, 2011; Wang et al., 2014). Thereafter other submaximal performance-related variables improve until the optimal age of peak performance is reached (Mikulic, 2011) which varies with the sport. In power-based sports such as sprinting, performance tends to peak relatively earlier at 23-24 years, and in Ironman triathlon performance peaks relatively later at 33-34 years (Rust et al., 2012; Schulz and Curnow, 1988). Our results are in agreement with those from Lara et al. (2014) indicating that marathon athletes achieve optimal performance on average between 25-29 years.

The significant intra-class effect in the male 30-34 class and the significant inter-class effect between the 30-34 and 35-39 age groups should be interpreted with some caution because these effects were most likely due to performance variation in our sample rather than true age-related effects. While our data showed peak marathon performance in the 25-29 age class, many elite marathon athletes have maintained a high performance level into their thirties. For example, the previous world record for the marathon was achieved by Wilson Kipsang Kiprotich aged 31 years in 2013, and Haile Gebrselassie was aged 35 years when he set a previous marathon world record in 2008 (Knechtle et al., 2014). Similarly, the effects in the 40-49 age groups are somewhat difficult to interpret because of inconsistent intra-class and inter-class results. Consequently, definitive conclusions cannot be made with respect to the validity of male age groups between 30-49 years.

A limitation of the study was that we were unable to fully control for other features which are known to affect distance running performance. These features include marathon experience, training volume and physiological factors (Lara et al., 2014). In order to mitigate this issue, data from the fastest ten athletes in each age group were analysed to increase the likelihood that the sample was homogeneous in their general approach to marathon competition and physiology. The results of this study are relevant for competitive masters athletes and their coaches. Masters athletes who perceive they are competing in one-sided competition are potentially at the greatest risk of reduced motivation to participate in future events. The results of this study provide athletes with the knowledge of the age groups in which performance significantly declines. In turn this knowledge reinforces the notion that competitiveness in masters athletics is cyclical thereby motivating competitive masters athletes to continue to train and compete until they are eligible for the subsequent age group.

Conclusion

Age is classified into 5-year age groups in marathon running and this study provided the first empirical evaluation of the validity of these groups. The results indicated that the relatively older male athletes in age groups over 50 years and the relatively older females in age groups over 40 years were competitively disadvantaged compared to the relatively younger athletes. The extent to which these effects were due to reduced participation in athletes aged over 40-50 years or reduced physiological functioning with aging remains to be established. Research is also required to establish if a change in the age classification system increases participation in masters athletes.

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References

Caspersen, C.J., Pereira, M.A. and Curran, K.M. (2000) Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Medicine and Science in Sports Exercise* **32(9),** 1601-1609.

Chicago Marathon. (2013) Chicago Marathon Results. Available from URL:http://www.chicagomarathon.com/participant-information/race-results/ (Retrieved 3 September, 2014).

Cohen, J. (1988) *Statistical Power Analysis for the Behavioral Sciences* 2nd edition. Erlbaum, Hillsdale, NJ: Psychology Press.

Faulkner, J.A., Davis, C.S., Mendias, C.L. and Brooks, S.V. (2008) The aging of elite male athletes: age-related changes in performance and skeletal muscle structure and function. *Clinical Journal of Sport Medicine* **18(6),** 501-507.

Helsen, W.F., van, W.J. and Williams, A.M. (2005) The relative age effect in youth soccer across Europe. *Journal of Sports Sciences* **23(6),** 629-636.

Knechtle, B., Assadi, H., Lepers, R., Rosemann, T. and Rust, C.A. (2014) Relationship between age and elite marathon race time in world single age records from 5 to 93 years. *BMC Sports Science, Medicine and Rehabilitation* **6,** 31.

Lara, B., Salinero, J.J. and Del, C.J. (2014) The relationship between age and running time in elite marathoners is U-shaped. *Age* **36(2),** 1003-1008.

Leyk, D., Erley, O., Gorges, W., Ridder, D., Ruther, T., Wunderlich, M., Sievert, A., Essfeld, D., Piekarski, C., Erren, T. (2009) Performance, training and lifestyle parameters of marathon runners aged 20-80 years: results of the PACE-study. *International Journal of Sports Medicine* **30(5),** 360-365.

Medic, N., Starkes, J.L. and Young, B.W. (2007) Examining relative age effects on performance achievement and participation rates in Masters athletes. *Journal of Sports Science* **25(12),** 1377-1384.

Medic, N., Young, B.W. and Grove, J.R. (2013) Perceptions of five-year competitive categories: model of how relative age influences competitiveness in masters sport. *Journal of Sports Science and Medicine* **12(4),** 724-729.

Medic, N., Young, B.W., Starkes, J.L., Weir, P.L. and Grove, J.R. (2009) Gender, age, and sport differences in relative age effects among US Masters swimming and track and field athletes. *Journal of Sports Sciences* **27(14),** 1535-1544.

Mikulic, P. (2011) Maturation to elite status: a six-year physiological case study of a world champion rowing crew. *European Journal of Applied Physiology* **111(9),** 2363-2368.

New York Marathon. (2013) New York City Marathon Results. Available from URL: http://www.tcsnycmarathon.org/about-

the-race/results (Retrieved 3 September, 2014)
Reaburn, P. and Dascombe, B. (2008) Endurance performance in masters athletes. *European Review of Aging and Physical Activity* **5,** 31-42.
Rust, C.A., Knechtle, B., Knechtle, P., Rosemann, T. and Lepers, R. (2012) Age of peak performance in elite male and female Ironman triathletes competing in Ironman Switzerland, a qualifier for the Ironman world championship, Ironman Hawaii, from 1995 to 2011. *Open Access Journal of Sports Medicine* **3,** 175-182.
Schulz, R. and Curnow, C. (1988) Peak performance and age among superathletes: track and field, swimming, baseball, tennis, and golf. *Journal of Gerontology* **43(5),** P113-120.
Tanaka, H. and Seals, D.R. (2008) Endurance exercise performance in Masters athletes: age-associated changes and underlying physiological mechanisms. *The Journal of Physiology* **586(1),** 55-63.
Tweedy, S.M., Beckman, E.M. and Connick, M.J. (2014) Paralympic classification: conceptual basis, current methods, and research update. *PM R* **6(8 Suppl),** S11-17.
Tweedy, S.M. and Vanlandewijck, Y.C. (2011) International Paralympic Committee position stand--background and scientific principles of classification in Paralympic sport. *British Journal of Sports Medicine* **45(4),** 259-269.
Vallerand, R.J. and Rousseau, F.L. (2001) Intrinsic and extrinsic motivation in sport and exercise. In: *Handbook of Sport Psychology*. Eds: R.N. Singer, H.A. Hausenblaus and C.M. Janelle. 2nd edition. New York: John Wiley & Sons, Inc.
Wang, E., Naess, M.S., Hoff, J., Albert, T.L., Pham, Q., Richardson, R.S. and Helgerud, J. (2014) Exercise-training-induced changes in metabolic capacity with age: the role of central cardiovascular plasticity. *Age* **36(2),** 665-676.

Key points

- Results showed a curvilinear relationship between age and marathon running performance with the negative effect of age becoming more pronounced in older runners.
- Relative age effects were found in all age groups over age 50 years in males and over age 40 years in females indicating that the relatively older runners were competitively disadvantaged compared to the relatively younger runners in these age groups.
- Relative age affected the 20-24 age classification which is consistent with the hypothesis that marathon performance improves until peak performance occurs in the 25-29 age classification.

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