The Interaction of Aging and 10 Years of Racing on Ultraendurance Running Performance

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The aim of this study was to examine the interaction between aging and 10 years of racing in endurance runners. Race-time data from 194 runners who had completed 10 consecutive 56-km ultramarathons were obtained. The runners were either 20.5 ± 0.7, 30.0 ± 1.0, 39.9 ± 0.9, or 49.4 ± 1.0 years old at their first race. Each runner’s race speed was determined for each race over the 10 years. Data were analyzed using repeated-measures ANOVA, one-way ANOVA, and independent t tests and showed that performance improved and declined at greater rates for younger runners; younger runners had a greater capacity for improvement than older runners; ≈4 years were required to reach peak racing speed, regardless of age; it was not possible to compete at peak speed for more than a few years; and the combined effects of 10 years of aging and racing neither improve nor worsen net performance. In conclusion, these data suggest that although these runners showed similar patterns of change in race speed over a 10-year period, the extent of change in performance was greater in younger than in older runners.

Key Words: ultramarathon, speed, age groups, longitudinal

Chronological aging is characterized by a functional decline in the major biological systems including the cardiovascular (Pugh & Wei, 2001), metabolic (Wilson & Morley, 2004), respiratory (Guenard & Rouatbi, 2002), and neuromuscular systems (Delbono, 2003). These changes manifest as a reduced functional capacity during activities of daily living and exercise. More specifically, the age-related alterations to physical capacity can be, at least partially, attributed to the observed changes in skeletal-muscle strength (Lynch et al., 1999), morphology (Mattiello-Sverzut, Chimelli, de Assis Moura, Teixeira, & de Oliveira, 2003), metabolism (Coggan et al., 1992a; Russ & Kent-Braun, 2004), and changes in the neuromuscular system (Laidlaw, Bilodeau, & Enoka, 2000; Thompson, 1994).

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In contrast to the decline in physical capacity associated with chronological aging, regular physical activity effects many favorable adaptations to these biological systems. For example, it is widely accepted that regular moderate-intensity exercise improves one’s risk profile for chronic lifestyle diseases (Topp, Fahlman, & Boardley, 2004). Furthermore, regular endurance training not only improves exercise capacity (Hawkins, Wiswell, & Marcell, 2003) but also delays the age-associated decline in skeletal-muscle strength (Tarpenning, Hamilton-Wessler, Wiswell, & Hawkins, 2004) and the development of disabilities in older individuals (Wang, Ramey, Schettler, Hubert, & Fries, 2002). Older sedentary people adapt to endurance training similarly to their younger counterparts (Coggan et al., 1992b; Cox, Cortright, Dohm, & Houmard, 1999), suggesting that regular exercise training delays the functional decline associated with the aging process.

The interactive effect of the two seemingly antagonistic stimuli of chronological aging and endurance training on performance is less well documented. Age-group records, which reflect the best possible performance by an individual in a certain age category, clearly show that an age-associated decline in performance is inevitable. The U.S. age-group records for the standard marathon show that the performance of male athletes declines steadily by approximately 6–9% each decade between the ages of 30 and 70 years, after which the deterioration in performance is greater (Joyner, 1993). The decline in physical capacity with age (Pimentel, Gentile, Tanaka, Seals, & Gates, 2003) can be attributed to both the aging process and a decrease in training and racing volume (Katzel, Sorkin, & Fleg, 2001). These cross-sectional data should be interpreted with caution (Masoro, 2001), because they cannot account for individual variability in changes in aging and performance and they do not take into account any cumulative effects of ultraendurance training and racing.

The analysis of longitudinal data allows changes in performance to be associated with the combined effects of chronological aging and cumulative endurance training. A longitudinal case study showed that the performance of a competitive masters runner changed from a 40-min 10-km time at the age of 30 years to a time of 61 min 59 s at the age of 64 (Lambert et al., 2002). This equates to a 50% decline in performance over a 34-year period, which is 20% more than that predicted by the cross-sectional age-group-records model. This suggests that cross-sectional data on the decline in performance with chronological aging underpredict these changes. Alternatively, this decline in performance is not linear. Longitudinal studies of larger groups of masters distance runners show that masters athletes have better maximum oxygen uptake, maximum heart rate, and minute ventilation than do their sedentary peers at any given age (Katzel et al., 2001; Pollock et al., 1997). These studies measured physiological markers of performance, however, as opposed to actual performance. Therefore, the aim of this study was to examine the interaction between chronological aging and the cumulative effects of ultraendurance racing by analyzing the longitudinal changes in running performance during a 56-km ultramarathon race over 10 successive years for runners in four age groups (20-, 30-, 40-, and 50-year-olds).
Methods

DATABASE

The data used for this study were obtained from the Two Oceans 56-km Ultra-Marathon database. This electronic database, maintained by the information-technology-services company Advanced Software Technologies (www.ast.co.za) is available in the public domain (www.twooceansmarathon.org.za). The database contains data for each person ($N = 49,750$) who has competed in the Two Oceans Ultra-Marathon since 1970. Specifically, these data describe each runner’s date of birth, gender, race times, and the year in which each race was completed.

DATA GROUPING

The study group consisted of male and female runners who had completed 10 Two Oceans Ultra-Marathons. To ensure that this group was large enough for sufficient statistical power, runners who had also completed 9 or 11 races were included. Specifically, only the data for runners who had completed 10 or 11 consecutive races, 10 races over 11 or 12 years, or 9 races over 10 or 11 years were selected from the original database. To identify these runners from the database, data were sorted initially by name, then date of birth, and finally by the year of race. Data for runners who did not fall into one of these three categories were excluded from further analysis.

The age of a runner on the day of a race was determined for each race by subtracting the runner’s year of birth from the year of the race. The runners were then grouped according to the age at which they completed their first race. Those who finished their first race at the age of 19, 20, or 21 were included in the 20-year-old age group. Similarly, the 30-, 40-, and 50-year-old age groups contained runners who ran their first race at 29, 30, or 31; 39, 40, or 41; and 49, 50, or 51 years of age, respectively. Data for runners who did not fall into one of these four age groups were also excluded from further analysis. The number of runners in each group is shown in Table 1.

RACE-SPEED ANALYSIS

The original database reported race time as hours:minutes:seconds. This was converted to minutes and used to calculate the race speed (km/hr) for each race of each runner. The mean race speed of Races 1–11 was determined for each age group and plotted against race number. The mathematical relationship between mean race speed and race number was described best by a third-order polynomial function, $y = ax^3 + bx^2 + cx + d$, where $y$ is mean race speed (km/hr) and $x$ is race number. The standard deviation and coefficient of variation for each mean race speed of each runner were determined. Finally, changes in race speed from the first to the last race, from the first to the fastest, and from the fastest to the last race were calculated for each age group.
STATISTICAL ANALYSIS

An analysis of variance (ANOVA) with repeated measures was used to determine differences in race speed between age group and race number. A one-way ANOVA was used to examine differences in change in race speed between the groups. Tukey’s HSD post hoc test was used when the group $F$ value for paired data was significant, and Fisher’s LSD post hoc test was used for unpaired data. An independent $t$ test was used to determine differences between first and last race speeds between groups. A Bonferroni adjustment was made to the $\alpha$ level to reduce the risk of a familywise error rate. Significance was accepted at $p < .05$ or $p < .025$ (Bonferroni adjustment). Statistical analysis was performed using STATISTICA (a data-analysis software system), version 6.1 (StatSoft®, Inc., Tulsa, OK).

Results

Race-speed data were obtained for all male and female runners who had run 9, 10, or 11 races in the Two Oceans 56-km Ultra-Marathon over a period of 9–12 years. Four age groups of runners were analyzed in which the runners completed their first race at the age of either 20.5 ± 0.7 years ($n = 20$, of which 19 were men), 30.0 ± 1.0 years ($n = 62$, of which 57 were men), 39.9 ± 0.9 years ($n = 97$, of which 86 were men), or 49.4 ± 1.0 years ($n = 15$, of which 14 were men). The number of runners in each group and their average ages are summarized in Table 1.

The mean race speed of the first race was significantly slower than the mean race speed of the fastest race ($p < .001$ for the 20-, 30-, and 40-year-olds; $p < .05$ for the 50-year-olds) for all four age groups, as shown in Table 2. The mean race speed of the fastest race was significantly faster than that of the last race ($p < .001$) for all four age groups. Therefore the performance of each group improved and declined significantly over the 10-year period.

The mean race speeds of the first race were not significantly different among the four age groups (Table 2). The same was true for the last race, but the mean
Table 2  Race-Speed (km/hr) Data of the First, Fastest, and Last Races for Each Age Group, $M \pm SD$

<table>
<thead>
<tr>
<th>Age group</th>
<th>Mean race speed (km/hr)</th>
<th>Time to fastest race (years)</th>
<th>Change from first to last race (%)</th>
<th>Change from first to fastest race (%)</th>
<th>Change from fastest to last race (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20s</td>
<td>First race(^a) 11.13 ± 1.19</td>
<td>4.1 ± 2.0</td>
<td>-3 ± 14</td>
<td>15 ± 10(^{d,e,f})</td>
<td>-18 ± 10(^{i,j,k})</td>
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<tr>
<td></td>
<td>Fastest race(^a,b) 12.79 ± 1.22(^c)</td>
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<td></td>
<td>Last(^b) 10.75 ± 1.66</td>
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<tr>
<td>30s</td>
<td>First race(^a) 11.02 ± 1.27</td>
<td>4.4 ± 2.1</td>
<td>-2 ± 12</td>
<td>11 ± 10(^{d,e,h})</td>
<td>-14 ± 9(^i)</td>
</tr>
<tr>
<td></td>
<td>Fastest race(^a) 12.23 ± 1.41</td>
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<tr>
<td></td>
<td>Last(^b) 10.75 ± 1.60</td>
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<tr>
<td>40s</td>
<td>First race(^a) 10.81 ± 1.05</td>
<td>3.7 ± 2.1</td>
<td>-5 ± 8</td>
<td>9 ± 7(^{e,g})</td>
<td>-14 ± 6(^i)</td>
</tr>
<tr>
<td></td>
<td>Fastest race(^a) 11.72 ± 1.14</td>
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<tr>
<td></td>
<td>Last(^b) 10.21 ± 1.11</td>
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<tr>
<td>50s</td>
<td>First race(^a) 10.32 ± 0.65</td>
<td>4.1 ± 2.2</td>
<td>-6 ± 7</td>
<td>7 ± 6(^{i,h})</td>
<td>-13 ± 7(^k)</td>
</tr>
<tr>
<td></td>
<td>Fastest race(^a) 11.01 ± 0.98(^e)</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Last(^b) 9.67 ± 0.73</td>
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</tbody>
</table>

\(^a\)p < .001; the first versus the fastest race of the 20-, 30-, and 40-year-old age groups. \(^b\)p < .05; the first versus the fastest race of the 50-year-old age group. \(^c\)p < .001. The fastest versus the last race of the 20, 30, 40 and 50-year-old age groups. \(^d\)p < .05. The fastest race of the 20 versus 50-year-old age groups. \(^e\)p < .05. The change from the first to the fastest race of the 20 versus 40-year-old age groups. \(^f\)p < .001. The change from the first to the fastest race of the 20 versus 50-year-old age groups. \(^g\)p < .05. The change from the first to the fastest race of the 30 versus 40-year-old age groups. \(^h\)p < .05. The change from the first to the fastest race of the 30 versus 50-year-old age groups. \(^i\)p < .05. The change from the fastest to the last race of the 20 versus 30-year-old age groups. \(^j\)p < .05. The change from the fastest to the last race of the 20 versus 40-year-old age groups. \(^k\)p < .05. The change from the fastest to the last race of the 20 versus 50-year-old age groups.
Race speed of the fastest race for the 20-year-old age group was significantly faster than that of the 50-year-old age group ($p < .05$). There was no difference among the fastest mean race speeds of the 30-, 40-, and 50-year-old age groups. The fastest mean race times for the 20-, 30-, 40-, and 50-year-old age groups occurred after $4.1 \pm 2.0$, $4.4 \pm 2.1$, $3.7 \pm 2.1$, and $4.1 \pm 2.2$ years of racing, respectively, and this time taken to reach peak racing speed was not significantly different among the four groups.

Also shown in Table 2 are the changes in mean race speed from the first to the last race, from the first to the fastest race, and from the fastest to the last race for each of the four age groups. The changes in race speed between the first and the last race were not different among groups. In contrast, the $15\% \pm 10\%$ increase in mean race speed from the first to the fastest race of the 20-year-old age group was significantly greater than both the $9\% \pm 7\%$ ($p < .05$) and the $7\% \pm 6\%$ ($p < .05$) increases in mean race speed that occurred in the 40- and 50-year-old age groups, respectively. The 30-year-old age group also showed a greater improvement in mean race speed ($11\% \pm 10\%$) between the first and the fastest race than did the 40-year-old ($p < .05$) and 50-year-old ($p < .05$) age groups. This suggests that the 20- and 30-year-old age groups had a greater capacity to improve their 56-km race performance than did the runners who started at the ages of 40 and 50 years.

With respect to the change in mean race speed from the fastest to the last race, the 20-year-old age group decreased speed by $18\% \pm 10\%$, which was significantly greater than the $14\% \pm 9\%$ ($p < .05$) decrease of the 30-year-old age group, the $14\% \pm 6\%$ ($p < .05$) decrease of the 40-year-old age group, and the $13\% \pm 7\%$ ($p < .05$) decrease of the 50-year-old age group. The decreases in speed from the fastest to the last race were not different among the 30-, 40-, and 50-year-old age groups. Thus, the younger runners had a greater decline in performance once they had reached their peak than the older runners did.

Figure 1 illustrates the line of best fit for mean race speed and race number for each age group (20-, 30-, 40-, and 50-year-olds). The variance around each curve is not plotted, but it can be estimated from the standard deviation of the mean race speed for each age group. The $SD$ for the 20-year-old age group ranges from 1.19 to 1.85 km/hr. The 30-, 40-, and 50-year-old age groups had ranges in $SD$ from 1.27 to 1.55 km/hr, 1.05 to 1.25 km/hr, and 0.65 to 1.05 km/hr, respectively.

Repeated-measures analysis of variance (ANOVA) was used to determine the interaction among the four groups and the first, fastest, and last races. In the first- versus last-race analysis, there were significant main effects for group (20-, 30-, 40-, and 50-year-olds, $p < .05$) and race number (first and last race, $p < .001$), but there was no interaction between group and race number. This implies that the change in mean race speed from the first to the last race was not different among the four age groups.

When the first- versus the fastest-race data were analyzed, there was also a significant main effect for both group ($p < .05$) and race number (first and fastest race, $p < .001$). In addition, there was an interaction between group and race
number \((p < .001)\), which suggests that the groups differed in the extent to which they improved race speed between the first and fastest races.

Finally, the differences between the fastest last races were analyzed, and significant main effects for group \((p < .001)\) and race number (fastest and last race; \(p < .001\)) were found. There was also an interaction between group and race number \((p < .05)\), indicating that the decline in mean race speed from the fastest to the last race was different among the four age groups.

One-way ANOVA was used to determine differences between the last race of one age group and the first race of the subsequent age group to examine the effects of 10 years of racing on performance. The mean race speed of the last race of the 20-year-old age group \((10.75 \pm 1.66 \text{ km/hr})\), for which this group of runners would have been 29 years old, was not significantly different than the mean race speed of the first race of the 30-year-old age group \((11.02 \pm 1.05 \text{ km/hr}; \text{Figure 2})\). Similarly, the last race of the 30-year-old age group \((10.75 \pm 1.60 \text{ km/hr})\), representing 39-year-old runners, was not significantly different from the first race of the 40-year-old age group \((10.81 \pm 1.05 \text{ km/hr})\). Finally, the mean race speed of last race of the 40-year-old age group \((10.21 \pm 1.11 \text{ km/hr})\), when the runners would have been 49 years old, was not significantly different from that of the first race of 50-year-old age group \((10.32 \pm 0.65 \text{ km/hr})\).

**Discussion**

The aim of this study was to examine the interaction between chronological aging and the cumulative effects of ultraendurance racing by analyzing the changes in
Figure 2. The smoothed mean race speed of the 10 successive races completed by each of the four age groups plotted along a continuum of age from 20 to 59 years.
running performance in a 56-km ultramarathon race over 10 successive years for runners in four age groups (20-, 30-, 40-, and 50-year-olds). Running performance, defined as mean race speed, was determined for each of the 10 races completed by runners in the 20-, 30-, 40-, and 50-year-old age groups, and the longitudinal data were examined for differences among the groups with respect to change in race speed over the 10-year period.

The first important finding relates to the pattern of change in performance in this 56-km race over 10 years for each of the four age groups (Figure 1). Although all four age groups ran their first race at a similar speed and improved their performances significantly from the first to the fastest race, the extent of this improvement was greater in the younger runners (20-year-old age group) than in the older runners (50-year-old age group).

Collectively, these data suggest that runners who complete their first Two Oceans Ultra-Marathon at a younger age have a greater capacity to improve their 56-km ultraendurance running performance than do those who first competed in the race later on in life. It is well established that endurance training induces adaptations in various biological systems that result in an improvement in physical capacity in both young and older sedentary individuals (Coggan et al., 1992b; Kohrt et al., 1991; Sial, Coggan, Hickner, & Klein, 1998). In addition, the extent of adaptation in older people and younger people has been shown to be similar (Coggan et al., 1992b). These adaptations, however, have only been related to changes in physiological measures associated with physical capacity, such as maximum oxygen uptake, maximum heart rate, and minute ventilation, and not to actual performance such as race time for an ultraendurance event. The data from this study demonstrate that the younger runners (20- and 30-year-old age groups) had a greater capacity to improve their absolute and relative 56-km race time than did older runners (40- and 50-year-old age groups). This suggests that chronological age might be one of the factors that affect the extent to which an individual can improve ultraendurance performance in this particular 56-km race. Presumably, either younger runners simply have a greater capacity to adapt to training than do older runners or the younger runners in this study underwent training of a greater volume and/or intensity that in turn led to greater improvements in race time.

The second important finding was that each age group took approximately 4 years to reach peak running speed for this ultraendurance race (Table 2). Assuming that the runners trained regularly and that they were always trying to achieve a personal-best time, it seems that regardless of the age at which the runners completed their first race, a period of about 4 years was required for the manifestation of adaptations associated with peak running performance during this ultraendurance event. It has been shown that after only 8 weeks of regular endurance training significant acute metabolic and respiratory changes in skeletal muscle, presumed to be positive adaptations to the training, have occurred (Henriksson & Reitman, 1977). Further adaptations needed to elicit optimal ultraendurance performance must therefore require a more chronic stimulus. One possible adaptation might be that of learned pacing strategies (Lambert, Dugas, Kirkman, Mokone, &
Waldeck, 2004). Alternatively, neuromuscular adaptations such as changes in preactivation and musculotendinous stiffness might contribute to this delayed adaptation.

Third, our data show that it was not possible for any of the age groups to compete at their fastest race speed for more than a few years (Figure 1). Instead, mean race speed decreased significantly for all four age groups between the fastest and the last race over a period of approximately 6 years, to a speed similar to that of the first race. In addition, the rate at which this decline occurred was different among the four age groups. It is interesting to note that despite the fact that the runners had the necessary adaptations to compete at their optimal capacity in a 56-km race, they were still unable to continue racing at this peak speed. One conclusion might be that chronological aging contributes to this decline in performance. Age-group race records show that there is an inevitable slowing of race speed (Joyner, 1993) with increasing age, which might be attributed to either aging or a decrease in training and racing volume. If chronological aging had been solely responsible for the performance decrement seen in the four age groups in this study, one would have expected the 50-year-old age group to have slowed down more than the younger groups. The data showed the opposite to be true, however: the 20-year-old age group had a significantly greater decrease in mean race speed between the fastest and the last race than did the 30-, 40-, and 50-year-old age groups. Given that the main difference between the 20- and 50-year-old age groups was that the younger group initially improved more and ran faster than the older group, it might be that race speed is an important factor contributing to the seemingly inevitable age-associated decline in 56-km ultraendurance performance over time when runners under the age of 60 years old are studied. Another possible explanation for the runners in this study being unable to maintain their peak race speed might be that although muscle can adapt to, and tolerate, a given volume and intensity of training over a number of years, there might be a threshold after which additional training stress leads to maladaptations in the muscle.

The fourth finding was that over the 10-year period the net change in mean race speed between the first and the last race was not different among the four age groups ($p > .05$) and that the mean race speed of the last race was not significantly slower than that of the first race for all four age groups. This suggests that the combined effects of 10 years of racing and 10 years of chronological aging neither improve nor worsen net performance during a 56-km ultraendurance race in individuals between the ages of 20 and 60 years. Despite a more limited ability to improve 56-km running performance, older runners do not face a greater decline in performance over 10 years of racing than do younger runners. This implies that between the ages of 20 and 60 years, runners are equally susceptible to any performance-limiting effects that might be imposed by an accumulation of training and racing distance over a 10-year period. One might argue that the older runners would be less likely to train at the same speeds and volumes as the younger runners and would therefore not be subjected to the same cumulative stress. A longitudinal study of older and younger runners following a training program of
the same absolute pace and volume and the same racing schedule over at least 10 years could answer this question.

Finally, the effect of 10 years of ultraendurance racing on performance during a 56-km race was examined by comparing the last race of each age group with the first race of the next-oldest age group. For example, the mean speed of the last race of the 30-year-old group, who would by then have been 39 years old, was compared with the mean speed of the first race of the 40-year-old age group. If competing in the Two Oceans Ultra-Marathon for 10 years has an adverse effect on a runner’s performance, one would expect to see a difference in performance between two similarly aged competitors, 1 of whom had completed 10 races, the other having run the 56-km race for the first time. The final finding of this study showed that there was no difference in mean race speed between the last race of one age group and the first race of the subsequent group (Figure 2). Therefore, despite 10 years of racing, runners between the ages of 20 and 50 years are still able to run this 56-km race at speeds similar to those of their age-matched peers who have only just begun racing. This suggests that 10 years of ultraendurance racing has no adverse effects on performance during a 56-km race. An alternative interpretation is that it appears that 10 years of training does not have any advantage over short-term training. The difficulty in making this comparison, however, is that the runners are presumably in different stages of adaptation. Those completing their first race might not yet have undergone all the training-induced adaptations associated with ultraendurance racing that allow them to reach their optimal performance level and are presumably still going to improve, whereas runners competing in their 10th race have passed their optimal performance point and are in the process of decline.

A limitation of this study is that we assumed that the runners in each age group were relatively inexperienced ultramarathon runners when they ran their first race. Although we are not able to check the validity of this assumption, we are confident that in most cases this would have been true. We know that the runners in this study had never run a 56-km race before, but we acknowledge that they might well have completed any number of marathon or half-marathon events. Because the data were analyzed as means, a few runners deviating from this assumption would not have had a significant impact on the trends and therefore the overall interpretation.

In summary, our data showed that for this 56-km ultraendurance running race, (a) performance improved and declined at greater rates for younger runners; (b) younger runners had a greater capacity to improve their performance than did older runners; (c) approximately 4 years of racing and training are required to reach peak racing speed, regardless of age; (d) it is not possible to compete at this peak racing speed for more than a few years; and (e) the combined effects of 10 years of chronological aging and 10 years of racing neither improve nor worsen net performance in runners between 20 and 60 years old. In conclusion, these data suggest that although all four age groups of runners in this study showed similar patterns of change in 56-km race speed over a 10-year period, the extent of change in performance was greater in the younger runners than in the older runners.
References


