Case studies in Physiology: Analysis of the World record time for combined father and son marathon

Authors: Julien Louis[1], Bastien Bontemps[1,2], Romuald Lepers [3]

Affiliations:

[1] *Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, Liverpool, UK*

[2] *Unité de Recherche Impact de l'Activité Physique sur la Santé (UR IAPS N°201723207F) University of Toulon, Toulon, France*

[3] *INSERM UMR1093, CAPS, Faculty of Sport Sciences, University of Bourgogne Franche-Comté, Dijon, France*

Corresponding author: Romuald Lepers
Laboratoire INSERM UMR1093
CAPS – Faculty of Sport Sciences
University of Bourgogne Franche-Comté, Dijon, France
E-mail: romuald.lepers@u-bourgogne.fr

Running title: Combined father and son marathon

Conflicts of interest

All authors declare no conflicts of interest.

Funding disclosure

This work did not receive any specific grant from funding agencies in the public, commercial or not-for-profit sectors.

Abstract

The aim of this study was to examine the physiological profiles and the pacing strategies of the father (59 years old) and son (34 years old) who broke the World record time (4:59:22; father : 2:27:52, son : 2:31:30) for combined father and son marathon in 2019. Oxygen uptake ($\dot{V}O_2$), heart rate (HR), ventilation ($\dot{V}E$), blood lactate concentration (La), and running economy (RE) were measured during treadmill-running tests. The total distance of the marathon was divided into 8 sections of 5 km and 1 last section of 2.195 km, and the relative average running velocity on each section was calculated individually. $\dot{V}O_{2max}$, HR_{max}, $\dot{V}E_{max}$, La_{max}, were 65.4 $ml.kg^{-1}.min^{-1}$, 165 $beats.min^{-1}$, 115 $l.min^{-1}$, 5.7 $mmol.l^{-1}$ for the father and 66.9 $ml.kg^{-1}.min^{-1}$, 181 $beats.min^{-1}$, 153 $l.min^{-1}$, 11.5 $mmol.l^{-1}$ for the son, respectively. At 17 $km.h^{-1}$, RE was 210 $ml.kg^{-1}.km^{-1}$ for the father and 200 $ml.kg^{-1}.km^{-1}$ for the son, and % $\dot{V}O_{2max}$ sustained was 90.9% for the father and 84.5% for the son, respectively. The father maintained an even running velocity during the marathon (running velocity CV $< 1\%$) while the son ran the second half-marathon 7% slower than the first one, and his running velocity markedly dropped from the 35th kilometer. Father and son who broke the World record time for combined father and son marathon had a similar level of performance but their physiological profiles and pacing strategies during the marathon were different. A more even speed for the son could help them to improve their own record in a near future.

Key Words: Running, Oxygen consumption, Aerobic exercise, Aging, Endurance, $\dot{V}O_{2max}$

New & Noteworthy

We provide novel data demonstrating that different physiological profiles can lead to the same level of performance on the marathon, even at different ages. The novelty of our study is in the report of the physiological characteristics, training routine and in-race pacing strategy that allowed a father (59 years old) and son (34 years old) to break the World record time for combined father and son marathon, the father also establishing a new World record marathon time for the age of 59.

Introduction

Similar levels of endurance running performance can be reached with different physiological profiles. There are many possible combinations among the physiological determinants ($\dot{V}O_{2max}$, lactate threshold, and running economy) to lead to a similar performance in marathon running (9, 23). For example, some elite marathoners do not have particularly exceptional $\dot{V}O_{2max}$ or lactate threshold values, but have a very good running economy (25).

Performance in marathon running also depends on pacing (4), that is defined as how an athlete distributes work and energy throughout the race (3). The regulation of pace is thought to be primarily dictated by the ability of an athlete to resist to fatigue by appropriately expending energy from aerobic and anaerobic sources, even if central control may also interact (33). A better pacing strategy could provide marathon runners with an economical pathway to significant performance improvements. Although a negative pace distribution (i.e. second half run faster than the first half of the marathon) has been proposed as the most efficient option, a pacing strategy characterized by very little speed changes across the whole race may also be a good option (11).

The heritability of athletic status, trainability, and exercise behavior has been estimated to account for 66, 47, and 62%, respectively, of athletic performance (35). If genetic factors may contribute to cardiorespiratory fitness and its response to exercise training, there is no evidence for a detailed genomic signature that differentiates endurance athletes from control subjects (6, 30). However, to the best of our knowledge, the comparison of physiological profiles between a father and a son who compete at a high level of physical performance is lacking in the literature. Being born to a father who was an elite athlete does not guarantee success for a son, though it may be an advantage.

In the present study, we evaluated the physiological profiles of the father and son who recently broke the Guinness World record time for combined father and son marathon in a total time of 4:59:22 in 2019 (2, 14, 26). The father, who was an Olympic marathoner in 1992 led the way with an age-59 world record of 2:27:52. The son, 34 years old, ran 2:31:30. Additionally, we analyzed their pacing strategy during the marathon to access how both father and son paced their running to reach a very similar performance.

Methods

Participants

At the date of the evaluation, father and son were 59 and 34 years old respectively. Both were Irish Caucasians, living in Northern Ireland. The athletes' anthropometric characteristics and season best performances are presented in table 1. The father was a full-time runner from the age of 21 to 32. His best marathon performance (2:13:59) was set at 32 years old. Following a 16-year break, he resumed training at the age of 48 and competed in running events from 5-km to marathon. On April 7th 2019, the athlete ran the Rotterdam marathon in 2:30:15 establishing the new single age world record performance (24). The son had no structured sport training until 30 years old. He completed his first 10-km running race at 30 years old in a time of ~42 min while he trained twice a week. At the age of 32, his personal best on 10 km was 35 min with five to six training sessions per week. At 34 years old, during the season preceding the marathon, he decreased his personal best to 00:30:51 on 10-km and 1:08:30 on half-marathon with five to seven training sessions per week (See table 1). He had no previous experience on the marathon before this study.

Both athletes volunteered and were informed about the nature and aims of the study, as well as the associated risks and discomfort prior to giving his oral and written consent to participate in the investigation. The protocol was in conformity with the Declaration of Helsinki (last modified in 2013). The experimental protocol was approved by the Research Ethics Committee of Liverpool John Moores University.

Experimental design

In the summer of 2019, the two athletes (father and son) decided to train for the Frankfurt marathon (27 October 2019) where they aimed to break the World record time for combined father and son marathon. According to the Guinness World Records, the previous record was established at the 2015 London Marathon by a father (50 years old, 2:32:01) and his son (30 years old, 2:30:20) with a total time of 5:02:21 (2). However, in 1987 at the Neuf Brisach marathon (France), a 43-year old father (2:22:54) and his 23-year old son (2:23:10) ran a total time of 4:46:04, but this performance has not been validated by the Guinness World Records (1).

The two athletes undertook a cardiorespiratory assessment in laboratory and their training was monitored for the last 2 months prior to the marathon. The pacing and nutritional strategies were finally followed during the marathon.

Cardiorespiratory assessment

Before each test, the athletes' body composition was assessed via a whole-body fan beam dual-energy X-ray absorptiometry (DXA) measurement scan (Hologic Discovery A, WA, USA) according to the methods described by Nana et al. (27). The cardiorespiratory assessment was performed on a motorized treadmill (HP Cosmos, Germany) in the morning of the same day for both athletes. It consisted of a submaximal running economy (RE) test followed by an incremental running test until volitional exhaustion (maximal oxygen consumption - $\dot{V}O_{2max}$ - test). Oxygen uptake was measured using indirect calorimetry via an automated open circuit system (Oxycon Pro, Carefusion, Germany). Heart rate (HR) was monitored via a Polar V800 heart rate monitor (Polar, Finland). We used the same testing protocol as Robinson et al. (31) but with higher running velocities. After completion of a 6-min warm-up at running velocities varying from 12 to 15 $km.h^{-1}$, the athletes ran at four pre-selected velocities (15, 16, 17, 18 $km.h^{-1}$) for 5 min with 5 min of passive recovery in between. Following the last RE stage, the athletes performed the $\dot{V}O_{2max}$ test during which a velocity of 16 $km.h^{-1}$ was held constant while the treadmill gradient was increased by 1% every minute until volitional exhaustion. A 30-s interval containing the two highest 15-s O_2 consumption values was used to determine $\dot{V}O_{2max}$. Blood lactate (La) was measured in finger-prick blood samples (50μl) using a portable lactate analyzer (Lactate Pro2, Arkray, Japan). Measurement was performed before and one minute after each RE stage and after the $\dot{V}O_{2max}$ test. VO_{2max} is also expressed relative to lean lower-body mass (17). A foot pod monitor (Stryd Powermeter, Boulder, CO, USA) was attached to the left shoe during the RE submaximal test in order to evaluate stride parameters. The *Stryd* foot pod is valid and reliable for the monitoring of step length and step frequency at running speeds ranging from 8 to 20 $km.h^{-1}$ (15).

Training for combined father and son marathon

In the last 2 months prior to the marathon, the athletes' training routine was monitored via activity monitor watches (Garmin, Forerunner 230, USA). The average training volume was 180±21 and 140±33 $km.week^{-1}$ for father and son, respectively. As the athletes mainly trained according to their sensations, no specific information regarding training intensity was recorded, though the athletes reported that most of their training was performed at running velocities under or close to marathon pace. The athletes reached higher velocities (above marathon pace) during local competitions (from 5-km races to half-marathons) they entered almost every week-end.

Father and son had very similar basic dietary habits. They eat porridge oats with fresh or dried fruits for breakfast, a whole meal sandwich for lunch and potatoes or rice or pasta with vegetables and mostly chicken for dinner. The father also drinks a small glass of organic beetroot juice every day. In the last few days prior to the marathon, they ate plenty of pasta.

Combined father and son marathon

On Sunday 27 October 2019, father and son participated in the Frankfurt marathon (Germany). The start time was 10:00 am CET and the average ambient temperature and relative humidity were 13°C and 78%, respectively. The total distance of the marathon was divided into 8 sections of 5-km and 1 section of 2.195 km. The time to complete each section was monitored via the electronic chips attached to the athletes' shoes and the average running velocity of each section was calculated. For the race, father and son wore the same running shoes (Nike Vaporfly Next%, Beaverton, OR, USA) and outfit (light running short and vest). To beat the previous father and son marathon world record time (05:02:12), both athletes had to run at an average speed >16.75 $km.h^{-1}$ during the whole race. During the race, the father ingested 2 energy gels (25 g carbohydrates and 85 mg salt per unit, Maurten AB, Gothenburg, Sweden) at mid-race and 32nd km, along with water at the majority of water stations. The son ingested 1 energy gel (same reference as his father) and a few sips of sports drink (79 g carbohydrates and 500 mg salt per 500 ml of drink, Maurten AB, Gothenburg, Sweden).

Results

Cardiorespiratory variables

RE values calculated during the RE submaximal test are presented in figure 1. RE was 203 vs. 204 $ml.kg^{-1}.km^{-1}$, 211 vs 202 $ml.kg^{-1}.km^{-1}$, 210 vs 199 $ml.kg^{-1}.km^{-1}$ and 206 vs 197 $ml.kg^{-1}.km^{-1}$, at 15 $km.h^{-1}$, 16 $km.h^{-1}$, 17 $km.h^{-1}$ and 18 $km.h^{-1}$ for father vs. son, respectively. At the record marathon pace, oxygen uptake was higher for the father (~59 $ml.kg^{-1}.min^{-1}$) compared to his son (~56 $ml.kg^{-1}.min^{-1}$) and corresponded to 90.9 % and 84.5 % of their $\dot{V}O_{2max}$, respectively. HR corresponded to 90.9 % and 93.3 % of HR_{max} for father and son, respectively, while blood lactate was the same between them.

The results of the $\dot{V}O_{2max}$ test are presented in table 1 and figure 2. Maximal values of $\dot{V}O_2$, HR, ventilation, respiratory exchange ratio, and lactate concentration were higher for the son compared to his father. When comparing the athletes' $\dot{V}O_{2max}$ with the American College of Sports Medicine average percentile values (29), both ranked above the 99th percentile for their respective age groups.

Race performances

The father completed the marathon in 02:27:52 (average speed 17.12 $km.h^{-1}$, 76th overall, +16.3% of the winner time) and his son finished in 2:31:30 (average speed 16.71 $km.h^{-1}$, 115th overall, +19.2% of the winner time) for a combined time of 04:59:22, improving the combined father and son world record by 00:02:50. The athletes' pacing strategy during the race is presented in figure 3. The father was able to follow a negative split strategy with the first and second half of the race covered in 01:14:12 and 01:13:20, corresponding to an average speed of 17.06 and 17.26 $km.h^{-1}$, respectively. In contrast, the son followed a positive split strategy as he could not maintain the pace during the second half of the race. He covered the first and second half in 01:12:54 and 01:18:36, corresponding to an average velocity of 17.36 and 16.10 $km.h^{-1}$, respectively. The coefficient of variation (CV) of their running velocity was 0.8% and 8.5% for the father and son, respectively.

Discussion

This study reports the physiological profiles and the pacing strategies of the father and son who broke the World record time for combined father and son marathon in 2019. Father and son's individual performances were relatively similar (the father ran only 2.5% faster than his son) although their physiological characteristics and their pacing strategies during the marathon were different.

Physiological profiles

During the incremental maximal running test, the father reached a slightly lower maximal oxygen consumption (-2%) compared to his son but much lower values of maximal heart rate (-9%) and ventilation (-25%). Oxygen pulse was very similar between father and son, suggesting that the father's slower heart rate is a major factor responsible for his lower $\dot{V}O_{2max}$ compared with his son (22). The 59-year-old father who was an ex-Olympian athlete has conserved a very high cardiorespiratory capacity as shown through a $\dot{V}O_{2max}$ of 65 $ml.kg^{-1}.min^{-1}$; $\dot{V}O_{2max}$ values of ~45 $ml.kg^{-1}.min^{-1}$ are classically reported in age-matched well-trained runners (32). A decline in maximal heart rate and ventilation is generally observed with aging even in well-trained athletes (10, 21) and the observed difference between the father and son could be expected.

If their maximal respiratory exchange ratio during the test was not very different (+1.9% for the son), maximal lactate concentration was much greater for the son (11.5 $mmol.l^{-1}$) compared to his father (5.7 $mmol.l^{-1}$) but the values remained in the range of those observed in top level marathoners (34). The higher peak lactate concentration of the son could be explained by the additional 90 seconds of running the son performed after his $\dot{V}O_2$ plateaued, whereas his father stopped the tests immediately after he reached $\dot{V}O_{2max}$.

However, it is interesting to note that while the maximal lactate concentration was much greater for the father compared to the son, both father and son exhibited the same lactate concentration (~2 $mmol.l^{-1}$) at the marathon pace.

The submaximal running test revealed physiological differences between the two athletes. At the marathon pace, the father's oxygen uptake corresponded to ~90% of his $\dot{V}O_{2max}$ while the son's value was ~85%. While an intensity corresponding to 85% of $\dot{V}O_{2max}$ sustained during the marathon is common for well-trained athlete, a value of 90% appears very high and can be observed only in younger top class marathon runners (5). This value of 90% for the father is also in accordance with the study of Robinson et al. (31) who reported that the over 70 years' marathon World record holder for men was able to sustain a running velocity eliciting 93% of $\dot{V}O_{2max}$ during the marathon.

At their marathon speed, both father and son had a good running economy with values comprised between 200 and 210 $ml.kg^{-1}.km^{-1}$ corresponding to those measured by Billat et al. (5) in top class male marathon runners (marathon performance time < 2:12:00). However, these values remain higher compared to those of the best Eritrean runners for whom running economy is closed to 185 $ml.kg^{-1}.km^{-1}$ at 17 $km.h^{-1}$ (25). Running economy was 5% lower for the son compared to the father which may be considered as an advantage, though it is not known whether this difference remained throughout the whole marathon. Indeed, running economy has been found to either remain stable or decrease during a prolonged submaximal running exercise (7, 16, 19). A drift in $\dot{V}O_2$ during submaximal exercise may be associated to changes in biomechanical (e.g. running pattern) and physiological (e.g. muscle fatigue, thermoregulation, substrate turnover) factors (20).

Pacing strategies

The marathon pacing greatly differed between father and son. The father maintained an even velocity during the race (running speed CV < 1%) and adopted a slightly negative split strategy with a second half-marathon ran ~1% faster than the first one. In contrast, the son ran the second-half marathon 7% slower than the first one, and his running velocity really dropped from the 35th kilometer of the marathon. Although authors suggested a non-linear pacing strategy to be optimal (11), slower marathon finishers had generally greater variability of pace compared to faster marathoner finishers (18). Moreover, it seems that age could influence the pacing strategy in marathon with older runners generally presenting a relatively more even pace compared with runners of younger age groups (28). It has also been shown that elite marathoners, especially race winners maintained a relatively constant running velocity throughout the race, whereas still accomplished marathon runners but of lesser ability set an initially fast first half-marathon, after which, they gradually slowed down for the remainder of the race (13). In contrast to his father who raced several marathons in the past, the son performed his first marathon following four years of training. The son probably selected an early running velocity that was faster than the average running velocity he could sustained for the whole race. Consequently, his velocity decreased gradually during the second half of the race, and more markedly after the 35th kilometer.

Practical implications and limitations

This study confirms that different physiological profiles can lead to the same level of performance on the marathon, even at different ages. The data also show that the effects of aging on endurance performance may be partly overcome thanks to maintained training volume, and a different in-race pacing strategy compared to younger athletes. It is also noteworthy that both father and son's nutritional strategies on the marathon were far from optimal recommendations for carbohydrates to maintain optimal substrate availability for the muscle and the brain (8). Should father and son had followed these guidelines, had their performances been better or pacing strategy different? In addition, it would have been interesting to evaluate the neuromuscular function following the marathon, to identify potential differences in muscle fatigue between father and son that could impact pacing strategy (12). Although the data reported are encouraging for older athletes, certain limitations must be considered. Only two athletes were studied and no physiological measurement was possible during the race. However, we believe the data presented can contribute to the ever exciting debate on the optimal conditions to perform on the marathon.

Conclusion

Father and son who broke the Guinness World record time for combined father and son marathon had a similar level of performance (2.5 % difference) but their physiological profiles and pacing strategies during the marathon were different. Compared to his son, the father sustained a higher fraction of maximal oxygen consumption during the race, despite a lower running economy and slightly lower maximal oxygen uptake. The father also had a more even pacing strategy than his son during the race. We can expect that with more experience, the son should be able to maintain a more even running velocity during a marathon and improve his performance. Assuming that the father can maintain his level of performance despite his age, father and son could break their own record in a near future.

Acknowledgements

The authors would like to thank Pierre Clos for his helpful suggestions.

Author contributions

JL, BB and RL designed the research experiments; JL, BB and RL performed experiments; JL, BB and RL analyzed data, JL and RL interpreted results of experiments; JL and RL prepared the figures; JL and RL drafted the manuscript; JL and RL edited and revised the manuscript; JL, BB and RL approved the final version of manuscript.

References

1. http://csl-neuf-brisach-athletisme.fr/Anciennes-organisations.php?ancienne_org=Marathon.
2. Guinness World Records: Fastest-marathon-run-by-parent-and-child www.guinnessworldrecords.com/world-records/fastest-marathon-run-by-parent-and-child?fb_comment_id=675885362509036_978163862281183.
3. **Abbiss CR, and Laursen PB**. Describing and understanding pacing strategies during athletic competition. *Sports Med* 38: 239-252, 2008.
4. **Angus SD**. Did recent world record marathon runners employ optimal pacing strategies? *J Sports Sci* 32: 31-45, 2014.
5. **Billat VL, Demarle A, Slawinski J, Paiva M, and Koralsztein JP**. Physical and training characteristics of top-class marathon runners. *Med Sci Sports Exerc* 33: 2089-2097, 2001.
6. **Bray MS, Hagberg JM, Perusse L, Rankinen T, Roth SM, Wolfarth B, and Bouchard C**. The human gene map for performance and health-related fitness phenotypes: the 2006-2007 update. *Med Sci Sports Exerc* 41: 35-73, 2009.
7. **Brisswalter J, Hausswirth C, Vercruyssen F, Collardeau M, Vallier JM, Lepers R, and Goubault C**. Carbohydrate ingestion does not influence the change in energy cost during a 2-h run in well-trained triathletes. *Eur J Appl Physiol* 81: 108-113, 2000.
8. **Burke LM, Jeukendrup AE, Jones AM, and Mooses M**. Contemporary Nutrition Strategies to Optimize Performance in Distance Runners and Race Walkers. *Int J Sport Nutr Exerc Metab* 29: 117-129, 2019.
9. **Coyle EF**. Physiological regulation of marathon performance. *Sports Med* 37: 306-311, 2007.
10. **Degens H, Maden-Wilkinson TM, Ireland A, Korhonen MT, Suominen H, Heinonen A, Radak Z, McPhee JS, and Rittweger J**. Relationship between ventilatory function and age in master athletes and a sedentary reference population. *Age (Dordr)* 35: 1007-1015, 2013.
11. **Diaz JJ, Fernandez-Ozcorta EJ, and Santos-Concejero J**. The influence of pacing strategy on marathon world records. *Eur J Sport Sci* 18: 781-786, 2018.
12. **Easthope CS, Hausswirth C, Louis J, Lepers R, Vercruyssen F, and Brisswalter J**. Effects of a trail running competition on muscular performance and efficiency in well-trained young and master athletes. *Eur J Appl Physiol* 110: 1107-1116, 2010.

13. **Ely MR, Martin DE, Cheuvront SN, and Montain SJ**. Effect of ambient temperature on marathon pacing is dependent on runner ability. *Med Sci Sports Exerc* 40: 1675-1680, 2008.

14. **Francis A**. 1992 Olympic marathoner and son break world record at Frankfurt Marathon (unofficial) https://runningmagazine.ca/sections/runs-races/1992-olympic-marathoner-and-son-break-world-record-at-frankfurt-marathon-unofficial/.

15. **Garcia-Pinillos F, Roche-Seruendo LE, Marcen-Cinca N, Marco-Contreras LA, and Latorre-Roman PA**. Absolute Reliability and Concurrent Validity of the Stryd System for the Assessment of Running Stride Kinematics at Different Velocities. *J Strength Cond Res* 2018.

16. **Glace BW, McHugh MP, and Gleim GW**. Effects of a 2-hour run on metabolic economy and lower extremity strength in men and women. *J Orthop Sports Phys Ther* 27: 189-196, 1998.

17. **Gonzalez-Saiz L, Fiuza-Luces C, Sanchis-Gomar F, Santos-Lozano A, Quezada-Loaiza CA, Flox-Camacho A, Munguia-Izquierdo D, Ara I, Santalla A, Moran M, Sanz-Ayan P, Escribano-Subias P, and Lucia A**. Benefits of skeletal-muscle exercise training in pulmonary arterial hypertension: The WHOLEi+12 trial. *International journal of cardiology* 231: 277-283, 2017.

18. **Haney TA, Jr., and Mercer JA**. A Description of Variability of Pacing in Marathon Distance Running. *Int J Exerc Sci* 4: 133-140, 2011.

19. **Hausswirth C, Brisswalter J, Vallier JM, Smith D, and Lepers R**. Evolution of electromyographic signal, running economy, and perceived exertion during different prolonged exercises. *Int J Sports Med* 21: 429-436, 2000.

20. **Hausswirth C, and Lehenaff D**. Physiological demands of running during long distance runs and triathlons. *Sports Med* 31: 679-689, 2001.

21. **Hawkins SA, Marcell TJ, Victoria Jaque S, and Wiswell RA**. A longitudinal assessment of change in VO2max and maximal heart rate in master athletes. *Med Sci Sports Exerc* 33: 1744-1750, 2001.

22. **Heath GW, Hagberg JM, Ehsani AA, and Holloszy JO**. A physiological comparison of young and older endurance athletes. *Journal of applied physiology: respiratory, environmental and exercise physiology* 51: 634-640, 1981.

23. **Joyner MJ, Ruiz JR, and Lucia A**. The two-hour marathon: who and when? *J Appl Physiol (1985)* 110: 275-277, 2011.

24. **Lepers R, Bontemps B, and Louis J**. Physiological Profile of a 59-Year-Old Male World Record Holder Marathoner. *Med Sci Sports Exerc* 2019.

25. **Lucia A, Esteve-Lanao J, Olivan J, Gomez-Gallego F, San Juan AF, Santiago C, Perez M, Chamorro-Vina C, and Foster C**. Physiological characteristics of the best Eritrean runners-exceptional running economy. *Appl Physiol Nutr Metab* 31: 530-540, 2006.

26. **Middlebrook H**. Father and Son Break 5 Hours to Set World Record for Fastest Combined Marathon Time https://www.runnersworld.com/runners-stories/a29726106/father-son-fastest-combined-marathon-time-record/?utm_source=facebook&utm_campaign=socialflowFBRW&utm_medium=social-media&fbclid=IwAR2iVuSeMDPEase0bPmx2J1h8iXdCnTyKc1Vzh9blkfyV05x1j6zhSopX1M.

27. **Nana A, Slater GJ, Hopkins WG, and Burke LM**. Techniques for undertaking dual-energy X-ray absorptiometry whole-body scans to estimate body composition in tall and/or broad subjects. *Int J Sport Nutr Exerc Metab* 22: 313-322, 2012.

28. **Nikolaidis PT, and Knechtle B**. Effect of age and performance on pacing of marathon runners. *Open Access J Sports Med* 8: 171-180, 2017.

29. **Pescatello LS, Arena R, Riebe D, and PD. T**. ACSM's Guidelines for Exercise Testing and Prescription. 9th ed. Philadelphia (PA): Lippincott Williams & Wilkins, 2014.
30. **Rankinen T, Fuku N, Wolfarth B, Wang G, Sarzynski MA, Alexeev DG, Ahmetov, II, Boulay MR, Cieszczyk P, Eynon N, Filipenko ML, Garton FC, Generozov EV, Govorun VM, Houweling PJ, Kawahara T, Kostryukova ES, Kulemin NA, Larin AK, Maciejewska-Karlowska A, Miyachi M, Muniesa CA, Murakami H, Ospanova EA, Padmanabhan S, Pavlenko AV, Pyankova ON, Santiago C, Sawczuk M, Scott RA, Uyba VV, Yvert T, Perusse L, Ghosh S, Rauramaa R, North KN, Lucia A, Pitsiladis Y, and Bouchard C**. No Evidence of a Common DNA Variant Profile Specific to World Class Endurance Athletes. *PloS one* 11: e0147330, 2016.
31. **Robinson AT, Watso JC, Babcock MC, Joyner MJ, and Farquhar WB**. Record-Breaking Performance in a 70-Year-Old Marathoner. *N Engl J Med* 380: 1485-1486, 2019.
32. **Schroeder TE, Hawkins SA, Hyslop D, Vallejo AF, Jensky NE, and Wiswell RA**. Longitudinal change in coronary heart disease risk factors in older runners. *Age Ageing* 36: 57-62, 2007.
33. **Skorski S, and Abbiss CR**. The Manipulation of Pace within Endurance Sport. *Front Physiol* 8: 102, 2017.
34. **Tam E, Rossi H, Moia C, Berardelli C, Rosa G, Capelli C, and Ferretti G**. Energetics of running in top-level marathon runners from Kenya. *Eur J Appl Physiol* 112: 3797-3806, 2012.
35. **Wang G, Tanaka M, Eynon N, North KN, Williams AG, Collins M, Moran CN, Britton SL, Fuku N, Ashley EA, Klissouras V, Lucia A, Ahmetov, II, de Geus E, Alsayrafi M, and Pitsiladis YP**. The Future of Genomic Research in Athletic Performance and Adaptation to Training. *Med Sport Sci* 61: 55-67, 2016.

Figure and table legends

Figure 1. Oxygen uptake (Panel A), heart rate (Panel B) and blood lactate values (Panel C) obtained at different running velocities during the running economy test. The dashed line represents the average speeds of the father (17.12 $km.h^{-1}$) and son (16.71 $km.h^{-1}$) during their record-breaking marathon performance.

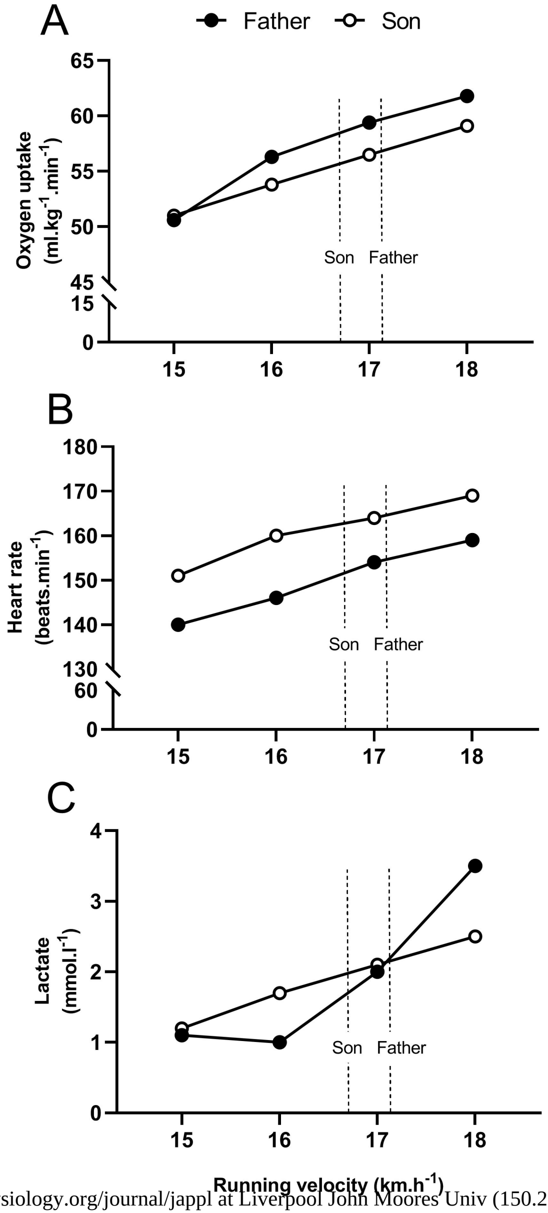
Figure 2. Changes in oxygen uptake during the incremental running test for both the father and son. The father's and son's $\dot{V}O_{2max}$ were 65.4 $ml.kg^{-1}.min^{-1}$ and 66.9 $ml.kg^{-1}.min^{-1}$, respectively.

Figure 3. Changes in average running velocity during the marathon for both the father and son.

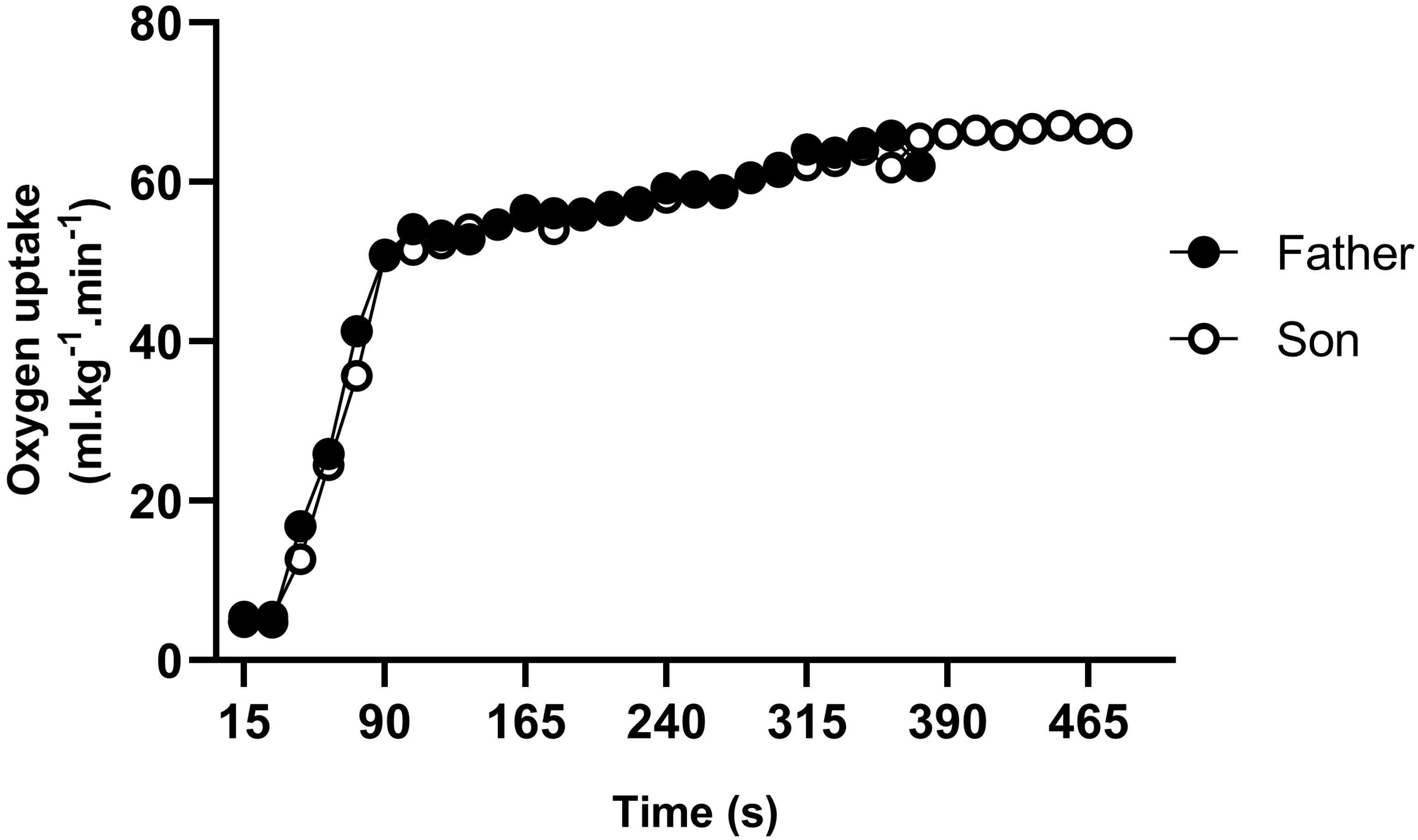
Table 1. Anthropometry, running performances and physiological characteristics (during maximal and maximal running tests) of both the father and son.

Table 1. Anthropometry, running performances and physiological characteristics (during maximal and maximal running tests) of both the father and son.

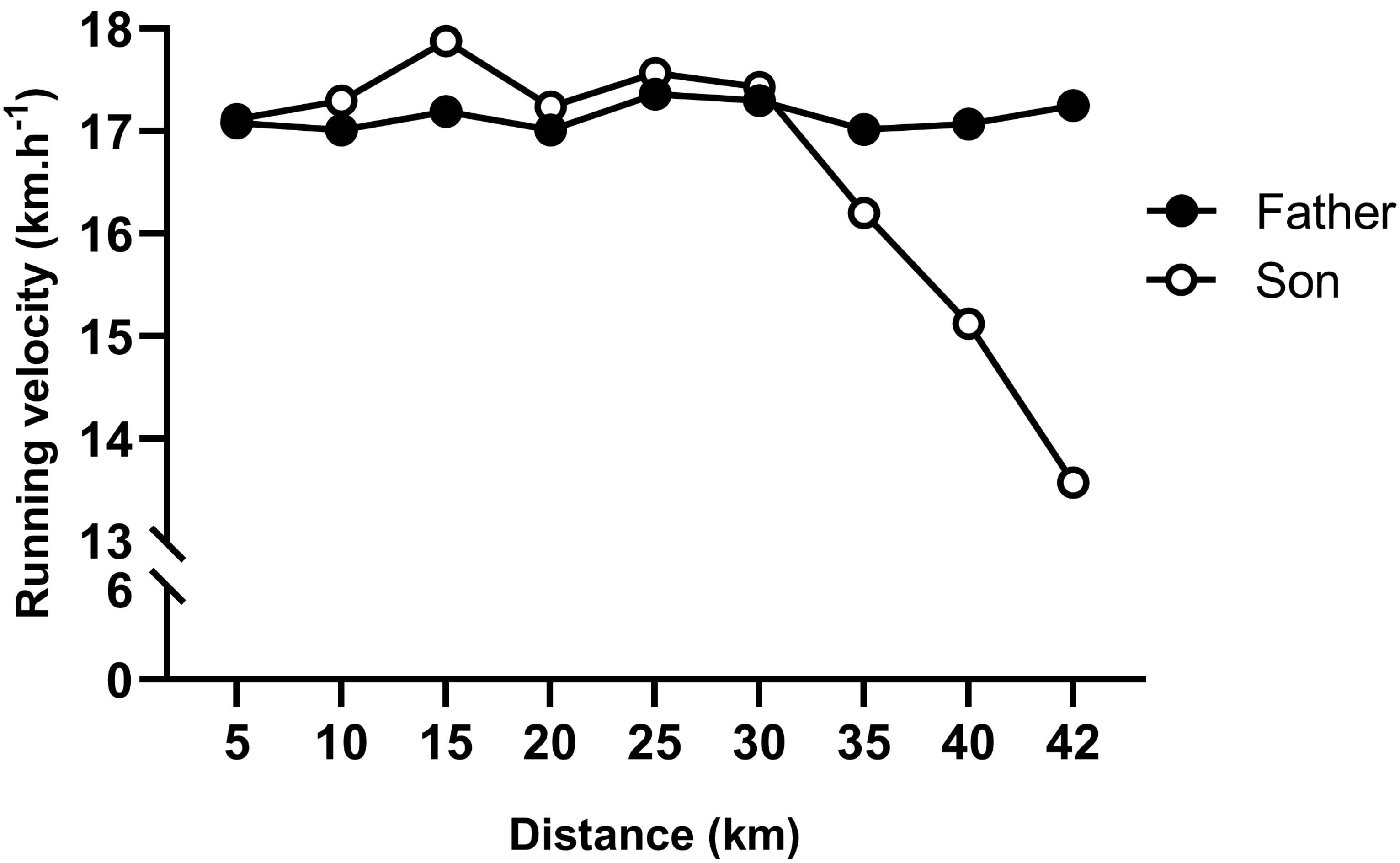
	Father	Son
Age & Anthropometry		
Age (years)	59	34
Height (cm)	169.0	181.5
Weight (kg)	61.2	67.4
% Fat	10.9	12.7
Running performances		
Marathon time (h:min:s)	2:27:52	2:31:30
Marathon speed ($km.h^{-1}$)	17.12	16.71
Season best		
10 km (min:s)	33:13	30:51
21 km (h:min:s)	1:11:58	1:08:30
Mean (± SD) training volume the two months before marathon ($km.week^{-1}$)	180 ± 21	140 ± 33
Physiological characteristics		
Maximal incremental running test		
$\dot{V}O_{2max}$ ($ml.kg^{-1}.min^{-1}$)	65.4	66.9
$\dot{V}O_{2max}$ ($ml.kg^{-1}_{Lower\ Body\ Muscle\ Mass}.min^{-1}$)	204.4	213.2
HR_{max} ($beats.min^{-1}$)	165	181
O_2 pulse ($ml.beat^{-1}$)	24.3	24.9
$\dot{V}E_{max}$ ($l.min^{-1}$)	115	153
RER_{max}	1.04	1.06
La_{max} ($mmol.l^{-1}$)	5.7	11.5
Submaximal running test (17 $km.h^{-1}$)		
Rate of perceived exertion (6-20 scale)	13	14
Running Economy ($ml.kg^{-1}.km^{-1}$)	209.6	199.6
% $\dot{V}O_{2max}$ sustained	90.9	84.5
RER	0.92	0.85
La ($mmol.l^{-1}$)	2.0	2.1
Stride Frequency ($s.min^{-1}$)	199.2	174.2



A
Father
Son
65
60
55
50
45
15
0
Oxygen uptake (ml.kg-1.min-1)
Son
Father
15
16
17
18
B
180
170
160
150
140
130
60
0
Heart rate (beats.min-1)
Son
Father
15
16
17
18
C
4
3
2
1
0
Lactate (mmol.l-1)
Son
Father
15
16
17
18
Running velocity (km.h-1)



80
60
40
20
0
Oxygen uptake
(ml.kg-1.min-1)
15
90
165
240
315
390
465
Time (s)
Father
Son



18
17
16
15
14
13
6
0
Running velocity (km.h-1)
5
10
15
20
25
30
35
40
42
Distance (km)
Father
Son