Successful world-class 10,000 m runners display greater pace variation and form packs more than less successful competitors.

Running head: *Pacing in world-class distance races*

Andrew Renfree[1], Arturo Casado[2], Gonzalo Pellejero[3] and Brian Hanley[4]

[1]Insititute of Sport and Exercise Science, University of Worcester, Worcester, UK.
[2]Faculty of Health Sciences, Isabel I de Castilla University, Burgos, Spain.
[3]Techfriendly SL, Barakaldo, Spain.
[4]Carnegie School of Sports, Leeds Beckett University, United Kingdom.

Corresponding author: Dr. Arturo Casado, Department of Physical Education, Faculty of Physical Activity and Sport Sciences, Isabel I University. Calle Fernán González, 76; 09003; Burgos, SPAIN. E-mail: arturocasado1500@gmail.com
Tel: +34 947671731 ORCID: 0000-0001-7668-6844

Disclosures: There is no disclosure of funding to report for this study. Authors report no conflict of interest

Key words: Athletics, Middle distance, Tactics, Pacing.

Abstract word count: 245
Word count: 3242
Number of figures and tables: 1 Figure & 4 Tables

Successful world-class 10,000 m runners display greater pace variation and form packs more than less successful competitors.

Abstract

Purpose

To determine different relationships between, and predictive ability of, performance variables at intermediate distances with finishing time in elite male 10,000 m runners.

Methods

Official electronic finishing and 100 m split times of the men's 10,000 m finals at the 2008 and 2016 Olympic Games and IAAF World Championships in 2013 and 2017 were obtained (125 athlete performances in total). Correlations were calculated between finishing times and positions and performance variables relating to speed, position, time to the leader and time to the runner in front at 2000, 4000, 6000, 8000 and 9900 m. Stepwise linear regression analysis was conducted between finishing times and positions and these variables across the race. One-way ANOVA was performed to identify differences between intermediate distances.

Results

The standard deviation and kurtosis of mean time, skewness of mean time and position and time difference to the leader were either correlated with or significantly contributed to predictions of finishing time and position at one of the analysed distance at least ($0.81 \geq r \geq 0.30$ and $0.0001 \leq P \leq 0.03$, respectively). These variables also displayed variation across the race ($0.0001 \leq P \leq 0.05$).

Conclusions

The ability to undertake a high degree of pace variability, mostly characterised by acceleration in the final stages, is strongly associated with the achievement of high finishing positions in championship 10000 m racing. Furthermore, the adoption and maintenance of positions close to the front of the race from the early stages is important to achieve a high finishing position.

Keywords: PACING, ENDURANCE PERFORMANCE, TACTICS, RUNNING

Introduction

Optimal pacing is a fundamental requirement of successful performance in endurance athletic event,[1] and is an ongoing process reliant on continuous decision-making.[2] Previous analyses of successful competitors in running, [3,4] rowing[5] and speed skating [6] have demonstrated that faster performances in events lasting longer than 2 min are associated with a pacing strategy characterised by a quick start, deceleration or maintenance through the middle stages, and an acceleration or "endspurt" close to the end. This U-shaped pacing profile[7] has also been displayed in laboratory-based cycling time trials[1,8] and is thought to provide evidence of a physiological control system that regulates muscular work to prevent catastrophic loss of homeostasis.[9]

In championship running events, however, rewards are based on finishing position regardless of time taken to cover the distance,[2] meaning tactical behaviours deployed to finish ahead of other competitors can be more important than when the achievement of a fast finishing time is the primary goal. Indeed, previous analyses of elite championship running events have demonstrated that tactical behaviours are strongly associated with eventual finishing position.[10,11,12,13] For example, research on half marathon championship races[14] showed that covering most of the distance in a group with other runners led to superior performance than covering large portions of the distance alone. Such group membership provides benefits to the individual when the risks associated with membership are lower than those posed by non-membership. For example, group membership allows individuals to benefit from the potential for "drafting" behind competitors, thereby reducing the energetic cost of activity.[15,16] Similarly, an individual might opt for group membership for tactical reasons, as race position in the early and intermediate stages of endurance events is associated with achievement of a high finishing position.[17] However, non-membership of a group could equally confer an advantage if it leads to the selection of a more appropriate muscular work rate that allows an individual to optimise their own overall mean competition speed. Indeed, in an analysis of a women's World Championship marathon race, it has been demonstrated that athletes able to adopt individually optimal pacing strategies allowing greater realisation of performance potential could have achieved superior results in terms of finishing position. [17] Nonetheless, such a strategy could also be perceived as conferring a high degree of risk, especially if it means falling some distance behind direct competitors in the early stages of competition, or if it results in a clear lead that isolates the athlete for long periods.

Although absolute performance ability, reflected by season's best times,[17] intermediate positioning,[10,12] pace variability,[18] and group formation[14,19] have been associated with race outcomes in championship middle- and long-distance running events, the relative importance of each of these variables is unclear. These studies have typically been descriptive in nature or have calculated simple probabilities of specific race outcomes based on behaviours in various sections of races. As a result, their usefulness for coaches or scientists working with elite athletes is limited, and a new, more in-depth study that examines the specific contribution of these different factors is timely and necessary. The aim of this study was therefore to complete a novel analysis of elite athlete performance data using stepwise regression techniques to identify the contribution of each variable to finishing position and finishing time in 10,000 m world-class runners. We hypothesise that athletes who finished closer to the front of races will display greater pace variability, and spend more time running in packs than those who finished in lower positions.

Methods

Official electronic finishing and 100 m split times of the men's 10,000 m finals at the 2008 and 2016 Olympic Games and IAAF World Championships in 2013 and 2017 were obtained from the open-access IAAF website.[20,21] Overall, this is an observational research in which the performances of 125 athletes were analysed. The mean time per 100 m segment for each athlete was calculated, along with its standard deviation (SD), skewness and kurtosis. Similarly, the mean racing position at the end of each 100 m segment for each athlete was calculated as well as its SD, skewness and kurtosis. The time differences to the leader and to the runner immediately ahead at each 100 m distance were also calculated for each individual athlete.

The SDs of the time and position per 100 m segment indicate the variation in these variables, whereas skewness is a measure of the asymmetry of the distribution. A positive skewness means the right tail of the distribution is longer and the mass of the distribution is concentrated on the left of the figure. A negative skewness means the opposite. For example, a negative skewness of the mean time per 100 m segment would mean that an athlete maintained a relatively constant speed during most of the race, but also ran at higher speeds for short durations. A negative skewness of the mean position per 100 m segment would mean the athlete maintained a similar position throughout most of the race but was in a higher position for short periods. This situation would occur, for example, when an athlete accelerates during the final stages of the race and overtakes other competitors. Kurtosis of the mean time and mean position per 100 m segment refers to the "tailedness" of their distributions. A high kurtosis implies the existence of infrequent extreme deviations, as opposed to frequent modestly sized deviations. For example, a high kurtosis of the mean time per 100 m segment would mean that an athlete demonstrated extreme speed fluctuations (running very slow at some stages and fast at others) throughout the race, and a high kurtosis of mean position demonstrates that the position of the athlete changed regularly during the race. Conversely, a low skewness of mean time per 100 m segment would suggest an even pace throughout the race. Finally, the time difference to the runner in front is an indication of the degree of "packing" during the race. To illustrate this concept, an example has been provided. A hypothetical runner B would have beaten a hypothetical runner A by running faster during the latter stages of a race although they were running together for most of the distance. In this way, runner B would have displayed higher kurtosis and a more negative skewness of speed than runner A, with a longer left tail in the curve representing the distribution of times per segment covered throughout a race. (Figure 1).

Figure 1 near here

The athletes' best times from the previous 12 months were obtained from the All-Athletics website (www.all-athletics.com); for example, for those athletes competing in the 2017 IAAF World Championships, their best time was recorded between January 1st, 2015 and the beginning of the championships in August 2017. We chose this time frame because the tactical nature of races mean athletes often run slower than their best times at major championships, and because using season's best times could lead to underestimation of ability due to injuries or because of periodisation in training (i.e., not peaking until the championships).[11] These times were 1664.3 ± 32.0 s.

Statistical analysis

Statistical analyses of data were performed using the Statistical Package for the Social

Sciences 24.0 (SPSS, Chicago, IL, USA). Data were screened for normality of distribution and homogeneity of variances using a Shapiro-Wilk normality test and a Levene test, respectively. When the assumption of sphericity was violated, Greenhouse–Geisser corrections were employed. Linear regression assumptions were checked using residual versus fitted, normal QQ, and Cook's distance plots. Pearson's correlations were calculated between finishing times and final positions with 32 months' best times, mean time per 100 m segment (and its SD, skewness and kurtosis), mean position per 100 m segment (and its SD, skewness and kurtosis), time difference to the leader and time difference to the runner in front (all at 2000, 4000, 6000, 8000 and 9900 m). Correlation effects were interpreted as small (r value of 0.10 – 0.29), moderate (0.30 – 0.49), large (0.50 – 0.69) or very large (≥ 0.70).[22] Two stepwise linear regression analyses were conducted between finishing times and positions and the variables described at 2000, 4000, 6000, 8000 and 9900 m. Only variables that were correlated significantly to finishing times or positions at any analysed distance (2000, 4000, 6000, 8000 and 9900 m) were introduced into the stepwise regression analysis. Pearson's multivariate coefficient of determination (R^2), unstandardized beta (regression) coefficient (B), standard error of B (B SE), standardized beta (regression) coefficient (β), and F for change in R^2 were calculated.

One-way (time) repeated measures analysis of variance (ANOVA) were conducted on the different variables studied (excepting position and mean position per 100 m segment because they display the same mean and SD across time) with Bonferroni post hoc to identify changes between successive analysed distances. Statistical significance was accepted at $P < 0.05$. Effect sizes (ES) were calculated using partial eta-squared (η_p^2) for the ANOVA tests, and Cohen's d [23] for the post hoc analyses. The latter was considered to be either small (0.21 – 0.60), moderate (0.61 – 1.20), large (1.21 – 2.00), very large (2.01 – 4.00) or nearly perfect (> 4.00).[22] Differences were considered to occur when $P < 0.05$ and Cohen's d displayed at least a moderate effect ($d \geq 0.61$). All data are presented as mean ± SD.

Results

All races were characterised by frequent fluctuations in running speed, race position, and pack membership. For illustrative purposes, figure 2 displays cumulative speed to each 100 m point of all competitors in the 10000 m race at the 2008 Beijing Olympic Games race.

*** Figure 2 near here ***

Table 1 shows the means and standard deviations of TS, SD of TS, skewness and kurtosis of TS, position skewness and kurtosis of TS, position, SD of PS, time difference to the leader and the runner immediately in front and 32 months' best times at 2000, 4000, 6000, 8000 and 9900 m.

****Table 1 here****

Table 2 shows the results of the Pearson's correlations for these variables with finishing times and positions. The strength of the correlations of the SD of the TS with finishing times (Table 2) increased continuously with distance until it became very large by 6000

m. The correlation with finishing position (Table 2) was moderate at this distance. The skewness of the TS was not strongly correlated with finishing times or finishing positions (Table 2). Skewness of position was negatively correlated with positions (Table 2) throughout, although this relationship with finishing time was not evident. The kurtosis values of the TS and position were weakly correlated to both finishing times and positions (Table 2). The time difference to the runner in front was strongly correlated with finishing times, demonstrating a large or very large effect at all points after 2000 m (Table 2). In addition, 32 months' best times were moderately correlated with finishing positions ($r = 0.36$, $P = 0.03$).

****Table 2 here****

The results of the stepwise regression analyses at 2000, 4000, 6000 and 8000 m are presented in Tables 3 and 4. The time difference to the leader, mean time per 100 m segment, the SD of mean time per 100 m segment, skewness of mean position per 100 m segment and kurtosis of mean time per 100 m segment were significant predictors of finishing time at all stages (Table 3). The mean time per 100 m segment and mean position per 100 m segment were significant predictors of finishing position (Table 4).

****Table 3 here****

****Table 4 here****

The time effect for mean time per 100 m segment was significant ($F_{1.33,165.14} = 8.02$, $P < 0.001$, $\eta_p^2 = 0.061$), increasing from 6000 m to 8000 m (p = 0.006, $d = 0.90$). The time effect for the SD of mean time per 100 m segment was significant ($F_{1.65,205.66} = 5.64$, $P = 0.007$, $\eta_p^2 = 0.044$) as was the time effect for skewness of mean time per 100 m segment ($F_{2.37,294.38} = 8.22$, $P < 0.001$, $\eta_p^2 = 0.062$). The time effect for kurtosis of mean time per 100 m segment was significant ($F_{1.62,201.06} = 6.53$, $P = 0.004$, $\eta_p^2 = 0.05$) and increased from 2000 m to 4000 m ($P < 0.001$, $d = 0.62$). The time effect for SD of mean position per 100 m segment was significant ($F_{1.77,219.18} = 24.85$, $P < 0.001$, $\eta_p^2 = 0.167$), increasing from 2000 m to 4000 m ($P < 0.001$, $d = 0.62$). The time effect for skewness of mean position per 100 m segment was significant ($F_{2.06,255.67} = 3.00$, $P = 0.05$, $\eta_p^2 = 0.024$), as was the time effect for kurtosis of mean position per 100 m segment ($F_{2,247.99} = 20.42$, $P < 0.001$, $\eta_p^2 = 0.141$). The time effect for time difference to the leader was significant ($F_{1.17,144.72} = 19.12$, $P < 0.001$, $\eta_p^2 = 0.134$), and the time effect for time difference to the runner in front was also significant ($F_{1.174,215.58} = 6.75$, $P = 0.002$, $\eta_p^2 = 0.052$).

Discussion

The aim of this study was to complete a novel analysis of elite athlete performance data using stepwise regression techniques to identify the contribution of each variable to finishing position and finishing time in 10,000 m world-class runners. The results of the analyses presented in this paper demonstrate that the measured performance variable of SD of mean time per 100 m segment was strongly related to finishing time, suggesting that superior overall performances were associated with a greater degree of pace variability. This greater variability is likely the result of a greater degree of acceleration, or endspurt, in the final stages, a finding that is consistent with the observations of Filipas et al.[11] and Thiel et al. [24] in 10,000 m races and Mytton et al.[18] in championship 1500 m races. The high degree of variability could also be partially due to relatively slow initial speeds that are typical of championship in comparison with non-championship races where pacemakers are often employed to facilitate the achievement of fast finishing times. We do acknowledge that a high SD of time per 100 m segment could also result from large decelerations in the later stages by athletes who were unable to maintain their initial speeds. However, the effect of this variable increased with athletes' performance standard and the ability to vary pace is therefore a key component of successful 10,000 m racing (i.e., achieving a high finishing position) that needs practice in training.

The skewness of the mean position per 100 m segment was negatively correlated with both finishing time and position, suggesting that runners who achieved high finishing positions maintained stable positions close to the lead throughout the race. Furthermore, the predictive ability of this variable on both finishing time and position is very high even early in the race, suggesting that the adoption and maintenance of a high position from the early stages of a 10,000 m race is important if the goal is to finish in the leading positions. This finding is similar to the observation of Aragón et al.[25] who found that winners of men's 5000 m races at major championships (European and World Championships and Olympic Games) maintained a position within the leading five athletes throughout the race and were within the leading three positions when a fast sprint was initiated during the last lap. Given that there is a limit as to how much distance a trailing athlete may realistically catch up in the endspurt,[26] it seems athletes aiming to finish in leading positions should run closely to their main rivals (which might not include the leader, if they are judged to have run too quickly too early), even if a this requires a potentially more fatiguing variable pace than is normally associated with faster finishing times.

In our analysis, low values of kurtosis would suggest the race was characterised by an even pace. Therefore, an increase in kurtosis of mean throughout the race would mean pace variability was also increasing throughout. Given that kurtosis of both mean times and positions increased during the race until the 8 km, this suggests runners pace and position were changing substantially until that point. In this way, these data are similar to those regarding SD of mean times and mean position, which also increased throughout the race. Therefore, this increase in kurtosis appears related to the duration for which competitors were largely running together (until the 8 km point), an observation that is in agreement with previous observations.[11] The absence of an increase in kurtosis of mean time and position between this point and the end of the race may be the result of both the end spurt displayed by the runners who achieved higher finishing positions and the deceleration of athletes who dropped back from the leading group during this period.[11] The two possible explanations for this phenomenon, may therefore suggest limited application as a measure of race behaviors, given that we are unable to identify a precise cause. Nonetheless, the most interesting feature of this variable (kurtosis) in the analysis of pacing profiles during endurance races is that it allows quantification of evenness of pace and intermediate positioning. Furthermore, it may allow prediction of eventual finishing times at either the 4 km point or the 8 km point (Table 3).

Athletes typically run at speeds similar to other competitors, resulting in pack formation, at least in the early stages of races [17,19,27,28] to obtain the potential benefits of pack running. Indeed, athletes have been found to slow at the same rate as other competitors in trying to maintain a pack, rather than adopting their own speed.[27] In the present analysis, the time difference to the runner in front was a strong predictor of finishing time, suggesting that athletes who ran in tightly packed groups were more likely to finish in high positions than those who ran separately for large portions of the race, a finding similar to that reported following an analysis of IAAF World Championship half marathon runners.[14] Further evidence that athletes spent much of the races (included in these analyses) in packs is provided by the skewness values that demonstrate athletes maintained relatively stable speeds and positions for most of the distance. The reason for the apparent benefit of running in a pack is not completely clear but could result from the energetic savings incurred by drafting,[15.16] which can preserve physiological reserve capacity in the early stages and thereby allowing a greater final acceleration. Alternatively, the presence of other competitors acts as social facilitators[29] or reduces mental fatigue induced through continuous tactical decision-making[30] that occurs when athletes must self-pace entirely.

Regardless of the possible reasons, pack running has been shown in this novel study to be an important factor in better 10,000 m performances in championship racing; specifically, athletes aiming for medal-winning or other high finishing positions are advised to stay close to the leader throughout and in a pack with those other athletes of similar ambition and ability.

Conclusions

In conclusion, these analyses of elite men's 10,000 m races demonstrate that the achievement of high finishing positions is associated with the ability to produce high pace variability, and in particular the ability to produce a large final acceleration or endspurt. This ability can be facilitated by running in a pack of other runners for most of the race, which potentially acts to reduce the energetic costs of running and decrease the development of mental fatigue. The relative importance of tactical factors, as opposed to physiological factors, in determining race outcomes remains uncertain. Although we assessed the relationship between various tactical and performance variables and eventual race outcome in a relatively homogenous group of elite athletes, it is nevertheless unclear to what extent tactical decision-making can compensate for inferior physiological capacity. It would seem likely that the greater physiological reserve capacity [30] in superior athletes provides an advantage in that it increases the number of behavioural options available at any point in the race.[2] However, we acknowledge this statement may be considered rather speculative given that we have no data regarding the actual physiological capacities of the athletes in these competitions.

Practical applications

Based on these analyses, some practical recommendations can be made for competitors in championship 10000 m running events and their coaches. First, the physiological ability to produce wide variations in pace is an important determinant of success in events of this kind. The physical preparation required to develop this might well differ from that which prepares athletes to run fast times at a steady speed. Secondly, and in line with previous analyses of other distance races,[14] it seems as though athletes who spend most of the race running in a pack have an advantage over those who run alone. This may have implications for those who train alone, and suggests that training in groups may positively effect performance.[29]

Acknowledgements

The authors would like to thank Dr Louise Martin of the University of Worcester for her constructive feedback on this manuscript.

References

1) Foster C, Schrager M, Snyder AC, Thompson NN. Pacing strategy and athletic performance. *Sports Med*, 1994:17(2):77-85.
2) Renfree A, Martin L, Micklewright D, St Clair Gibson A. Application of decision-making theory to the regulation of muscular work rate during self-paced competitive endurance activity. *Sports Med*, 2014:44(2): 147-158.
3) Tucker R, Lambert MI. Noakes TD. An analysis of pacing strategies during men's world-record performances in track athletics. *Int J Sports Physiol Perform*, 2006:1(3):233-245.
4) Noakes TD, Lambert MI. Hauman R. Which lap is the slowest? An analysis of 32 world mile record performances. *Br J Sports Med*, 2009:43(10):760-764.
5) Garland SW. An analysis of the pacing strategy adopted by elite competitors in 2000 m rowing. *Br J Sports Med*, 2005: 39(1):39-42.
6) Muehlbauer T, Schindler C, Panzer, S. Pacing and performance in competitive middle-distance speed skating. *Res Q Exerc Sport*, 2010: 81(1):1-6.
7) Abbiss CR, Laursen PB. Describing and understanding pacing strategies during athletic competition. *Sports Med*, 2008: 38(3):239-252.
8) Hettinga FJ, De Koning JK, Meijer E, Teunissen L, Foster C. Effect of pacing strategy on energy expenditure during a 1500-m cycling time trial. *Med Sci Sports Exerc*, 2007: 39(12):2212-2218.
9) St Clair Gibson A, Noakes TD. Evidence for complex system integration and dynamic neural regulation of skeletal muscle recruitment during exercise in humans. *Br J Sports Med*, 2004:38(6):797-806.
10) Renfree A, Mytton GJ, Skorski S, St Clair Gibson A. Tactical considerations in the middle-distance running events at the 2012 Olympic Games: a case study. *Int J Sports Physiol Perform*, 2014: 9(2):362-364.
11) Filipas L, La Torre A, Hanley B. Pacing profiles of Olympic and IAAF World Championship long-distance runners. *J Strength Cond Res*, 2008 DOI: 10.1519/JSC.0000000000002873
12) Casado A, Renfree A. Fortune favors the brave: tactical behaviors in the middle-distance running events at the 2017 IAAF World Championships. *Int J Sports Physiol Perform*, 2018: 13(10):1386-1391.
13) Hanley B, Stellingwerff T, Hettinga FJ. Successful pacing profiles of Olympic and IAAF World Championship middle-distance runners across qualifying rounds and finals. *Int J Sports Physiol Perform*, 2019:*14*(7):894-901.
14) Hanley B. Pacing profiles and pack running at the IAAF World Half Marathon Championships. *J Sports Sci*, 2015: *33*(11):1189-1195.
15) Pugh LG. Oxygen intake in track and treadmill running with observations on the effect of air-resistance. *J Physiol,* 1970: 207(3): 823–835.
16) Pugh LG. The influence of wind resistance in running and walking and the mechanical efficiency of work against horizontal or vertical forces. *J Physiol,* 1971: 213(2): 255–276.
17) Renfree A, St Clair Gibson A. Influence of different performance levels on pacing strategy during the Women's World Championship marathon race. *Int J Sports Physiol Perform*, 2013: 8(3):279-285.
18) Mytton GJ, Archer DT, Turner L, Skorski S, Renfree A, Thompson KG, St Clair Gibson A. Increased variability of lap speeds: differentiating medalists and nonmedalists in middle-distance running and swimming events. *Int J Sports Physiol Perform*, 2015: 10(3):369-373.

19) Hanley B. Pacing, packing and sex-based differences in Olympic and IAAF World Championship marathons. *J Sports Sci*, 2016:34(17):1675-1681.
20) International Association of Athletics Federations (2009). Beijing distance races analysed at 100m intervals. Available at: https://www.iaaf.org/news/news/beijing-distance-races-analysed-at-100m-inter. Accessed on January 18, 2019.
21) International Association of Athletics Federations. Competition archive. Available at: https://www.iaaf.org/results. Accessed on January 18, 2019.
22) Hopkins WG, Marshall SW, Batterham AM, Hanin, J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc,* 2009: 41(1):3-12.
23) Cohen J. *Statistical power analysis for the behavioural sciences* (2nd ed.), 1988. New Jersey: Lawrence Erlbaum
24) 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):1107-1115.
25) Aragón S, Lapresa D, Arana J, Anguera MT, Garzón B. Tactical behavior of winning athletes in major championship 1500-m and 5000-m track finals. *Eur J Sport Sci*, 2016: 16(3):279–286
26) Fukuba Y, Whipp BJ. A metabolic limit on the ability to make up for lost time in endurance events. *J Appl Physiol*, 1999: *87*(2):853-861.
27) Hanley, B., 2014. Senior men's pacing profiles at the IAAF World Cross Country Championships. *J Sports Sci*, *32*(11), pp.1060-1065.
28) Esteve-Lanao J, Larumbe-Zabala E, Dabab A, Alcocer-Gamboa A, Ahumada F. Running world cross-country championships: A unique model for pacing. *Int J Sports Physiol Perform*, 2014:*9*(6):1000-1005.
29) Casado A, Moreno-Pérez D, Larrosa M, Renfree A. Different psychophysiological responses to a high-intensity repetition session performed alone or in a group by elite middle-distance runners. *Eur J Sport Sci*, 2019:1-8.
30) Renfree A, Crivoi do Carmo E, Martin L, Peters DM. The influence of collective behavior on pacing in endurance competitions. *Front Physiol*, 2015:*6*:373.
31) Swart J, Lamberts, RP, Lambert MI, St Clair Gibson A, Lambert EV, Skowno J, Noakes TD. Exercising with reserve: evidence that the central nervous system regulates prolonged exercise performance. *Br J Sports Med*, 2009: *43*(10):782-788.

Figure caption

Figure 1. Distribution of times per segment covered throughout a race in two hypothetical runners.

Figure 2. Cumulative speed to each 100 m point of each competitor in the men's 10000m race at the 2008 Olympic Games (n = 35).