The age of the best ultramarathon performance – the case of the "Comrades Marathon"

Knechtle, Beat ; Nikolaidis, Pantelis Theodoros

Abstract: The aim of the present study was to determine the age of the fastest running speed in 202,370 runners (34,090 women and 168,280 men) competing in the "Comrades Marathon" between 1994 and 2015 using non-linear regression analysis (second order polynomial function). When all runners were considered in 1-year age intervals, the fastest running speed (9.61 ± 1.65 km/h) was achieved at the age of 29.89 years in men, whereas women achieved it at the age of 35.96 years 8.60 ± 1.10 km/h. When the fastest runners were considered in 1-year intervals, the fastest running speed (16.65 km/h) was achieved in men at the age of 36.38 years. For the fastest women, the age of the fastest running speed (13.89 km/h) was 32.75 years. To summarize, for all runners, men achieved the best ultramarathon performance 6 years earlier than women. When the fastest runners were considered, however, men achieved the best performance 4 years later than women.

DOI: https://doi.org/10.1080/15438627.2017.1282357

The age of the best ultra-marathon performance – The case of the 'Comrades Marathon'

Short running title: Age of peak ultra-marathon performance

Beat Knechtle [1,2], Pantelis Theodoros Nikolaidis [3]

1 Gesundheitszentrum St. Gallen, St. Gallen, Switzerland

2 Institute of Primary Care, University of Zurich, Zurich, Switzerland

3 Department of Physical and Cultural Education, Hellenic Army Academy, Athens, Greece

*Corresponding author
Prof. Dr. med. Beat Knechtle
Facharzt FMH für Allgemeinmedizin
Gesundheitszentrum St. Gallen
Vadianstrasse 26
9001 St. Gallen
Switzerland
Telefon +41 (0) 71 226 93 00
Telefax +41 (0) 71 226 93 01
E-Mail: beat.knechtle@hispeed.ch

Abstract

The aim of the present study was to determine the age of the fastest running speed in 202,370 runners (34,090 women and 168,280 men) competing in the 'Comrades Marathon' between 1994 and 2015 using non-linear regression analysis (second order polynomial function). When all runners were considered in 1-year age intervals, the fastest running speed (9.61±1.65 km/h) was achieved at the age of 29.89 years in men, whereas women achieved it at the age of 35.96 years 8.60±1.10 km/h. When the fastest runners were considered in 1-year intervals, the fastest running speed (16.65 km/h) was achieved in men at the age of 36.38 years. For the fastest women, the age of the fastest running speed (13.89 km/h) was 32.75 years. To summarize, for all runners, men achieved the best ultra-marathon performance ~6 years earlier than women. When the fastest runners were considered, however, men achieved the best performance ~4 years later than women.

Key words: Comrades Marathon, South Africa, ultra-marathon, peak age, athlete, running

Introduction

Ultra-marathon running is a sport event of increasing popularity (Hoffman, 2010). In the last decades, the number of races and successful runners increased in an exponential manner (Cejka et al., 2014). Athletes intending to compete in an ultra-marathon prepare specifically for this competition (Knechtle, 2012) and most of the successful runners are older than ~35 years old (Hoffman, 2010; Knechtle, Valeri, Zingg, Rosemann, & Rüst, 2014).

Each athletic performance has its age of peak performance (Allen & Hopkins, 2015). Although the age of peak marathon performance is at ~30-35 years (Hunter, Stevens, Magennis, Skelton, & Fauth, 2011; Knechtle et al., 2014; Lara, Salinero, & Del Coso, 2014), ultra-marathoners achieve their best performances at an older age, i.e. older than ~35 years (Cejka, Knechtle, Rüst, Rosemann, & Lepers, 2015; Knechtle et al., 2014; Romer et al., 2014; Rüst, Knechtle, Rosemann, & Lepers, 2013). Regarding the sex, the age of peak performance was older in women than men in marathon (Hunter, Stevens, Magennis, Skelton, & Fauth, 2011), whereas it was similar in women and men ultra-marathon runners competing in 100 km (Cejka, Knechtle, Rüst, Rosemann, & Lepers, 2015) and 100 miles races (Rüst, Knechtle, Rosemann, & Lepers, 2013).

Nevertheless, there are differences in the age of peak performance for ultra-marathons of different distances. Recent studies showed that the age of peak ultra-marathon performance increased with increasing race distance (Knechtle et al., 2014; Romer, Rüst, Zingg, Rosemann, & Knechtle, 2014). Although the age of the best running performance in distance-limited ultra-marathon distances of 100 km (Cejka et al., 2015) and 100 miles (Rüst et al., 2013) is ~35 years, athletes competing in time-limited ultra-marathons such as 48 hours, 72 hours, 6 days and 10 days achieved their best performance at ~45-50 years (Knechtle et al., 2014).

The abovementioned studies used different samples of athletes (*i.e.* recreational athletes or elite athletes), where in some instances data of several races were combined (Romer et al., 2014; Rüst, Zingg, Rosemann, & Knechtle, 2014). Furthermore, these authors used different methods, such as analysis of variance, linear or non-linear regression analyses, to determine the age of peak running performance (Knechtle et al., 2014; Lara et al., 2014; Lehto, 2015). Recently, Lehto (2015) demonstrated that a second-order polynomial ($t = a + bx + cx^2$) modeled 99.7% of the variation in the average race time (t) as a function of age (x) in 312,342 male marathoners competing in 36 Stockholm Marathons held from 1979 to 2014.

To date, no study has determined the age of peak ultra-marathon performance using non-linear regression analysis. This analysis has the advantage to fit data with more complicated non-linear functions (Brown, 2001). Therefore, the aim of the present study was to determine the age of peak running speed in ultra-marathon performance using non-linear regression analysis with a second order polynomial function in one of the largest and oldest ultra-marathons held worldwide, the 'Comrades Marathon', covering a distance of 87-89 km depending upon the race edition. Based on respective findings on marathon and ultra-marathon runners, we hypothesized that the age of peak running performance in 'Comrades Marathon' would be (*i*) similar for women and men, and (*ii*) older than marathoners (*i.e.* age nearer to 35-40 years than to 30 years, respectively) due to the length of the race.

Methods

Ethics

All procedures in the study were approved by the Institutional Review Board of Kanton St. Gallen, Switzerland with a waiver of the requirement for informed consent of the participants as the study involved the analysis of publicly available data.

The Race

The 'Comrades Marathon' has been held since 1921 and is the ultra-marathon with the longest tradition worldwide and the highest number of participants (www.comrades.com). The organizer of the race is the Comrades Marathon Association (CMA). The race is held annually in the KwaZulu-Natal Province of South Africa between the cities of Durban and Pietermaritzburg. The direction of the race alternates each year between the 'up' run (87 km) starting from Durban and the 'down' run (89 km) starting from Pietermaritzburg. The time limit for the ~90 km route is 12:00 h:min. This race is a national sporting event broadcast in full on television. In the 'Comrades Marathon', any runner can compete; however, all entrants must comply with the 'Comrades Marathon' qualifying criteria (www.comrades.com/events/qualifying-races). The organizer requires, for example, the previous achievement of marathon race time of 5:00 h:min or a 100-km ultra-marathon race time of 13:30 h:min.

Data analysis and statistical analysis

Race times and ages of runners for the period 1994-2015 were retrieved from http://statistik.d-u-v.org and not the official website www.comrades.com, because the latest did not record the age of runners. Data before 1994 were not available on http://statistik.d-u-v.org. Since the 'Comrades Marathon' is held in two different directions each one with different distance, we calculated running speed (km/h) using race distance (km) and race time (h:min:sec) for each

edition. For each age group, we calculated the number of men and women, and determined the men-to-women ratio by dividing the number of men by the number of women. The trend of the men-to-women ratio across age groups was investigated using single linear regression analysis. To determine the age of peak running speed for women and men, we considered in a first analysis all women and men in 1-year age groups, whereas in a second analysis, we identified the fastest women and men for each 1-year age group interval. Since performance in marathon running follows a quadratic (second order polynomial) function (Lehto, 2015), we determined the non-linear regression model with a second order polynomial function ($y = a * x^2 + b * x + c$). The age of peak running speed and the corresponding running speed were determined by calculating the vertex of the quadratic function $p(x|y) = \left(-\frac{b}{2a}\middle|c - \frac{b^2}{4a}\right)$. Statistical analyses were performed using IBM SPSS Statistics (Version 22, IBM SPSS, Chicago, IL, USA) and GraphPad Prism (Version 6.01, GraphPad Software, La Jolla, CA, USA). Statistical significance was accepted at $P<0.05$.

Results

Between 1994 and 2015, data from 202,370 runners (34,090 women and 168,280) were complete with race time and age of each runner. These runners originated from 101 countries. Most of the runners originated from the Republic of South Africa (93.9%), followed by athletes from Great Britain (1.3%), Australia (0.8%), the United States of America (0.6%) and Zimbabwe (0.5%) (Table 1). In the 100 fastest women, 91 originated from South Africa and nine from other countries (*i.e.* four from Germany, and one from Australia, Bulgaria, Canada, Great Britain and New Zealand). In the 100 fastest men, most runners were from South Africa (52), and fewer from Russia (23), Zimbabwe (eight), Lesotho (six), Belarus (five), Spain (two), Poland (two), Sweden (one) and Switzerland (one).

Most of the runners were recorded in age group 35-39 years; most men were in this age group, but most women were in age group 40-44 years (Table 2). The men-to-women ratio was the highest in age group 18-24 years and the lowest in age group 40-44 years. The men-to-women ratio decreased across age groups (r^2=0.47, p=0.013). The mean age of all men and women was 40.19±8.96 and 40.07±7.85 years, respectively (Figure 1).

When all men and women were considered in 1-year age group intervals, men achieved the fastest running speed (9.61±1.65 km/h) at 29.89 years (Figure 2 upper panel). Women achieved the fastest running speed of 8.60±1.10 km/h at 35.96 years (Figure 2 lower panel). When the fastest men were considered in 1-year age group intervals, the fastest running speed (16.65 km/h) was achieved at 36.38 years (Figure 3 upper panel). For the fastest women in 1-year age group intervals, the age of the fastest running speed (13.89 km/h) was 32.75 years (Figure 3 lower panel).

Discussion

The purpose of this study was to determine the age of peak ultra-marathon running speed in one of the largest and oldest ultra-marathons held worldwide covering a distance of nearly 90 km with the hypothesis that the age of peak running performance would be the same for women and men and that this age would be near to ~35-40 years due to the length of the race. The most important findings were that (*i*) the fastest men were ~30 years, but the fastest women were at ~36 years, when all men and women were considered and (*ii*) when the fastest men and women were considered in 1-year intervals, peak running speed was achieved at ~36 years and ~33 years, respectively.

Based upon findings for marathoners (Hunter et al., 2011) and ultra-marathoners competing in 100 km (Cejka et al., 2015) and 100 miles (Rüst et al., 2013), we expected to find in this 90-km ultra-marathon the same age of peak running speed for both women and men. However, when all women and all men were considered in 1-year intervals, the age of peak running speed was ~6 years younger in men than in women. A potential explanation could be the distribution of the recorded athletes in the different age groups, which differed between women and men. Although most runners were recorded in age group 35-39 years, relatively more men were in age group 35-39 years, but more women were in age group 40-44 years. The men-to-women ratio was 5.2 in age group 35-39 years, but 3.0 in age group 40-44 years.

An interesting finding was that the age of peak running speed was younger in men compared to women (*i.e.* ~30 years versus ~36 years) when all runners were considered in 1-year intervals, but older in men compared to women (*i.e.* ~36 years versus ~33 years) when the fastest runners were considered. A potential explanation for the discrepancy between the fastest and all runners could be the nationality. It has been shown that East-African runners dominate marathon running (Onywera, Scott, Boit, & Pitsiladis, 2006; Scott et al., 2003), but runners from Japan were the fastest in 100-km ultra-marathon races (Cejka et al., 2014).

Among the 100 fastest runners in the 'Comrades Marathon' between 1994 and 2015, there were 91 men but only 52 women from South Africa. Future studies might analyse the influence of nationality in this ultra-marathon. It has been shown for other events and disciplines such as the 'Norseman Xtreme Triathlon' (Rüst, Bragazzi, Signori, Stiefel, Rosemann, & Knechtle, 2015), the 'Ironman Hawaii' (Dähler, Rüst, Rosemann, Lepers, & Knechtle, 2014), the 'Marathon des Sables' (Knoth, Knechtle, Rüst, Rosemann, & Lepers, 2012), and the 'English Channel Swim' (Knechtle, Rosemann, & Rüst, 2014b) that local athletes preferably compete and are among the fastest.

A further explanation could be the kind of data analysis. Lehto (2015) used a non-linear regression analysis, whereas others used an analysis of variance (Lara et al. 2014) or a linear regression analysis (Rüst et al. 2013). Furthermore, Lehto (2015) used all male runners in his analysis, whereas Lara *et al.* (2014) analysed finishing times of the top ten men and top ten women between 18 and 75 years in men and between 15 and 70 years in women for the New York City marathon held in 2010 and 2011. In the studies of the fastest 100 km (Cejka et al. 2014) and the fastest 100 miles ultra-marathoners (Rüst et al. 2013), only the annual top ten were considered. A limitation to top athletes might lead to different results.

In details, Hunter *et al.* (2011) investigated the age and race time of the five fastest women and men who competed in the seven marathons of the World Marathon Majors Series. In their study, the age of the runners was investigated using analysis of variance across the races Berlin marathon (1999–2009), Boston marathon (2000–2009), Chicago marathon (1997–2009), London marathon (2001–2009), New York City marathon (1990–2009), International Athletic Association Federation World Championship in marathon (1983, 1987, and every two years from 1991), and Olympic (every four years since 1984) marathons. Lara, Salinero and Del Coso (2014) analyzed running times of the top ten men and women at 1-year intervals (from 18 to 75 years) in the 'New York City Marathon' for the 2010 and 2011 races

using a non-linear quadratic regression for the relationship between running times and age. In contrast, Lehto (2015) analyzed age and finishing times using a second-order polynomial regression for a total of 312,342 male runners competing in 36 Stockholm Marathons held between 1979 and 2014. For the age of the best performance in 100 km (Cejka et al. 2015) and 100 miles (Rüst et al. 2013), the trend of the annual fastest and annual ten fastest women and men was investigated using linear regression analyses.

This literature review shows that the different results of the age of peak marathon and ultra-marathon performance are most likely due to differences in the considered samples (*i.e.* elite versus recreational), the number of considered athletes (*i.e.* top, top five, top ten versus the whole field) and the kind of the analysis (*i.e.* analysis of variance across races, linear regression analysis across time or non-linear regression analysis). A non-linear (*i.e.* polynomial) regression across several race editions and including as many runners as possible is most probably the best method to determine the age of peak ultra-marathon performance. It has been shown that the age of the ten fastest 100 km ultra-marathoners remained unchanged across all races held between 1960 and 2012 (Cejka et al. 2015).

A review of the existing literature suggested that aerobic capacity peaks at the third decade of life and then a loss of five to ten percent every decade occurs (Hawkins, 2010). On the other hand, it has been highlighted that athletes can counterbalance this loss during their fourth decade with exercise training (Navazio & Testa, 2007). This might explain the variation of sex differences in age of peak performance depending on the number of runners under consideration (*i.e.* all *versus* the best runners). When all runners are taken into account, the peak of performance would be expected at an age closed to the age of peak aerobic capacity. However, when the fastest runners were considered, their performance could peak even at an older age of the peak of aerobic capacity due to effect of training, since the elite runners were considered to practice more hours per week (Billat, Demarle, Slawinski, Paiva, & Koralsztein,

2001). Although aerobic capacity (expressed as maximal oxygen uptake) is an important determinant of endurance performance, other physiological parameters, such as anaerobic threshold and running economy, might also influence performance (Tanaka & Seals, 2008). Although, we found a difference in the age of peak running speed when all women and men were investigated compared to the fastest women and men, Lehto (2015) found a similar age of ~34 years when investigating 312,342 male recreational marathoners competing in the Stockholm Marathon between 1979 and 2014. Potential explanations for the disparate findings could be that we investigated ultra-marathoners (*i.e.* 90 km compared to 42.195 km), a shorter time frame (*i.e.* 22 years compared to 36 years) and a lower number of athletes (*i.e.* 168,280 men compared to 312,342 men) compared to Lehto (2015). Furthermore, we analysed both women and men. We found that the fastest men (~36 years) achieved their peak running speed at an older age compared to women (~33 years). A potential explanation could be anthropometric characteristics responsible for a fast ultra-marathon performance. It has been shown that low body fat, not skeletal muscle mass, is related to running performance in half-marathon, marathon and 100 km ultra-marathon performance (Knechtle et al., 2012a).

A further explanation could be previous experience. A study investigating time-limited ultra-marathons held from 6 hours to 10 days during 1975-2013 including 20,238 female and 76,888 male finishes showed that the athletes improved performance with increasing number of finishes and the age of peak ultra-marathon performance increased with increasing number of finishes (Knechtle, Valeri, Zingg, Rosemann, & Rüst, 2014a). For ultra-marathoners competing in distance-limited races such as a 100-km ultra-marathon (Knechtle, Wirth, Knechtle, & Rosemann, 2010; Knechtle, Knechtle, Rosemann, & Senn, 2011a) and in time-limited races such as 24-hours ultra-marathon (Knechtle, Wirth, Knechtle, Zimmermann, & Kohler, 2009; Knechtle, Knechtle, Rosemann, & Lepers, 2011b), personal best marathon time seemed to be a very important predictor variable.

To interpret the different age of peak running performance in ultra-marathon between women and men, we should consider age-related changes not only of maximal oxygen uptake, but also of other correlates of performance in ultra-marathon such as body mass and body composition (Reaburn & Dascombe, 2008). For instance, runners were continuously lighter with distance increments from 100 m to marathon (Sedeaud et al., 2014). Moreover, an increased fat-free mass and decreased fat mass would result in a reduction of the energy cost of motion (Ghiani et al., 2015), which is a factor of endurance (Tanaka & Seals, 2008). It has been highlighted that both sexes peaked their performance close to ~35 years, after which endurance performance was expected to decrease moderately till 50-60 years (Tanaka & Seals, 2008). On the other hand, it has been suggested that active muscle mass decreased after ~35 years, which might contribute to lower endurance (Reaburn & Dascombe, 2008). Moreover, the sex differences of age of peak performance should be considered with regards to whether both sexes have equally reached the limits of performance. It has been suggested that humans have reached their limits of endurance and these could be overcome only with the help of sports technology (Berthelot et al., 2015; Desgorces et al., 2012). The older age of peak performance in women might denote that, compared to men, they have reached the limits of their performance in a lower extent.

Limitations and implications for future research

A limitation of this study is the fact that environmental conditions, such as temperature, were not included. A study investigating the influence on ambient temperature in 161-km ultra-marathon performance showed that race times were less affected by warm weather for women than for men (Wegelin & Hoffman, 2011). A further limitation is that we did not consider previous experience in this race since performance in an ultra-endurance race has been shown to be an important predictor for future participations in the same race (Knechtle, Knechtle, Rüst, Rosemann, & Lepers, 2012b). A further limitation was that we did not perform a

separate analysis for the nationality and performance in this race since it has been shown that nationality in ultra-marathon running (*i.e.* 100-km ultra-marathon races) is of importance (Cejka, Rüst, Lepers, Onywera, Rosemann, & Knechtle, 2014). Future studies might consider the aspect of nationality in the 'Comrades Marathon'.

Practical applications

Coaches and athletes should be aware that women and men achieved their best performance in ultra-marathon running in the 'Comrades Marathon' at a different age. Most important, the fastest men achieve their best performance at a higher age compared to the fastest women whereas overall seen, men were faster at a younger age compared to women. Knowledge about the age-related trends of performance and their variation by sex might help coaches and athletes to design and implement individualized training programs for female and male ultra-marathoners intending to compete in the 'Comrades Marathon'.

Conclusions

In summary, when all runners were considered, men achieved the best ultra-marathon performance at a younger age than women (~30 years *versus* ~36 years, respectively). However, when only the fastest runners were examined, women achieved the best performance earlier than men (~33 years *versus* ~36 years, respectively). Future studies might compare linear and non-linear regression analyses to find the most appropriate method to determine the age of the fastest ultra-marathon performance.

References

Allen, S. V., & Hopkins, W. G. (2015). Age of peak competitive performance of elite athletes: A systematic review. *Sports Medicine, 45*(10), 1431-241. doi: 10.1007/s40279-015-0354-3.

Berthelot, G., Sedeaud, A., Marck, A., Antero-Jacquemin, J., Schipman, J., Saulière, G., Marc A, Desgorces, F. D., &Toussaint, J. F. (2015). Has athletic performance reached its peak? *Sports Medicine, 45*(9), 1263-1271. doi: 10.1007/s40279-015-0347-2

Billat, V. L., Demarle, A., Slawinski, J., Paiva, M., & Koralsztein, J. P. (2001). Physical and training characteristics of top-class marathon runners. *Medicine and Science in Sports and Exercise, 33*(12), 2089-2097

Brown, A.M. (2001). A step-by-step guide to non-linear regression analysis of experimental data using a Microsoft Excel spreadsheet. *Computer Methods and Programs in Biomedicine, 65*, 191-200

Cejka, N., Knechtle, B., Rüst, C. A., Rosemann, T., & Lepers, R. (2015). Performance and age of the fastest female and male 100-km ultramarathoners worldwide from 1960 to 2012. *Journal of Strength and Conditioning Research, 29*(5), 1180-1190. doi: 10.1519/JSC.0000000000000370

Cejka, N., Rüst, C. A., Lepers, R., Onywera, V., Rosemann, T., & Knechtle, B. (2014). Participation and performance trends in 100-km ultra-marathons worldwide. *Journal of Sports Sciences, 32*(4), 354-366. doi: 10.1080/02640414.2013.825729

Dähler, P., Rüst, C.A., Rosemann, T., Lepers, R., & Knechtle, B. (2014). Nation related participation and performance trends in 'Ironman Hawaii' from 1985 to 2012. *BMC Sports Science, Medicine and Rehabilitation, 6,*16.

Desgorces, F. D., Berthelot, G., Charmantier, A., Tafflet, M., Schaal, K., Jarne, P., & Toussaint, J. F. (2012). Similar slow down in running speed progression in species under human pressure. *Journal of Evolutionary Biology, 25*(9), 1792-1799. doi: 10.1111/j.1420-9101.2012.02563.x

Ghiani, G., Marongiu, E., Melis, F., Angioni, G., Sanna, I., Loi, A., Pusceddu, M., Pinna, V., Crisafulli, A., &Tocco, F. (2015). Body composition changes affect energy cost of running during 12 months of specific diet and training in amateur athletes. *Applied Physiology, Nutrition and Metabolism, 40*(9), 938-944. doi: 10.1139/apnm-2015-0023

Hawkins, S. A. (2010). The effects of aging and sustained exercise involvement on cardiovascular function in older persons. In J. Baker, S. Horton & P. Weir (Eds.), *The masters athlete, understanding the role of sport and exercise in optimizing aging*. Oxon, UK: Routledge.

Hoffman, M. D. (2010). Performance trends in 161-km ultramarathons. *International Journal of Sports Medicine, 31*(1), 31-37. doi: 10.1055/s-0029-1239561

Hunter, S. K., Stevens, A. A., Magennis, K., Skelton, K. W., & Fauth, M. (2011). Is there a sex difference in the age of elite marathon runners? *Medicine and Science in Sports and Exercise, 43*(4), 656-664. doi: 10.1249/MSS.0b013e3181fb4e00

Knechtle, B., Wirth, A., Knechtle, P., Zimmermann, K., & Kohler, G. (2009). Personal best marathon performance is associated with performance in a 24-h run and not anthropometry or training volume. *British Journal of Sports Medicine, 43,* 836-839.

Knechtle, B., Wirth, A., Knechtle, P., & Rosemann, T. (2010). Training volume and personal best time in marathon, not anthropometric parameters, are associated with performance in male 100-km ultrarunners. *Journal of Strength and Conditioning Research, 24,* 604-609.

Knechtle, B., Knechtle, P., Rosemann, T., & Senn, O. (2011a). What is associated with race performance in male 100-km ultra-marathoners--anthropometry, training or marathon best time? *Journal of Sports Sciences, 29,* 571-577.

Knechtle, B., Knechtle, P., Rosemann, T., & Lepers, R. (2011b). Personal best marathon time and longest training run, not anthropometry, predict performance in recreational 24-hour ultrarunners. *Journal of Strength and Conditioning Research, 25,* 2212-2218.

Knechtle, B. (2012). Ultramarathon runners: Nature or nurture? *International Journal of Sports Physiology and Performance, 7*(4), 310-312

Knechtle, B., Rüst, C. A., Knechtle, P., & Rosemann, T. (2012a). Does muscle mass affect running times in male long-distance master runners? *Asian Journal of Sports Medicine, 3*(4), 247-256

Knechtle, B., Knechtle, P., Rüst, C.A., Rosemann, T., & Lepers, R. (2012b). Age, training, and previous experience predict race performance in long-distance inline skaters, not anthropometry. *Perceptual and Motor Skills, 114*(1), 141-156

Knechtle, B., Valeri, F., Zingg, M. A., Rosemann, T., & Rüst, C. A. (2014a). What is the age for the fastest ultra-marathon performance in time-limited races from 6 h to 10 days? *Age, 36*(5). doi: 10.1007/s11357-014-9715-3

Knechtle, B., Rosemann, T., & Rüst, C.A. (2014b). Participation and performance trends by nationality in the 'English Channel Swim' from 1875 to 2013. *BMC Sports Science, Medicine and Rehabilitation, 6,* 34.

Knoth, C., Knechtle, B., Rüst, C.A., Rosemann, T., & Lepers, R. (2012). Participation and performance trends in multistage ultramarathons-the 'Marathon des Sables' 2003-2012. *Extreme Physiology & Medicine, 1,* 13.

Lara, B., Salinero, J. J., & Del Coso, J. (2014). The relationship between age and running time in elite marathoners is U-shaped. *Age, 36*(2), 1003-1008. doi: 10.1007/s11357-013-9614-z

Lehto, N. (2015). Effects of age on marathon finishing time among male amateur runners in Stockholm Marathon 1979-2014. *Journal of Sport and Health Science*. doi: 10.1016/j.jshs.2015.01.008

Navazio, F. M., & Testa, M. (2007). Benefits of physical exercise. In P. S. Timiras (Ed.), *Physiological basis of aging and geriatrics* (4th edition ed.). Boca Raton, Florida, USA: CRC Press.

Onywera, V. O., Scott, R. A., Boit, M. K., & Pitsiladis, Y. P. (2006). Demographic characteristics of elite Kenyan endurance runners. *Journal of Sports Sciences, 24*(4), 415-422. doi: 10.1080/02640410500189033

Reaburn, P., & Dascombe, B. (2008). Endurance performance in masters athletes. *European Review of Aging and Physical Activity, 5*(1), 31-42. doi: 10.1007/s11556-008-0029-2

Romer, T., Rüst, C. A., Zingg, M. A., Rosemann, T., & Knechtle, B. (2014). Age and ultra-marathon performance - 50 to 1,000 km distances from 1969 – 2012. *SpringerPlus, 3*(1). doi: 10.1186/2193-1801-3-693

Rüst, C. A., Knechtle, B., Rosemann, T., & Lepers, R. (2013). Analysis of performance and age of the fastest 100- mile ultra-marathoners worldwide. *Clinics, 68*(5), 605-611. doi: 10.6061/clinics/2013(05)05

Rüst, C. A., Zingg, M. A., Rosemann, T., & Knechtle, B. (2014). Will the age of peak ultra-marathon performance increase with increasing race duration? *BMC Sports Science, Medicine and Rehabilitation, 6*(1). doi: 10.1186/2052-1847-6-36

Rüst, C.A., Bragazzi, N.L., Signori, A., Stiefel, M., Rosemann, T., & Knechtle, B. (2015). Nation related participation and performance trends in 'Norseman Xtreme Triathlon' from 2006 to 2014. *Springerplus, 4,* 469.

Scott, R. A., Georgiades, E., Wilson, R. H., Goodwin, W. H., Wolde, B., & Pitsiladis, Y. P. (2003). Demographic characteristics of elite Ethiopian endurance runners. *Medicine and Science in Sports and Exercise, 35*(10), 1727-1732. doi: 10.1249/01.MSS.0000089335.85254.89

Sedeaud, A., Marc, A., Marck, A., Dor, F., Schipman, J., Dorsey, M., Haida, A., Berthelot, G., & Toussaint, J. F. (2014). BMI, a performance parameter for speed improvement. *PLoS ONE, 9*(2). doi: 10.1371/journal.pone.0090183

Tanaka, H., & Seals, D. R. (2008). Endurance exercise performance in Masters athletes: Age-associated changes and underlying physiological mechanisms. *Journal of Physiology, 586*(1), 55-63. doi: 10.1113/jphysiol.2007.141879

Wegelin, J. A., & Hoffman, M. D. (2011). Variables associated with odds of finishing and finish time in a 161-km ultramarathon. *European Journal of Applied Physiology, 111*(1), 145-153. doi: 10.1007/s00421-010-1633-1.

Republic of South Africa	189,999
Great Britain	2,676
Australia	1,641
United States of America	1,290
Zimbabwe	1,144
Germany	750
Brazil	652
Lesotho	391
Namibia	348
Canada	336
Switzerland	306
Swaziland	291
Japan	236
Russia	195
Netherlands	192
New Zealand	184
Botswana	156
France	155
Ireland	147
India	135
Portugal	128
Austria	123

Table 1: Distribution of runners sorted by nationality with at least 100 runners per country

Age group	Men	Women	Overall	Men-Women-Ratio
18-24	4,610	185	4,795	24.9
25-29	16,393	940	17,333	17.4
30-34	31,696	2,327	34,023	13.6
35-39	36,588	6,945	43,533	5.2
40-44	31,463	10,256	41,719	3.0
45-49	23,301	7,180	30,481	3.2
50-54	14,090	3,905	17,995	3.6
55-59	6,698	1,650	8,348	4.0
60-64	2,603	548	3,151	4.7
65-69	694	131	825	5.2
70-75	134	21	155	6.3
75-79	10	2	12	5.0

Table 2: Men and women sorted by age group

Figure legends

Figure 1 Box-whiskers plots for age of all male and female runners. Data are given as mean ± 95% confidence interval (CI).

Figure 2 Age of peak running speed in all men (upper panel) and women (lower panel). Data are given as mean ± standard deviation (SD).

Figure 3 Age of peak running speed for the fastest men (upper panel) and women (lower panel)

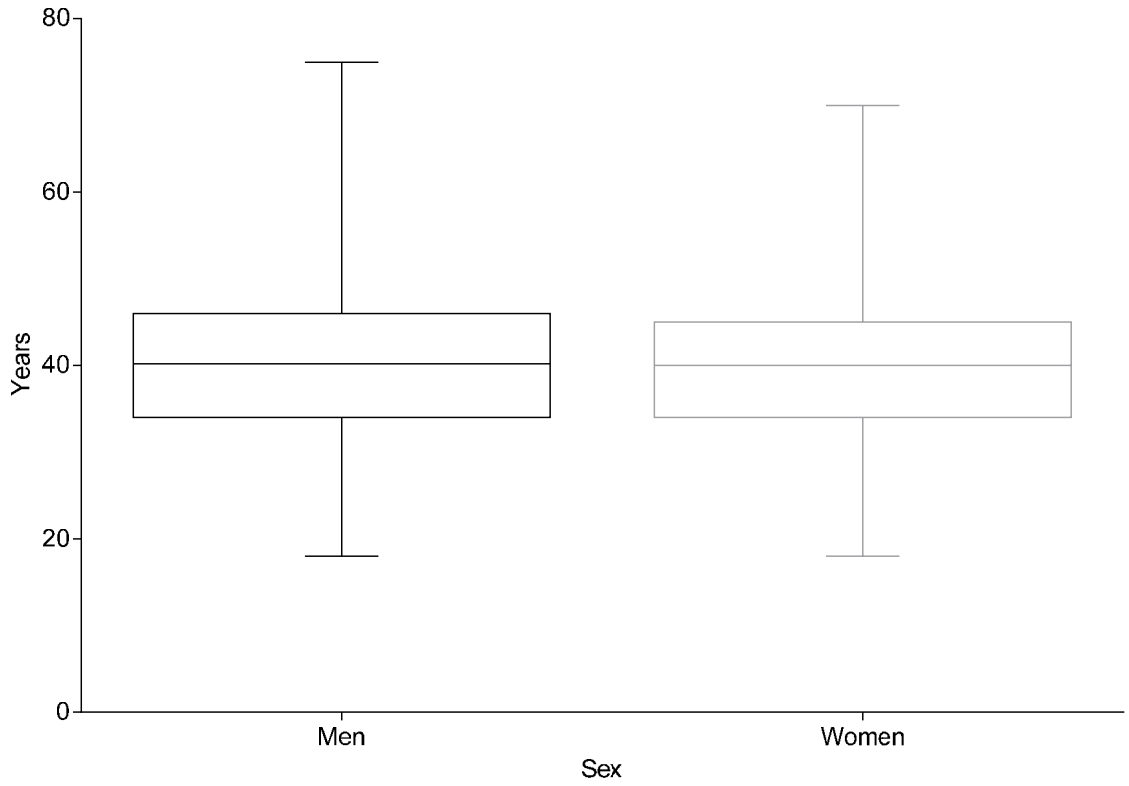
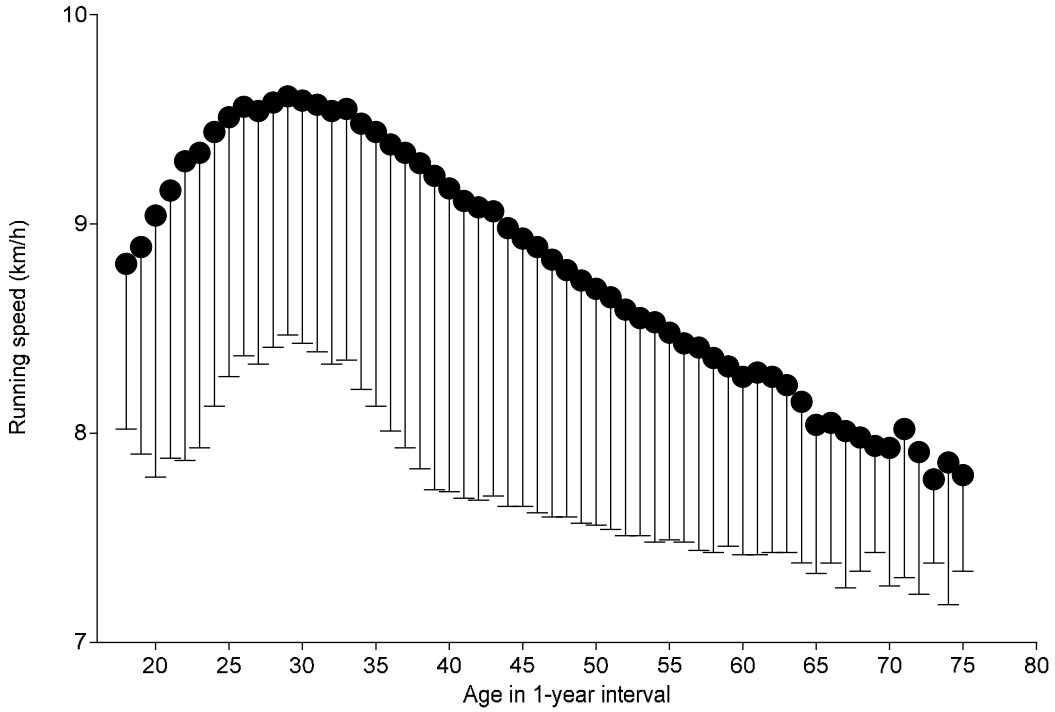


Figure 1


10
9
8
7
Running speed (km/h)
20
25
30
35
40
45
50
55
60
65
70
75
80
Age in 1-year interval

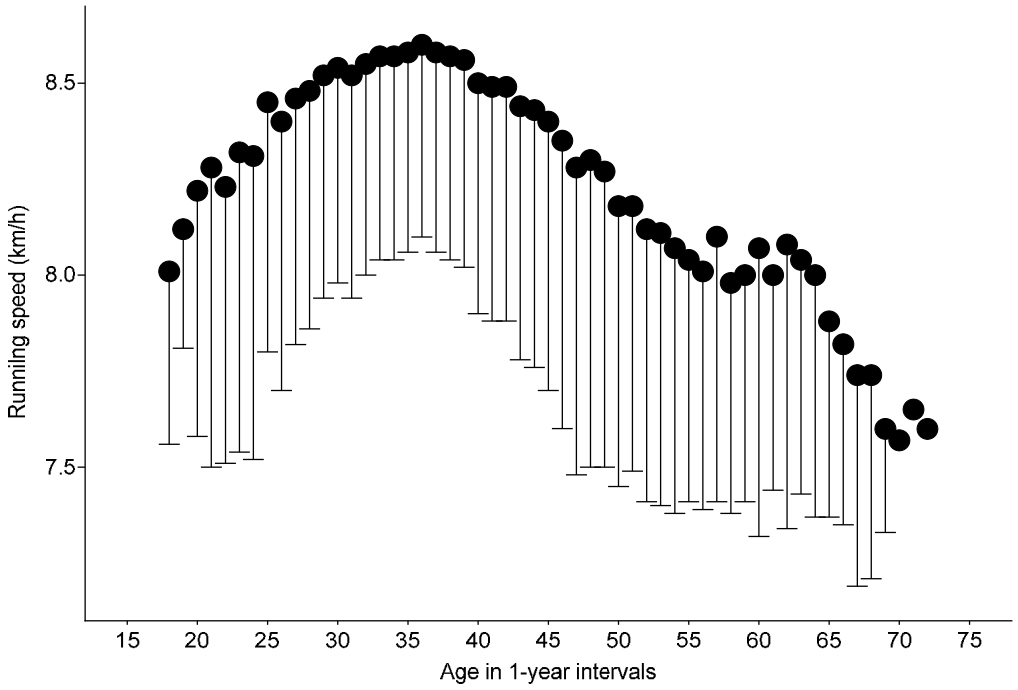
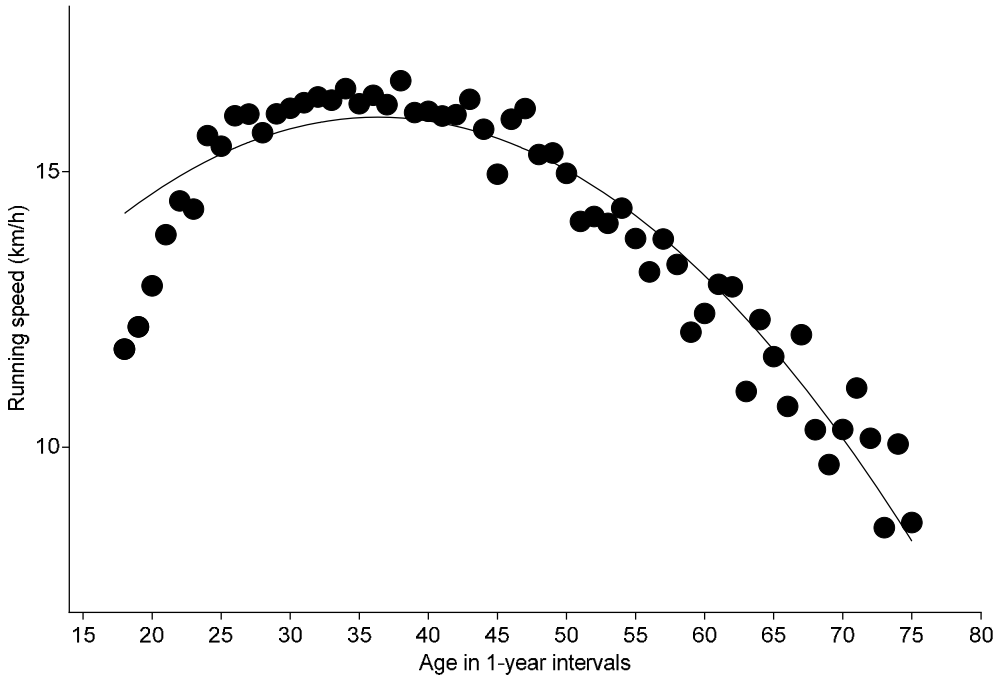

8.5
8.0
7.5
Runniling speed (km/h)
15
20
25
30
35
40
45
50
55
60
65
70
75
Age in 1-year intervals

Figure 2


Running speed (km/h)
15
10
15 20 25 30 35 40 45 50 55 60 65 70 75 80
Age in 1-year intervals

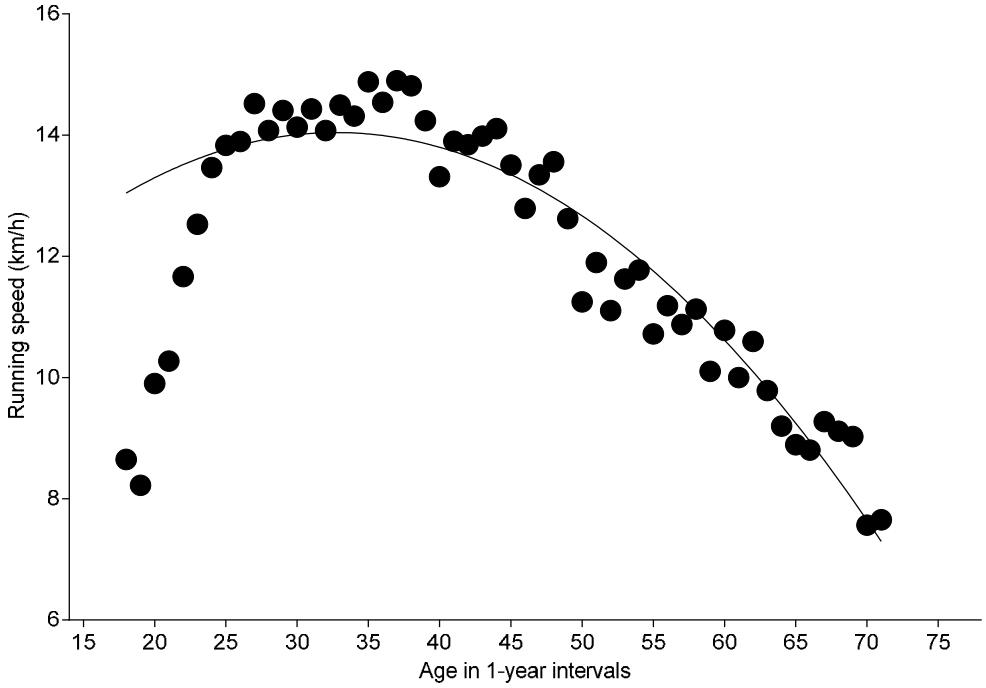

Running speed (km/h)
16
14
12
10
8
6
15 20 25 30 35 40 45 50 55 60 65 70 75
Age in 1-year intervals

Figure 3