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International Journal of Sports Physiology and Performance, **(Ahead of Print)**
https://doi.org/10.1123/ijspp.2022-0284

First Published Online: Nov. 30, 2022

Human Kinetics
BRIEF REPORT

Physiological, Spatiotemporal, Anthropometric, Training, and Performance Characteristics of a 75-Year-Old Multiple World Record Holder Middle-Distance Runner

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Purpose: This study assessed the cardiorespiratory capacity, anaerobic speed reserve, and anthropometric and spatiotemporal variables of a 75-year-old world-class middle-distance runner who previously obtained several European and world records in the age categories of 60–70 years, achieved 13 European titles and 15 world champion titles, and also holds several European records for the 75-year-old category. ***Methods:*** Heart rate, oxygen uptake, carbon dioxide production, ventilation, step frequency, contact time, and velocity at maximal oxygen uptake (VO_2max) were measured during treadmill running. Maximal sprinting speed was assessed during track sprinting and used to compute anaerobic speed reserve. Body fat percentage was assessed using air displacement plethysmography. ***Results:*** Body fat percentage was 8.6%, VO_2max was 50.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$, maximal ventilation was 141 $L{\cdot}min^{-1}$, maximum heart rate was 164 $beats{\cdot}min^{-1}$, maximum respiratory exchange ratio was 1.18, and velocity at VO_2max was 16.7 $km{\cdot}h^{-1}$. The average stride frequency and contact time during the last 30 seconds of the 4-minute run at 10 $km{\cdot}h^{-1}$ were 171 $steps{\cdot}min^{-1}$ and 241 ms and 187 $steps{\cdot}min^{-1}$ and 190 ms in the last 40 seconds at 17 $km{\cdot}h^{-1}$, respectively. The anaerobic speed reserve was 11.4 $km{\cdot}h^{-1}$, corresponding to an anaerobic speed reserve ratio of 1.68. ***Conclusion:*** This 75-year-old runner has an exceptionally high VO_2max and anaerobic speed reserve ratio. In addition, his resilience to injuries, possibly due to a relatively high volume of easy runs, enabled him to sustain regular training since his 50s and achieve international performance in his age group.

Keywords: aging, running, master athlete, oxygen consumption, aerobic exercise, anaerobic speed reserve

Master athletes constantly attract the attention of sport scientists and exercise physiologists because they represent a group that can provide essential insights into the ability of humans to maintain physical performance and physiological function with advancing age.[1] Age-related changes in physiological characteristics in master athletes have been mainly examined in endurance athletes such as marathoners. Recent studies[2–5] evidenced that some world-class endurance master athletes have a very high cardiorespiratory capacity as shown through a maximal oxygen uptake (VO_2max) of 64.5 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ at 60 years[2] and 46.9 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ at the age of 70 years,[3] respectively.

To our knowledge, the physiological profile of world-class master middle-distance runners has never been examined. While long-distance running performances are typically explained by 3 primary physiological variables (maximum oxygen uptake, running economy, and lactate threshold),[6] maximal sprinting speed is also considered as an essential performance determining factor for middle-distance running performances,[7] in particular among athletes with the same maximal aerobic speed.[8] In the present study, we investigated cardiorespiratory variables, maximal sprint speed, anthropometrics, and spatiotemporal variables of a 75-year-old world-class middle-distance runner who ran a 1500 m in 5 minutes 16 seconds in 2022, the second world fastest time in the age group of 75–79 years ever recorded.

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Methods

Subject

A 75-year-old Dutch world-class White middle-long distance athlete with a height and weight of 172.8 cm and 68.9 kg participated in this study. His competition distances were 800 to 5000 m, focusing on 800 to 1500 m. He started running at 16 years until 18 years, and again at 50. His best times as a junior athlete were 2:00 on 800 m, 2:37 on 1000 m, 4:07 on 1500 m, and 8.55 on 3000 m, respectively. His personal best times for selected master age categories are reported in Table 1. The athlete obtained several European and world records in the age categories of 60–70 years, achieved 13 European titles and 15 world champion titles, and holds several European records for the 75 years (Table S1 in the Supplementary Material [available online]).

His self-reported average weekly training distance during the preparation for the outdoor and indoor track seasons was 70 to 80 $km{\cdot}wk^{-1}$, completed in 4 to 5 training sessions per week with a maximum duration of 1 hour 45 min. He performed interval running sessions 1 to 2 times per week, whereas the other training sessions were low-intensity runs based on his feeling. During the competitive season, his typical weekly distance was 30 to 40 $km{\cdot}wk^{-1}$, performed over 4 to 5 sessions per week. The maximum duration of the sessions in this period was approximately 45 minutes. During this period, the athlete performed almost no interval running sessions as he participated in many competitions. The athlete completed no strength training but reported including easy hill runs in most of his training sessions as a form of strength training. He did not systematically record the volume or intensity of

Table 1 Personal Best Times Per Age Group Category

Distance	Running performance, min:s		
	65–70, y	70–74, y	75–79, y
800, m	2.18:17 (seventh on WR)[c]	2.24:02 (second on WR)[a]	2.34:05 (third on WR)
1500, m	4.44:23 (sixth on WR) *4.44:88*[d]	4.55:72 (third on WR)[a] *4.59:72*[d]	5.16:90 (second on WR)
Mile	—	4.43:02 (second on WR)[a]	5.41:20[b]
5000, m	18.15:62 (62th on WR)	20.21:00	—

Abbreviation: WR, all-time world ranking list. Note: Performances in italic correspond to the indoor performances.
[a]Current (outdoor) European record for this age group. [b]Current outdoor world record for this age group. [c]European (outdoor) record at that time for this age group. [d]Current indoor world record at that time for this age group.

his sessions in any way (eg, heart rate, session rating of perceived exertion or a log book).

The athlete volunteered for the study and was informed about its nature and aims, as well as the associated risks and discomfort, before giving his oral and written consent to participate in the investigation. The protocol was in conformity with the Declaration of Helsinki and was approved by the Research Ethics Committee of Maastricht University (approval number FHML-REC2022101). All experiments were performed on the same day.

Experiments

Anthropometrics. Height, weight, and body fat percentage were determined using the procedures described in Supplementary Material (available online).

Maximal Sprint Running Speed. Maximum sprint speed was assessed with four 50-m sprints on an outdoor athletics track. Due to the athlete's experience, he was instructed to perform a self-determined warm-up, consisting of approximately 2 laps of running and 5 minutes of low-intensity running drills. Timing cones (Freelap) were placed in the middle 2 lanes at 5-m intervals[9] between 30 and 50 m to capture split times using an application on an iPad (Freelap). Split times were offline converted into speed using the known distance. The athlete was instructed to accelerate at his own pace and reach a maximal speed between the timing cones. Rest between sprints was approximately 3 minutes to allow time for resynthesis of phosphocreatine while minimizing decreases in body temperature and consisted of slow walking and standing. The temperature was 23 °C and the wind speed was negligible. The athlete wore his running shoes (Nike, Dragonfly) during the sprints. The best 5-m split time was used to calculate maximal sprint speed.

Laboratory vVO$_2$max Assessment and Speed Reserve Ratio. The running protocol for measuring VO$_2$max and corresponding running speed (velocity at VO$_2$max [vVO$_2$max]) was in line with previous research[8] and is further detailed in the Supplementary Material (available online).

The vVO$_2$max was determined by identifying the 30 seconds over which VO$_2$ was the highest. If the athlete achieved VO$_2$max during a stage that was not sustained for 1 minute, vVO$_2$max was calculated in a pro rata manner.[8] For example, if the athlete ran only 40 seconds at the stage where VO$_2$max was achieved, the step increment (1 km·h^{-1}) was multiplied by the percentage of the stage completed (40/60 s = 67%) and added to the speed before the last stage. The anaerobic speed reserve ratio was calculated as maximal sprint speed (in kilometer per hour)/vVO$_2$max (in kilometer per hour).[8]

Results

Body fat percentage was 8.6%, corresponding to an estimated fat mass of 5.9 kg and fat-free mass of 63.0 kg. VO$_2$max was 50.5 mL·kg^{-1}·min^{-1}, maximal ventilation was 141 L·min^{-1}, maximum heart rate was 164 beats·min^{-1}, and the maximum respiratory exchange ratio was 1.18 (Figure 1). vVO$_2$max was reached in the last 40 seconds of the 17 km·h^{-1} stage, resulting in a pro rata manner vVO$_2$max of 16.7 km·h^{-1}. The average stride frequency and contact time during the last 30 seconds of the 4-minute run at 10 km·h^{-1} were 171 steps·min^{-1}, and 241 ms, and 187 steps·min^{-1} and 190 ms in the last 40 seconds at 17 km·h^{-1}, respectively.

The fastest 5-m split time was 0.64 seconds, corresponding to a maximal sprint speed of 28.1 km·h^{-1}. Therefore, the anaerobic speed reserve was equal to 11.4 km·h^{-1} (28.1–16.7), corresponding to an anaerobic speed reserve ratio of 1.68.

Discussion

This study reports the physiological profile of a world-class 75-year-old middle-distance runner. The athlete managed to maintain a very high cardiorespiratory capacity as indicated by a VO$_2$max of 50.5 mL·kg^{-1}·min^{-1}. To the authors' knowledge, this is the highest VO$_2$max value reported in the literature for this age group, although 1 study reported a VO$_2$max of 50 for an 80-year-old male.[10] A previous case study of a 77-year-old multiple world record holder middle-distance runner reported a VO$_2$max of 44.3 mL·kg^{-1}·min^{-1},[5] while a 70-year-old world record holder marathon reported a VO$_2$max of 46.9 mL·kg^{-1}·min^{-1}.[3] For comparison, untrained individuals of 75 years typically have VO$_2$max values approximately half of the observed value in this study (ie, ~30 mL·kg^{-1}·min^{-1}).[11] Interestingly, the VO$_2$max value of 50.5 would still put this athlete in the 75th percentile of 20- to 29-year-old males according to the 2013 American College of Sports Medicine tables.[11] The high VO$_2$max expressed relative to body mass may be partly due to a very low-fat percentage, as the fat percentage of 8.6% is considerably lower than reported for the 77-year-old middle-distance runner (13.5%),[5] or 70-year marathon runner (19.1%).[3] Similarly, the maximal heart rate of 164 was higher than previously reported for the 77-year-old middle-distance runner (160),[5] and 70-year-old marathon runner (maximum heart rate of 156)[3] and is also 5% higher than predicted for his age using the Tanaka equation (which is 156). An interesting observation was that the current athlete's records were faster by almost a minute on the 800 m and more than a minute on the 1500 m compared to a case study in a previous multiple world record holder middle-

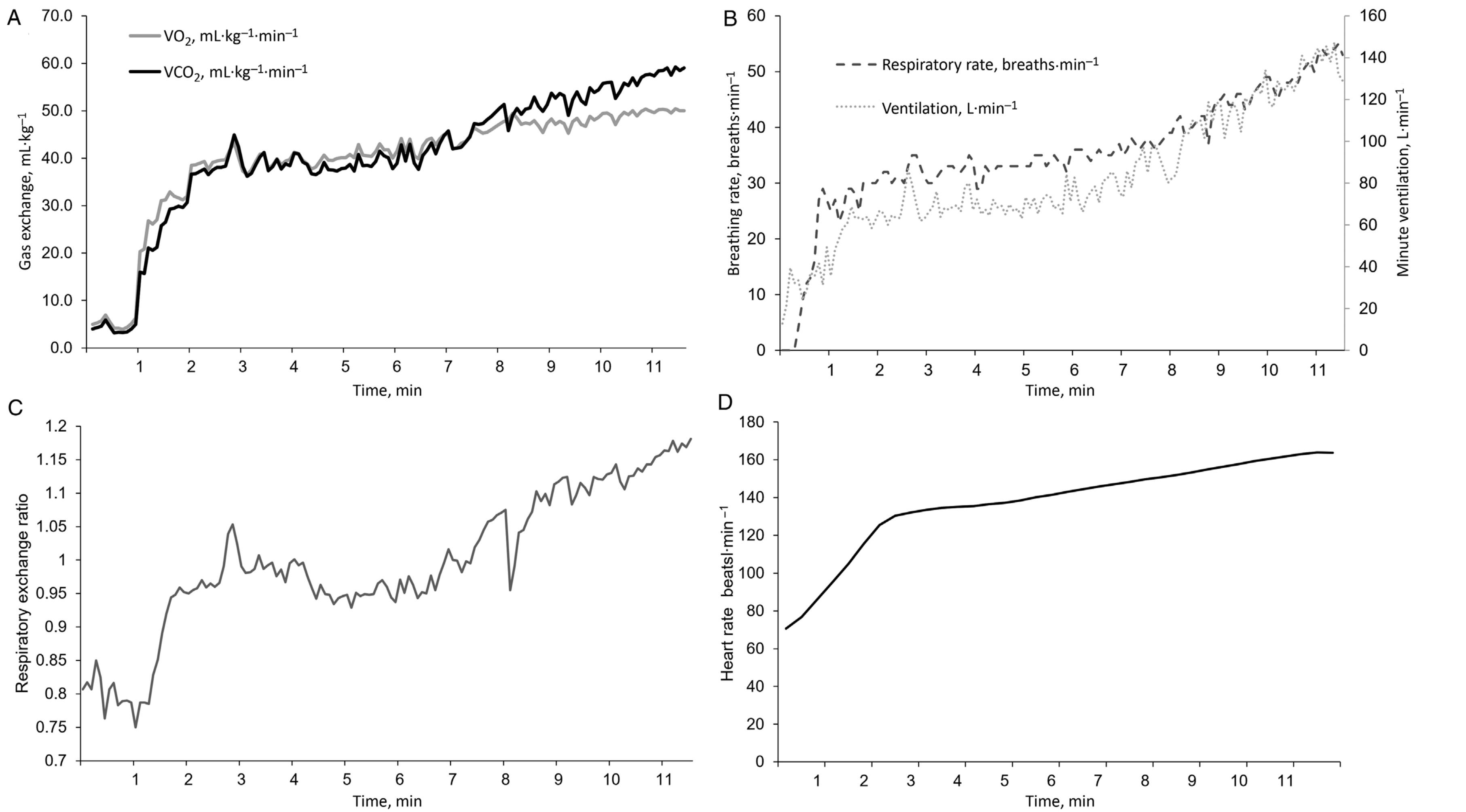

Figure 1 — Physiological outcomes during the laboratory vVO$_2$max assessment. (A) relative VO$_2$ and VCO$_2$ to body mass, (B) respiratory rate and minute ventilation, (C) respiratory exchange ratio, and (D) heart rate. VCO$_2$ indicates carbon dioxide production; VO$_2$, oxygen uptake; vVO$_2$max, velocity at maximal VO$_2$.

distance runner with an almost similar age (77 vs 75 y).[5] The substantial performance improvements are likely due to the higher VO_2max, and the large anaerobic speed reserve, although the latter was not measured in the previous study.

The age-related change in anaerobic speed reserve has not previously been documented in the literature. However, sprint performance has been reported to show a smaller relative decrease with aging compared to endurance performance,[1] suggesting that the anaerobic speed reserve ratio would increase with aging. Indeed, while the athlete considered himself to be more an 800-m to 1500-m specialist—which is also reflected by the world-class times on these distances—the anaerobic speed reserve ratio of 1.68 is in line with values reported for younger 400-m to 800-m specialists.[8] Nevertheless, this rather large anaerobic speed reserve ratio in combination with a high VO_2max likely explains the athlete's ability to perform at an exceptional level in his age category. Another key factor contributing to the athlete's outstanding performance is his injury resilience; indeed he did not report an absence from training for more than 1 week in 25 years of training. The athlete attributed this to performing most of his runs at an easy pace. In support of this, tissue damage increases exponentially with increases in running speed,[12–14] and the high volume of easy runs might therefore have induced relatively small damage and allowed sufficient time for adaptation to occur without injuries. Usually, master athletes reduce their training load to some extent as they age, potentially aiding recovery and thereby preventing injuries.[15] In the current study, the master athlete reported running approximately 140 $km \cdot wk^{-1}$ when he started running at 50, with this distance gradually reducing over time. This suggests that a strong aerobic basis is required to achieve exceptional middle-distance running performance at a high age. This strong aerobic basis might be best obtained by performing a relatively high volume of easy runs as this induces partly similar adaptations to high-intensity training,[16] but with lower damage per kilometer and thus lower injury risk as discussed previously. In support of this, world-class athletes have all been shown to perform high volumes of easy runs.[17]

An interesting observation is that the master athlete performed exceptionally at distances from 800 to 5000 m. Similar findings have been reported by a prior case study of a master middle-distance runner.[5] It has previously been argued that the additional approximately 15 seconds required to complete an 800 m by female athletes may nudge this event toward the aerobic end of the training spectrum.[18] A similar effect could be present for master athletes, increasing the relevance of a strong aerobic power as reflected by the VO_2max across multiple distances, allowing this athlete to perform exceptionally well across various distances.

A limitation of this study is that maximal sprint speed is underestimated as we determined this from the average speed over a 5-m interval instead of a maximum instantaneous speed, for example, obtained with a radar gun. Nevertheless, due to the short interval, this underestimation is likely small.[9] Second, we used the predicted lung volume rather than the measured lung volume for the body composition assessment. It could be argued that this procedure may underestimate lung volume in athletes and thereby overestimate body volume, thereby underestimate body density and thus overestimate body fat percentage. However, this effect is likely relatively small $< 5\%$.[19] Finally, as no data were collected on this athlete in the past it remains unknown how the athlete could maintain his fitness with increasing age.

Conclusion

In conclusion, this 75-year-old world-class middle-distance runner presents an exceptionally high VO_2max and anaerobic speed reserve ratio. In addition, his resilience to injuries enabled him to sustain regular training since his 50s and achieve international performances in different age-group categories. Further research is needed to better understand the interaction between injury occurrence, physiological capacity, and performance level with advancing aging.

Acknowledgments

The authors thank Pleun van der Lee and Guyvan Maessen for their assistance with data collection. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. Van Hooren conceived the study, collected and analyzed the data, and wrote the first draft of the manuscript, Plasqui and Lepers provided comments and edits. All authors approved the final version.

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