Publisher: Taylor & Francis & European College of Sport Science

Journal: *European Journal of Sport Science*

DOI: 10.1080/17461391.2021.1893828

Pacing behaviour of middle-long distance running & race-walking athletes at the IAAF U18 and U20 World Championship finals.

Stein Gerrit Paul Menting[1], Brian Hanley[2], Marije Titia Elferink-Gemser[1], Florentina Johanna Hettinga[3*]

1. Center for Human Movement Sciences, University Medical Center Groningen, University of Groningen, Groningen, the Netherlands.
2. Carnegie School of Sport, Leeds Beckett University, Leeds, United Kingdom.
3. Department of Sport, Exercise & Rehabilitation, Faculty of Health and Life Sciences, Northumbria University, Newcastle, United Kingdom.

* Department of Sport, Exercise & Rehabilitation
Faculty of Health and Life Sciences
Northumbria University
Room 238, Northumberland Building
Newcastle Upon Tyne
NE1 8ST
United Kingdom
E-mail: florentina.hettinga@northumbria.ac.uk;
Tel: +44 (0)1912273989

*Corresponding author

Abstract

The current study analysed the pacing behaviour of athletes competing in the middle-long track event finals of the IAAF Under 18 and Under 20 World Championships between 2015 and 2018. Official finishing times, 1000-m split times and positioning data of 116 female and 153 male athletes, competing in the middle-long distance running (3000m, 5000m and 10,00 m) and race walking (5000m and 10,000m) events, were gathered. Repeated measures analysis of variance, with 1000-m speed as within-subjects factor and final ranking (medallist, Top 8 or Top 12, rest of the field) as between-subjects factor, was performed to compare the pacing behaviour between athletes.

Positioning of the athletes was analysed by Kendall tau-b (T_b) correlation between the intermediate position and final position. Overall, medallists increased their speed throughout a race, with the exception of the 5000 m running event, in which a parabolic pacing behaviour was exhibited. The 1000-m segment in which a significant ($P > 0.05$) difference in speed was exhibited between differently ranked athletes was coincided with a strong ($T_b > 0.7$) correlation between intermediate and final positioning. These combined results point towards a separation between the athletes during the race, as the Top 8 or Top 12 and the rest of the field are unable to match the speed of the medallists. The distance, discipline, sex, age category and behaviour of competitors all influence the pacing behaviour of young track athletes during international level competition, emphasising the importance and complexity of developing adequate pacing behaviour in track athletes.

Keywords

Pacing, performance, race analyses, athletics, running, race walking, middle-long distance.

Introduction

The pathway to elite performance in track athletics requires athletes to master a wide range of aspects that characterise their sport (1), one of which is pacing. Pacing can be defined as the goal-oriented distribution of energy over a task (2) and is described as the decision-making process regarding how an individual expends their energy (3). Within this decision-making process, athletes determine the optimal distribution of energy while taking into account a multitude of factors, such as tactical considerations, environmental features and the behaviour of other competitors (4, 5). The outcome of this decision-making process determines an individual's behaviour (i.e. pacing behaviour), which is can be quantified by a measure of effort (power output or speed) over segments of the set exercise task (6). An athlete's pacing behaviour has been shown to be a decisive feature in athletic performance (5) and is influenced by a multitude of factors including the nature of the task (7, 8), the characteristics of the athlete (9) and the competitive environment (5, 10). The impact of these factors on the pacing behaviour of elite athletes has been thoroughly studied. Within a discipline, the goal (e.g. qualifying for the next round or winning the final) and the importance of the event (e.g. a single world cup competition or the Olympic final) could influence the behaviour of athletes (11, 12). In championship track athletic races, athletes competing in short-distance events (100 m and 200 m) most frequently exhibit an 'all-out' pacing behaviour, in which acceleration to near maximal speed is key (13). Conversely, in the middle-long distance track events (5000 m and 10,000 m), athletes generally exhibit an increase in speed over the race (14). Additionally, the middle-long distance track athletes who achieved the highest final ranking tend to pace their race differently from the rest of the field (14). It has been shown that medallists in middle-long distance track races separate themselves from the rest of the field due to their ability to maintain a constant speed or even to increase speed throughout the race (14, 15). Similar pacing behaviour was observed in championship race walking races (over 20-km and 50-km); however, race walkers also need to consider the option to walk in a pack, as it might reduce the chances of attracting the judges' attention (16). As for the characteristics of the athlete, previous research has established that the sex and the expertise of an athlete influence the distribution of energy over a single race and over consecutive races (15, 16).

Although the influence of pacing on elite athletic performance in adult athletes has been studied for over 30 years, the way athletes acquire their pacing behaviour has received less attention (18). This is remarkable as literature indicates that pacing is not an innate ability, but develops relative to an athlete's (meta-) cognitive and physical attributes (19) as well as the experience an athlete has with an exercise task (20). Evidence suggests that athletes who develop their pacing behaviour at a younger age achieve better race results during adulthood (21). Moreover, it has been proposed that the failure to develop adequate pacing behaviour can lead to mismanagement of energy distribution that could result in increased injury and drop-out rates among young athletes (22). Around the age of 10, children are first observed to seemingly reserve their energy to achieve the set exercise. This behaviour further develops during adolescence (19). Studies in swimming and speed skating found that although pacing behaviour is primarily determined by the characteristics of the task and the characteristics of the athletes, there are distinct differences in pacing behaviour between adolescent and adult athletes (23-25). For example, although the general pacing behaviour in speed skating is determined by the distance and the discipline (long- or short-track), athletes' pacing behaviour develops to become more conservative (featuring a slower start and faster finish) throughout adolescence (21, 25). Additionally, the development of pacing behaviour towards that of adults seems to commence earlier in female athletes (24). Because of the complexity of pacing behaviour development during adolescence, as well as the previously mentioned advantages and risks, coaches are encouraged to monitor the pacing behaviour of developing athletes and compare it against established benchmarks (18). It seems evident that the impact of pacing behaviour development on the path to elite performance should not be underestimated, and insight therein might improve training programmes. Although numerous international level youth sport events which feature reliable performance recording, such as the World Rowing Junior Championships and the World Junior Speed Skating Championships, have been organised for decades, the detailed data recorded during these events are not always publically available. Even if there is publically available data, the analysis of these data is complicated by the fact that youth athletes frequently do not compete in every edition of a championship (25). Nevertheless, the analysis of the distribution of effort (e.g. speed) over the duration of a race and the positioning of athletes within a race, based on publically available data from international level youth sports events, has allowed for some of the most rigorous studies on pacing behaviour development in adolescent athletes to date (21, 25). These studies form an excellent basis for the creation of informed practical guidelines for the development of pacing behaviour in young athletes (18). However, taking into account the fact that the characteristics of a sport have a large impact on the pacing behaviour of athletes (26), it cannot be taken for granted that the results found in one sport (e.g. speed skating) can be applied to another sport (e.g. track athletics) in an identical fashion. To assist future elite track athletes, it therefore seems essential to have access to research describing the pacing behaviour of young male and female international level athletes competing in specific track athletic events. The current study aims to document the pacing behaviour of young high-standard middle-long distance track athletes during international level championship finals. Previous studies in track athletics have shown that in adult athletes, the athletes who achieved the highest final ranking in the race (e.g., the medallists) determined the pace of the race, hereby influencing the behaviour of the rest of the field (14). It is therefore hypothesised that alongside the event characteristics (the combination of discipline, race distance and sex), the exhibited pacing behaviour will be linked to the final ranking of the competing athletes.

Methods

Official finishing times, 1000-m split times and positional data were gathered from men and women competing in the finals of the middle-long distance running (3000 m, 5000 m and 10,000 m) and race-walking (5000 m and 10,000 m) finals at the International Association of Athletics Federations (IAAF) Under 18 and Under 20 World Championships between 2015 and 2018. The collected data comprises all currently publically available data of athletes competing at Under 18 and Under 20 World Championships. Additional data collection included the date of competition, the date of birth of competing athletes and the temperature during competition. The temperature during the finals was 21.2 ± 3.7° C (14-25° C) . All data were obtained from the open-access website of the IAAF (since renamed World Athletics) (http://www.iaaf.org/results) (28). The study was approved by the local ethics committee and is in accordance with the Declaration of Helsinki. The split times were electronically recorded using transponders fit into the bibs worn by the athletes. Finishing times were recorded using electronic timing devices with an accuracy of a thousandth of a second, as required by the IAAF. Overall, a total of 116 female and 153 male athletes' performances were analysed.

Data analyses

The current study was designed as observational research. All collected data were categorised by discipline (race walking, running), distance (3000 m, 5000 m and 10,000 m) and sex (female, male). Data of the male 10,000 m race walking event from both U18 and U20 championships were available, therefore, an additional split in age category (U18 & U20) was made for this event. Next, the data were categorised by final ranking: medallists, Top 8 (3000 m & 5000 m) or Top 12 (10,000 m), and the rest of the field. The 1000-m split times were converted to speed to provide a better visual comparison between disciplines and distances. The age of the athletes (Table 1) was calculated by comparing the date of competition with the date of birth of the athlete.

Statistics

Data were analysed per discipline, distance, and sex. To analyse the difference in pacing behaviour by ranking, a repeated measures analysis of variance was performed, with the 1000-m speed as a within-subjects factor and the final ranking (medallists, Top 8 or Top 12, rest of the field) as a between-subjects factor. A significant ($P < 0.05$) within-between interaction effect indicates a difference in pacing behaviour between the groups of athletes with differing final rankings. In the analysis of the male 10,000 m race walking events, age category (U18 & U20) was included as additional between-subjects factor, allowing for an examination of the effect of age category on pacing behaviour. For all repeated measures analysis of variance, the effect sizes were calculated using Cohen's *f,* and categorised as small ($f < 0.1$), medium ($f < 0.3$), and large ($f < 0.5$). If a significant difference in pacing behaviour between ranked athletes was found, a multiple comparison post hoc analysis, including Tukey correction, was performed to identify the difference in speed between differently ranked athletes in each individual 1000-m segment of the race. The effect sizes for the differences in speed between ranked athletes were calculated using Cohen's *d*, and categorised as either trivial ($d <$ 0.20), small (0.21-0.60), moderate (0.61-1.20), large (1.21-2.00) or very large (2.01-4.00) (29). To analyse the impact of positioning during the race, the relationship between position at 1000-m segments and final position of the athlete (first, second, third, etc.) was analysed by means of a Kendall's Tau-b (T_b) correlation. A positive correlation would indicate that an athlete positioned in the front of the race at a specific 1000-m segment was also among the first to finish. Correlations were perceived as not present/low ($T_b < 0.50$), moderate ($0.50 \leq T_b < 0.70$), or high ($T_b \geq 0.70$), as used in previous research (24, 30).

Results

Finishing times of the young athletes in all events, categorised for final ranking, can be found in Table 1. In the male 10,000 m race walking event, a significant interaction effect between age category (U18 vs U20), final ranking and speed at 1000-m segments, indicating a difference in pacing behaviour between age categories, was found ($F_{8.93, 388.45} = 2.14$, $P \leq 0.01$, large). The U18 and U20 male 10,000 m race walking events shall therefore be considered as separate events. A significant interaction effect, indicating a difference in pacing behaviour between athletes categorised by final ranking, was found in all events (Table 1). The speed per 1000-m segment for the male and female running events can found in Figure 1. The speed per 1000-m segment for the male and female race walking events can be found in Figure 2. The positioning data, describing the correlation between the intermediate position at 1000 m segments and final position, of all events can be found in Figure 3.

Discussion

Pacing behaviour is an important element in the development of athletes (18). To guide future athletes in developing adequate pacing behaviour, a better understanding of the pacing behaviour of young athletes is needed (18). As pacing behaviour is impacted by the characteristics of the sport performed, race distance and sex of the athletes, these factors should all be taken into account. The aim of the current study was to document the pacing behaviour of young international level track athletes during middle-long distance events. Differences in pacing behaviour were evident between the differently ranked athletes in all analysed events. As hypothesised, higher ranking athletes (medallists and Top 8 or Top 12) generally exhibited a pacing behaviour characterised by an increasing speed, whereas the rest of the field exhibited a decrease in speed over the course of the race. Overall, the pacing behaviour of medallists was characterised by an increase in speed over the course of the race. The exception to this was the 5000 m running event, in which a more parabolic pacing behaviour was exhibited, characterised by a decrease in speed from the start of the race and an increase in speed at the end of the race. The pacing behaviour of the athletes in the Top 8 or Top 12 generally matched the behaviour of the medallists, with differences in speed occurring later in the race. By this point, the athletes in the Top 8 or Top 12 failed to match the speed exhibited by the medallists. The group of athletes making up the rest of the field exhibited a pacing behaviour characterised by a decrease in speed throughout the race, failing to match the speed of the medallists early on. A similar pattern of pacing behaviour was previously found in adult athletes competing in the 5000 m and 10,000 m running events, whereby the medallists and top eight finishing athletes increased speed during the race, the top 16 athletes demonstrated a constant pace, and the lower-finishing rest of the field showed a decrease in speed over the course of the race (15). The positioning data provide further insight into the pacing behaviour of the athletes. In all included events, it is evident that the 1000-m segment at which a difference in speed between differently ranked athletes occurs is coinciding with the segment in which there is a strong correlation between intermediate position and final position. This finding provides further evidence that the non-medallists, especially the Top 8 or Top 12 group, match the speed of the medallists for a period of time, during this time the groups of differently ranked athletes exhibit a similar speed and there is a low or medium correlation between intermediate and final positioning. However, eventually the non-medallists are not able to match the speed of the medallists any more, an event marked by a difference in speed between the groups and a high correlation between intermediate and final positioning. The moment in the race at which the speed profiles of medallists start to follow a different trajectory from those of other competitors has previously been termed the separation point (14). An explanation for the separation of higher-ranked athletes from lower-ranked athletes during a race could be found in differences in physiological capabilities of the athletes, or in factors influencing the decision-making making process of effort regulation during competition. It is possible that the physiological capabilities determining performance in track athletics (such as oxidative capacity) of medallists exceed those of other competitors. This would mean that by keeping up with higher ranking athletes, the lower ranking athletes are performing at a unsustainable effort (15). Continuous work at the upper limit of an athletes' physiological capacity is unsustainable and fatigue will increase rapidly, forcing a decrease in power output in order to prevent lasting damage to the homeostasis (31). If the goal of the race was purely to cross the given distance in the shortest time, as is seen in time trial sports, performing for a prolonged duration at a the upper limit of an athletes' performance capacity at the initial section of an exercise task (with a duration lasting over 120 seconds) generally leads to a sub-optimal performance (7). However, as middle-long distance track athletics is a head-to-head competition, the goal is to finish before the other athletes in the race, altering the decision-making process regarding the distribution of effort (5, 11). Being in the presence of a direct opponent affords the athlete the beneficial effects influencing motivation and opportunities for drafting (32). Furthermore, in the discipline of race walking, walking in a pack could reduce the chances of attracting the judges' attention (16). Although it has been shown that adult athletes are able to use the presence of an opponent to improve their sports performance (33), similar results have thus far not been shown in younger individuals (34, 35). It has been proposed that younger individuals are still gathering the necessary experience and developing the required cognitive skillset needed to optimally integrate environmental factors (such as opponents) in their pacing behaviour (24, 34). It could therefore be difficult for younger athletes to optimally navigate the complex decision-making making process regarding energy distribution during competition.

The inclusion of similar events in male and female athletes in the current study provides the opportunity to compare the pacing behaviour between sexes. Comparing the pacing behaviour exhibited by male and female athletes in the 3000 m and 5000 m running events, it was evident that the separation point between the differently ranked athletes occurred earlier on in the male event, compared to female event. On first glance, these findings seem to contradict a previous study in elite adults athletes which concluded that, in the 5000 m events, female medallists separate themselves at an earlier stage of the race, between 2000 and 3000 m, and male medallists differentiate themselves from the rest of the field after 4000 m (14). However, it has previously been suggested that the development of pacing behaviour differs between male and female athletes (24, 37), with girls experiencing growth spurt-related physical changes and development of the prefrontal cortical functioning associated with energy expenditure, at an earlier age (38, 39). The change in cognitive development and maturation of the musculoskeletal system could be the reason for the difference in pacing behaviour exhibited by male and female athletes in the observed races (24, 27), however, more extensive research is needed.

Notwithstanding the fact that this study is a response to the need for more sport-specific literature on the pacing behaviour of young athletes (18, 27), some limitations should be addressed. Although the current study includes all currently available data of youth athletes performing at international underage championships, only data of athletes performing in a limited number of races (all finals of a championships) were available. The use of a limit number of races provides the disadvantage of not having the possibility to account for inter-race variability, which decreases the generalisation of the findings. However, the examination of a small number of races, including singles races, has previously been shown to provide valuable new insights into the behaviour of athletes in endurance athletic events (42, 43). In this trend, the current study provides novel insights into the behaviour of young (U18 and U20) middle-long distance track athletes. It should nevertheless be mentioned that the use of larger datasets, including data from more athletes, over more years, and from different stages of competition (e.g. heats and semi-finals), has provided valuable information regarding the pacing behaviour of athletes in other sports such as short-track speed skating (11, 25). Access to data from a larger number of athletes, made publicly available by the IAAF or collected with the permission of the athletes, would provide the opportunity to expand on the novel findings of the current study. Secondly, the resolution of the publicly available data from athletes performing in the IAAF Under 18 and Under 20 World Championships was low when compared data used to previous studies (14, 44). Using data with a higher resolution will allow for a more detailed description of the variation in speed over the course of the race, and therefore a more detailed description of an athletes' pacing behaviour (44). The gathering of higher resolution data has previously been achieved through a collaboration with official timing companies linked to athletic events or the use of video recording (14, 45). Lastly, to properly study the development of pacing behaviour during adolescence, a longitudinal design, following athletes throughout adolescence and controlling for each athletes' sport specific experience, is desirable (25, 46). Future research, featuring a longitudinal design, higher resolution data from a larger number of athletes and the inclusion of different stages of competition should be conducted to further our understanding of the development of young track athletes.

Conclusion

The current study analysed the pacing behaviour of athletes performing in international U18 and U20 middle-long distance track athletic finals. The pacing behaviour of these athletes is linked to the athletes' final ranking in the race. The highest ranking athletes (the medallists) increased their speed throughout the race. Over the course of the race, the other athletes failed to match the speed of the medallists, likely causing a separation between the higher and lower ranking athletes. The distance at which athletes exhibit a failure to match the speed of the medallists differentiates the Top 8 or Top 12 athletes (late separation from medallists) and the rest of the field (early separation from medallists). The differences in pacing behaviour between young track athletes of different sexes competing in the same event, fit the current general knowledge regarding pacing behaviour development of youth athletes. However, more extensive longitudinal research is needed to provide further details of the development of pacing behaviour in track athletics.

Declaration of interest statement

The authors do not have any conflict of interest. The authors declare that the results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. The authors received no specific funding for this work.

References

1. Elferink-Gemser MT, Jordet G, Coelho-E-Silva MJ, Visscher C. The marvels of elite sports: how to get there? British journal of sports medicine. 2011;45(9):683.
2. Edwards AM, Polman RCJ. Pacing and awareness: brain regulation of physical activity. Sports Medicine. 2013;43:1057-64.
3. Smits BLM, Pepping G-J, Hettinga FJ. Pacing and decision making in sport and exercise: the roles of perception and action in the regulation of exercise intensity. Sports Medicine. 2014;44:763-75.
4. Renfree A, Martin L, Micklewright D, Gibson ASC. Application of decision-making theory to the regulation of muscular work rate during self-paced competitive endurance activity. Sports Medicine. 2014;44(2):147-58.
5. Konings MJ, Hettinga FJ. Pacing Decision Making in Sport and the Effects of Interpersonal Competition: A Critical Review. Sports Medicine. 2018;48(8):1829-43.
6. Foster C, Schrager M, Snyder AC, Thompson NN. Pacing strategy and athletic performance. Sports Medicine. 1994;17(2):77-85.
7. Abbiss CR, Laursen PB. Describing and understanding pacing strategies during athletic competition. Sports Medicine. 2008;38:239-52.
8. Muehlbauer T, Melges T. Pacing Patterns in Competitive Rowing Adopted in Different Race Categories. 2011;25(5):1293-8.
9. Micklewright D, Papadopoulou E, Swart J, Noakes TD. Previous experience influences pacing during 20 km time trial cycling. British journal of sports medicine. 2010;44:952-60.
10. Edwards AM, Noakes TD. Dehydration. Sports Medicine. 2009;39(1):1-13.
11. Konings MJ, Hettinga FJ. The impact of different competitive environments on pacing and performance. International journal of sports physiology and performance. 2018;13(6):701-8.
12. Hanley B, Hettinga FJ. Champions are racers, not pacers: an analysis of qualification patterns of Olympic and IAAF World Championship middle distance runners. Journal of Sports Sciences. 2018;36(22):2614-20.
13. Casado A, Hanley B, Jiménez-Reyes P, Renfree A. Pacing profiles and tactical behaviors of elite runners. Journal of Sport and Health Science. 2020.
14. Hettinga FJ, Edwards AM, Hanley B. The Science Behind Competition and Winning in Athletics: Using World-Level Competition Data to Explore Pacing and Tactics. Frontiers in Sports and Active Living. 2019;1(11).
15. Filipas L, La Torre A, Hanley B. Pacing profiles of Olympic and IAAF World Championship long distance runners. Journal of strength and conditioning research. 2018.
16. Hanley B. An Analysis of Pacing Profiles of World-Class Racewalkers. International Journal of Sports Physiology and Performance. 2013;8(4):435.
17. Hanley B. An analysis of pacing profiles of world-class racewalkers. Int J Sports Physiol Perform. 2013;8(4):435-41.
18. Menting SGP, Hendry DT, Schiphof-Godart L, Elferink-Gemser MT, Hettinga FJ. Optimal Development of Youth Athletes Toward Elite Athletic Performance: How to Coach Their Motivation, Plan Exercise Training, and Pace the Race. Frontiers in Sports and Active Living. 2019;1(14).

19. Micklewright D, Angus C, Suddaby J, St Clair GA, Sandercock G, Chinnasamy C. Pacing strategy in schoolchildren differs with age and cognitive development. Medicine & Science in Sports & Exercise. 2012;44:362-9.
20. Foster C, Hendrickson KJ, Peyer K, Reiner B, Lucia A, Battista RA, et al. Pattern of developing the performance template. British journal of sports medicine. 2009;43:765-9.
21. Wiersma R, Stoter IK, Visscher C, Hettinga FJ, Elferink-Gemser MT. Development of 1500-m Pacing Behavior in Junior Speed Skaters: A Longitudinal Study. International Journal of Sports Physiology and Performance. 2017;12:1-20.
22. Schiphof-Godart L, Hettinga FJ. Passion and Pacing in Endurance Performance Frontiers in Physiology 2017;8 83.
23. Menting SGP, Elferink-Gemser MT, Huijgen BC, Hettinga FJ. Pacing in lane-based head-to-head competitions: A systematic review on swimming. Journal of sports sciences. 2019;37(20):2287-99.
24. Menting SGP, Konings MJ, Elferink-Gemser MT, Hettinga FJ. Pacing Behavior of Elite Youth Athletes: Analyzing 1500-m Short-Track Speed Skating. International Journal of Sports Physiology and Performance. 2019;14:222-31.
25. Menting SGP, Huijgen BC, Konings MJ, Hettinga FJ, Elferink-Gemser MT. Pacing Behavior Development of Youth Short-Track Speed Skaters: A Longitudinal Study. Medicine & Science in Sports & Exercise. 2020;52(5):1099-108.
26. Mytton GJ, Archer DT, St Clair Gibson A, Thompson KG, Gibson AS, Thompson KG, et al. Reliability and Stability of Performances in 400-m Swimming and 1500-m Running. Int J Sports Physiol Perform. 2014;9:674-9.
27. Elferink-Gemser MT, Hettinga FJ. Pacing and Self-Regulation: Important Skills for Talent Development in Endurance Sports. International Journal of Sports Physiology and Performance. 2017:1-17.
28. IAAF. Competition Archive iaaf.org2019 [Available from: http://www.iaaf.org/results.
29. Hopkins W, Marshall S, Batterham A, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Medicine & Science in Sports & Exercise. 2009;41(1):3.
30. Konings MJ, Noorbergen OS, Parry D, Hettinga FJ. Pacing behavior and tactical positioning in 1500-m short-track speed skating. International journal of sports physiology and performance. 2016;11(1):122-9.
31. Edwards A, Polman R. Pacing in sport and exercise: a psychophysiological perspective: Nova Science Publishers; 2012.
32. Zouhal H, Abderrahman AB, Prioux J, Knechtle B, Bouguerra L, Kebsi W, et al. Drafting's Improvement of 3000-m Running Performance in Elite Athletes: Is It a Placebo Effect? Int J Sports Physiol Perform. 2015;10(2):147-52.
33. Konings MJ, Schoenmakers PPJM, Walker AJ, Hettinga FJ. The behavior of an opponent alters pacing decisions in 4-km cycling time trials. Physiology & behavior. 2016;158:1-5.
34. Menting SGP, Elferink-Gemser MT, Edwards AM, Hettinga FJ. Effects of experience and opponents on the pacing behaviour and 2-km cycling performance of novice youths. . Research Quarterly for Exercise and Sport. 2019;90(4):609-18.
35. Lambrick D, Rowlands A, Rowland T, Eston R. Pacing strategies of inexperienced children during repeated 800 m individual time-trials and simulated competition. Pediatric exercise science. 2013;25:198-211.
36. Aragón S, Lapresa D, Arana J, Anguera MT, Garzón B. Tactical behaviour of winning athletes in major championship 1500-m and 5000-m track finals. European Journal of Sport Science. 2016;16(3):279-86.
37. Deaner RO, Lowen A. Males and females pace differently in high school cross-country races. Journal of strength and conditioning research. 2016;30(11):2991-7.
38. Malina RM, Bouchard C, Bar-Or O. Growth, maturation, and physical activity: Human kinetics; 2004.

39. Blakemore SJ, Burnett S, Dahl RE. The role of puberty in the developing adolescent brain. Human brain mapping. 2010;31:926-33.
40. Hettinga FJ, Konings MJ, Pepping G-J. The science of racing against opponents: Affordance competition and the regulation of exercise intensity in head-to-head competition. Frontiers in Physiology. 2017;8.
41. Lander PJ, Butterly RJ, Edwards AM. Self-paced exercise is less physically challenging than enforced constant pace exercise of the same intensity: influence of complex central metabolic control. British Journal of Sports Medicine. 2009;43(10):789-95.
42. Renfree A, Mytton GJ, Skorski S, Gibson ASC. Tactical Considerations in the Middle-Distance Running Events at the 2012 Olympic Games: A Case Study. International Journal of Sports Physiology and Performance. 2014;9(2):362.
43. Renfree A, Gibson ASC. Influence of different performance levels on pacing strategy during the Women's World Championship marathon race. International Journal of Sports Physiology and Performance. 2013;8(3):279-85.
44. Thiel C, Foster C, Banzer W, De Koning J. Pacing in Olympic track races: competitive tactics versus best performance strategy. Journal of sports sciences. 2012;30(11):1107-15.
45. Mytton GJ, Archer DT, Thompson KG, Renfree A, Gibson ASC. Validity and reliability of a 1500-m lap-time collection method using public videos. International Journal of Sports Physiology and Performance. 2013;8(6):692-4.
46. Elferink-Gemser MT, te Wierike SC, Visscher C. 16 Multidisciplinary Longitudinal Studies: A Perspective from the Field of Sports. The Cambridge Handbook of Expertise and Expert Performance. 2018:271.

Table 1. Means (± SD) for age (years) and finish time (min:s) as well as the outcome of the tests for a difference in pacing behaviour between the athletes with differing final rankings (medallists, Top 8/12, rest of the field), per discipline, distance and sex.

Discipline	Distance (m)	Sex	Age category	Age	Finish time (min:s)			Pacing behaviour (split times* final ranking)
					Medallists	Top 8 / Top 12	Rest of the field	
Run	3000	Male	U18	16.7 (± 0.7)	07:49.0 (± 1.75)	08:20.1 (± 15.1)	08:57.4 (± 23.8)	$F_{4,18} = 9.96$ $P \leq 0.001$, large.
		Female	U18	16.8 (± 0.6)	09:25.9 (± 2.20)	09:47.3 (±	10:45.6 (±	$F_{4,20} = 9.73$ $P \leq 0.001$, large.
	5000	Male	U20	17.6 (± 1.0)	13:20.5 (± 0.32)	13:40.8 (± 25.4)	14:46.7 (± 34.3)	$F_{2.89, 24.56} = 9.65$ $P \leq 0.001$, large.
		Female	U20	18.5 (± 0.9)	15:31.9 (± 1.84)	15:50.5 (± 6.1)	16:35.6 (± 24.4)	$F_{4.13, 22.70} = 13.49$ $P \leq 0.001$, large.
	10,000	Male	U20	18.8 (± 0.6)	27:36.6 (± 14.04)	29:29.9 (± 56.2)	31:28.5 (± 40.8)	$F_{6.67, 83.36} = 9.23$ $P \leq 0.001$, large.
Race Walk	5000	Female	U18	17.0	22:39:2	23:24.5	25:13.9	$F_{6.62, 175.52} = 17.06$

				(± 0.5)	(± 6.65)	(± 21.7)	(58.6)	*P* ≤ 0.001, large.
	10,000	Male	U18	16.8 (± 0.5)	41:59.1 (± 43.5)	43:51.0 (± 69.0)	47.18.7 (± 103.3)	$F_{8.72, 248.61} = 4.16$ *P* ≤ 0.001, large.
			U20	18.6 (± 0.6)	42:26.7 (± 120.9)	43:43.4 (± 132.8)	47.22.9 (± 212.8)	$F_{6.55, 98.25} = 9.67$ *P* ≤ 0.001, large.
		Female	U18	18.4 (± 0.6)	44:17.0 (± 2.83)	45:48.6 (± 37.9)	50:15.5 (± 118.2)	$F_{5.88, 88.23} = 8.98$ *P* ≤ 0.001, large.

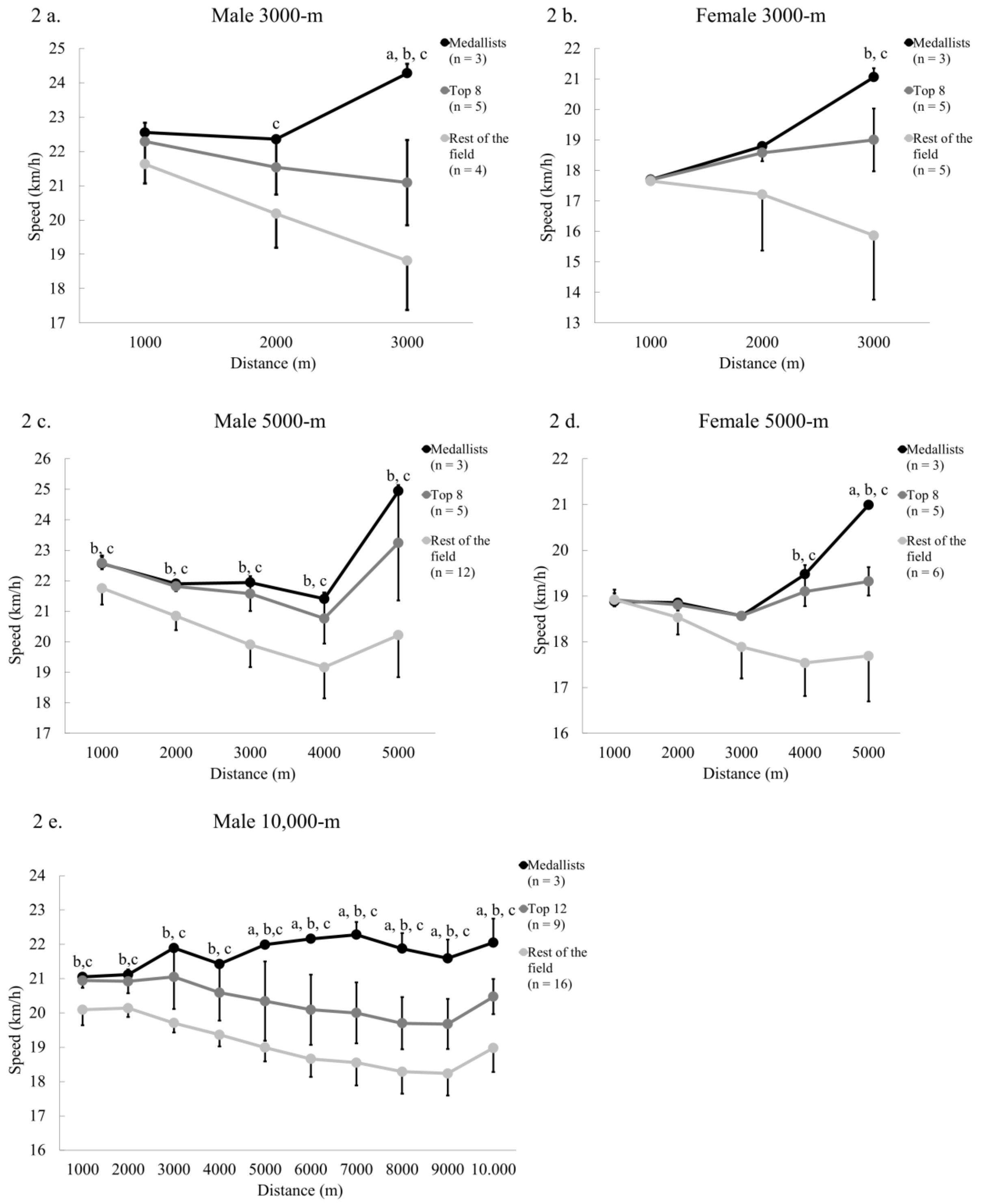

Figure 1. Mean (SD) 1000-m segment speed of young athletes during 3000 m, 5000 m and 10,000 m running events. Significant differences ($P < 0.05$, $d \geq 0.61$) between athletes with different final rankings are annotated as: a = difference between medallists and Top 8 (5000 m) or Top 12 (10,000 m), b = difference between Top 8 (5000 m) or Top 12 (10,000 m) and the rest of the field, c = difference between medallists and the rest of the field.

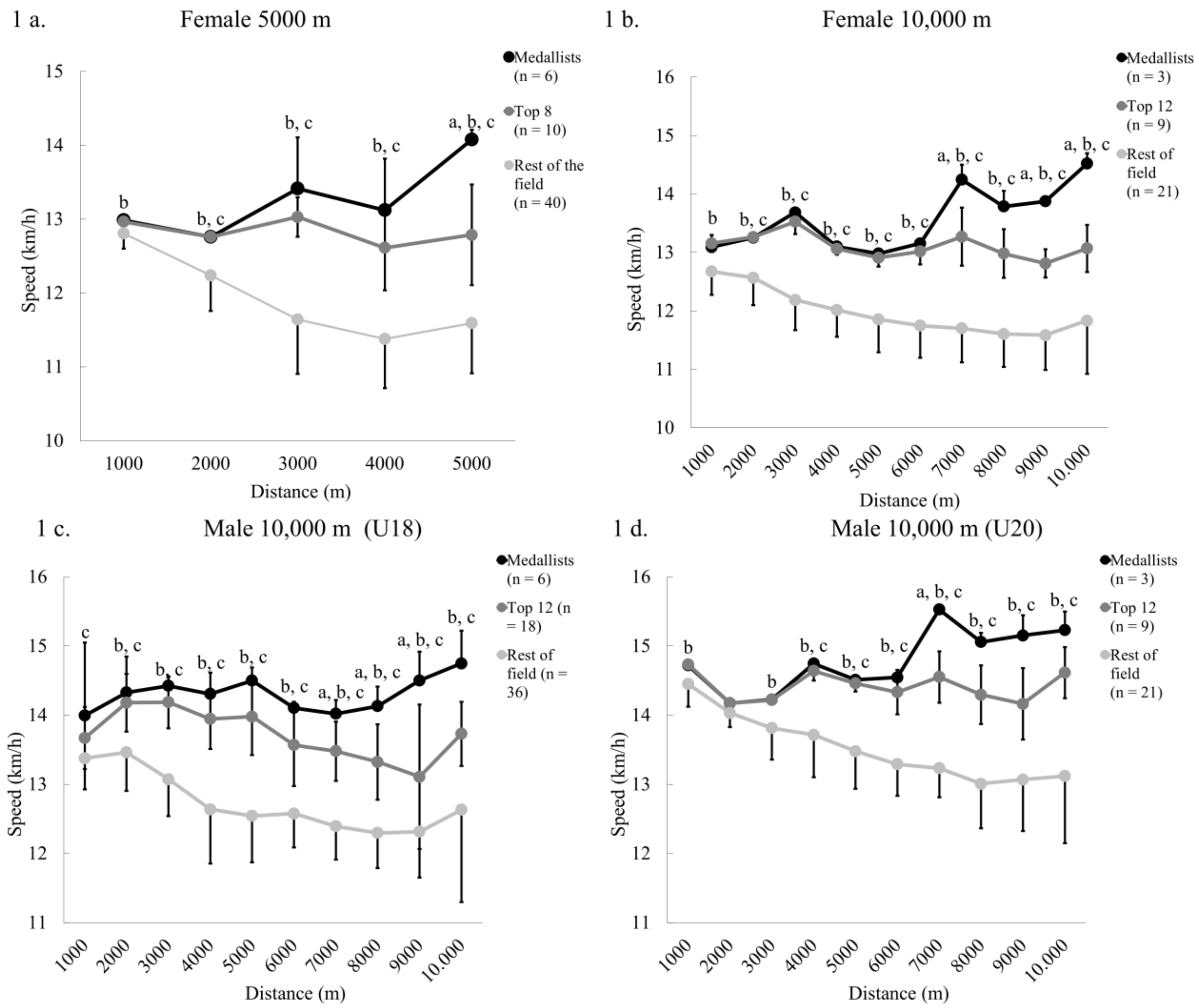

Figure 2. Mean (SD) 1000 m segment speed of young athletes during 5000 m and 10,000 m race walk events. Significant differences ($P < 0.05$, $d \geq 0.61$) between athletes with different final rankings are annotated as: a = difference between medallists and Top 8 (5000 m) or Top 12 (10,000 m), b = difference between Top 8 (5000 m) or Top 12 (10,000 m) and the rest of the field, c = difference between medallists and the rest of the field.

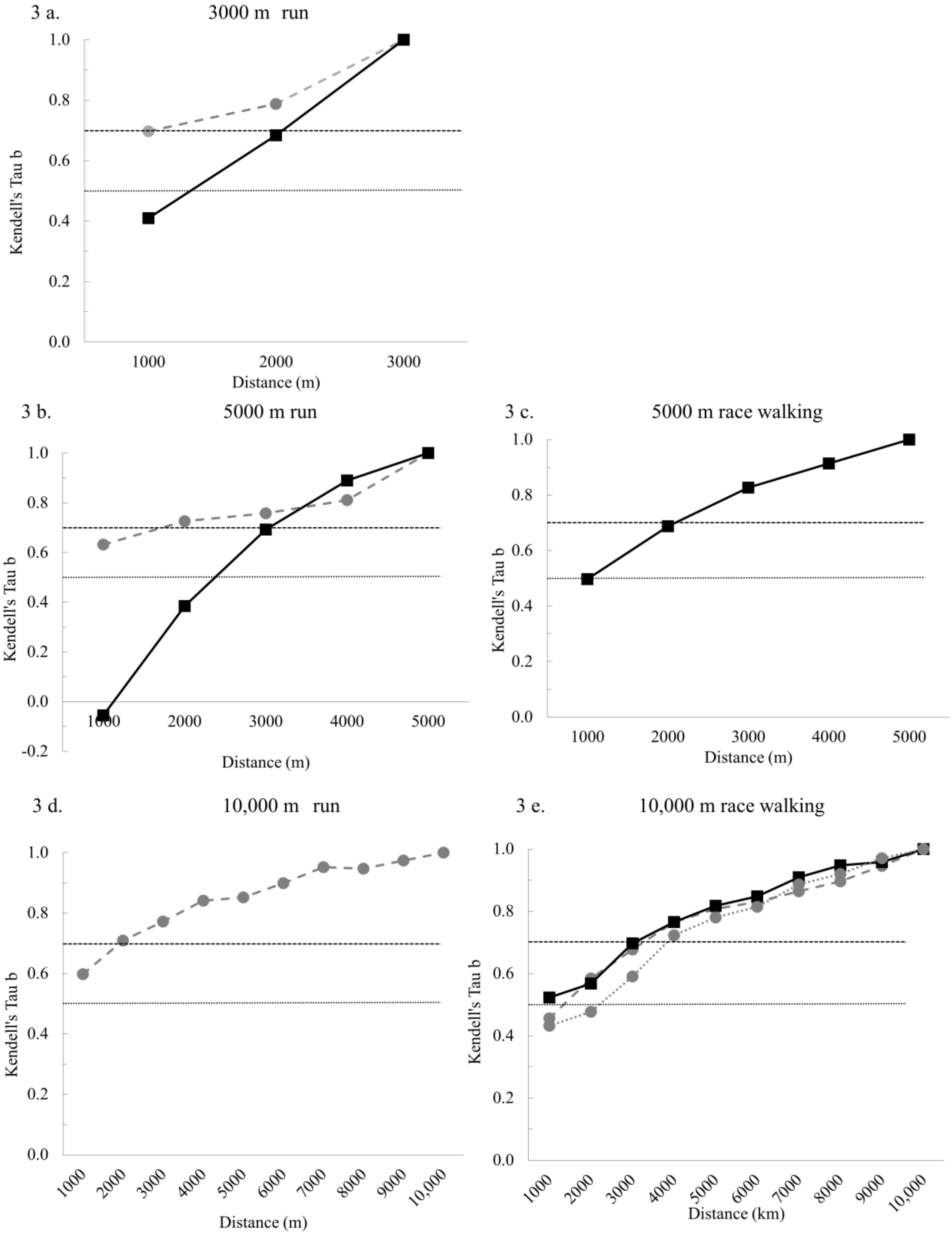

Figure 3. Correlation between position at 1000 m segments and final ranking. Black squares indicating females, grey circles indicating males. In the 10,000 m race walking event, U18 males are indicated with a fine dotted line and U20 males with a broad dotted line. The two horizontal lines indicate a Kendell's Tau b correlation of 0.5 (moderate) and 0.7 (high), respectively.