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Original Article

Comparison of winning and record tactics in elite-level male middle-distance running

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Abstract
The research aimed to investigate, over a longer period (1983-2018), how the most successful male middle-distance runners (800m, 1500m) behave during Grand Prix races (R) and International Championship finals (W) in terms of pace and positioning. Using Kinovea 0.8.15 video analysis software, we analyzed split times and instantaneous position data per lap during 1500m and per 200m during 800m. In the 1500m, we analyzed 13 athletes' global competition medal-winning performances and personal best runs achieved in Grand Prix races (n=26). In the 800m, the top 3 finishers of 23 Grand Prix races and 25 Olympic and World Championship finals were investigated (n=144). Results: At both distances, the average race speed during the race was significantly ($p < 0.05$) better for R runs (800m: R 7.76 ± 0.04 m/s vs W 7.67 ± 0.08m/s; 1500m: 7.20 ± 0.04 m/s vs W 6.90 ± 0.15m/s). For the 800m R tactic, the average speed decreased steadily during the 200m stages. In both groups, there was a significant difference between the first and second laps. In terms of positioning, the athletes behaved similarly during the two tactics. 1500m: For the R tactics, the average speeds achieved between the first and last 400m were similar (7.30 ± 0.10 m/s; 7.34 ± 0.10 m/s), being significantly faster than the two middle laps of the steadily slow (7.03 ± 0.08 m/s; 7.09 ± 0.11 m/s). There was a significant difference between the average speeds achieved in the first 800m and last 700m of the distance for both the R and W tactics in favor of the second half of the distance, but the significance level was higher for W. During the W races, the two lowest average speeds of 400m were measured in the first two laps. The highest average speed was achieved during the last 400m (7.58 ± 0.19 m/s). The number of position changes was higher for W in all cases, with the largest difference for position changes between 800m and 1200m Conclusions: a slowing down (negative pacing) after a fast start at 800m yields the fastest results, while a more steady (inverted U-shaped) run at 1500m yields the record times. In Championship finals, later medalists do not try to control the pace in the first half of the distance in most cases, and cannot make up the time deficit in the second half.
Keywords: Race Tactics, pacing, 800m, 1500m

Introduction

The 800m and 1500m men's track races are classic middle-distance events that have been part of the Olympic athletics program since the first modern Olympic Games and have been staged at every world competition since then. Since fellow competitors run on the same track and achieve relatively high average speeds (7-8 m/s), proper tactical behavior is essential for success in these events. Such behavior includes proper pacing and positioning within the field, which help runners cover the shortest distance possible around the bend and prevent being 'locked in' (Martin & Coe, 1997). The right pacing is a prerequisite for outstanding endurance performance. This is influenced by several external and internal factors: muscle fatigue (St Clair Gibson et al., 2013), various psychophysiological variables (Casado et al., 2019), race-tactics (Renfree et al., 2020), and environmental conditions such as wind resistance (Pugh, 1973). From a theoretical point of view, a steady pace seems to be the most efficient, however, there is a large body of empirical evidence that the most efficient pace for some races is time and race distance dependent (Casado et al., 2021c).

In the literature, two distinct race tactics have been described (Hettinga, Edwards & Renfree, 2019; Renfree & Casado, 2018): one is the so-called 'Record Tactic', which is aimed at achieving the best times possible (world records, national records), primarily at Grand Prix races with cash prizes, while final ranking being a secondary consideration. In these races, the use of pace-runners promotes the fastest possible time results by reducing the cognitive load associated with the ongoing decision-making process (Renfree et al., 2014) and allows record-aspirants to take advantage of drafting (Pugh; 1971). By contrast, the 'Winning Tactic' is mainly observed

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in the finals of international competitions where competitors only focus on medal winning and do not consider time results as important (Abbis & Laursen, 2008; Aragón et al., 2015; Foster et al., 2004). Therefore, it is expected that at middle- distances, record results are achieved in meets with money prizes, rather than in the finals of global championships. A notable exception is the case when a so-called 'front runner' is in the field, who tries to outpace his or her rivals at an early stage of the race, as was the case with men's 800m final at the 2012 London Olympics, where David Rudisha from Kenya set a new world record, or with men's 1500m final at the 2020 (2021) Tokio Olympics, where Jakob Ingebrigtsen from Norway set a new European record (Kelemen et al., 2022). Regarding the shorter 800m distance, several studies have concluded that the best results are achieved by 'positive' pacing, when a fast first lap is followed by a slower second lap (Tucker, Lambert & Noakes, 2006; Filipas et al., 2018; Thiel et al., 2012; Casado et al., 2021a; Sandford et al., 2018).

Furthermore, analyses of world championship finals have concluded that a 'seahorse' pacing (largely U-shaped, with a slower „tail" between 200 and 300 meters) is typical across the four 200m intervals (Hanley, Stelligwerff & Haettinga, 2019; Hettinga, Edwards & Hanley, 2019, Amo et al., 2021). For 1500 meters, few previous studies analyzed the pacing of record runs (Casado et al., 2021a, Casado et al., 2021b). Noakes et al. analyzed world records for the mile and concluded that the average lap speeds follow a U shape, with the first and last laps being similarly fast and the two intermediate laps being equally slower on average (Noakes, Lambert & Hauman, 2008). Carl Foster analyzed the pacing characteristics of 2000m cycling time trials, which are similar in duration to the 1500m track race. The best times were obtained using slightly negative pacing where the first half of the distance was 1 to 2% slower than the second half. Those participants who were much slower in the first half compared to the average speed of the time trial could not compensate for their accumulated time deficit in the second half. Slightly negative pacing was also found to be superior to positive pacing in the study (Foster et al., 2013). Two further studies (Fukuba & Whipp, 1999; Morton, 2008) have demonstrated that it is not possible in middle- and long-distance races to compensate for the time deficit accumulated at the beginning of the distance, thus a steady or slightly negative pacing is the most effective tactic. The 1500m World Championship finals are characterized by 'negative / low-J' pacing, that is, athletes start the chase during the last two laps after a slow start (Aragón et al., 2015; Casado & Renfree, 2018; Casado et al., 2021c).

The present study analyzed and compared the tactical behaviors (R vs W) of the world's top male middle-distance runners in terms of pace and positioning in the finals of world competitions (Olympic and World Championships vs. Grand Prix races). The research covered a period of several decades (1983-2018) in order to draw general conclusions on the tactical behaviors associated with the two racing goals (i.e., medal winning vs. record setting) in 800m and 1500m distance running.

Materials and Methods

Two independent samples were collected for the analysis. The 1500m sample included R and W runs of the 13 best performers of all time (n = 26). The athletes' individual bests are among the 30 fastest runs in the world rankings, and they have medaled in Olympic and World Championship finals. For these runners, their individual bests in Grand Prix races (R) and their international medal-winning runs (W) were analyzed with paired sample t-tests. The 800m sample included a total of 69 runs of the three top-ranking runners at 23 world-class Grand Prix races (R) and a total of 75 runs of the three top-ranking runners at 25 Olympic and World Championship finals (W) over the last 35 years (from 1983 to 2018; n = 144).

Video analysis (Kinovea 0.8.15 software) was used to determine the instantaneous positions and split times (at 400m, 800m, 1100m, and 1200m for the 1500m event, and at 200m, 400m, and 600m for the 800m event) and to record the final results. Descriptive statistics (means, standard deviations) were calculated, and dichotomous groups for the 800m (W vs R) were compared with independent samples t-tests. Kolmogorov Smirnov Test were used testing normality. The pace distributions of the intervals of each run were analyzed by repeated measures ANOVA with Bonferroni post hoc test in both distances. The significance level was set at $p < 0.05$. The statistical analysis was conducted with the IBM SPSS Statistics v. 25 software program.

Results

1500 m

Overall performance and average race speed were significantly better for R runs (3:28.28 ± 1.3sec; 7.20 ± 0.04m/s) than for W runs (3:37.22 ± 4.9sec; 6.90 ± 0.15m/s; $p < 0.05$). In all cases, athletes medaled in the world finals with slower tactical runs compared to their individual bests. In addition to the differences in the overall results, significant differences were observed in terms of pacing and positioning across intervals. The average speed for each 400m interval is shown in **Figure 1**. The pace distribution of the R runs was consistent with the lap time distribution of mile world recorders [12]. A fast first lap was followed by two middle laps with a steadily slower pace, and the final 400m was run at a pace similar to that of the first lap. No significant difference was found between the average speeds of the first vs. last 400m (7.30 ± 0.10 m/s vs. 7.34 ± 0.10 m/s) or between those of the second vs. third interval (7.03 ± 0.08 m/s vs. 7.09 ± 0.11 m/s). W runs showed a gradually increasing pace. The first and second intervals were the slowest, with no significant difference between the two (6.45 ± 0.30 m/s vs. 6.59 ± 0.39 m/s, respectively), while the last interval was the fastest (7.58 ± 0.19 m/s), significantly faster than any of the other three intervals, including the third interval (7.22 ± 0.14 m/s).

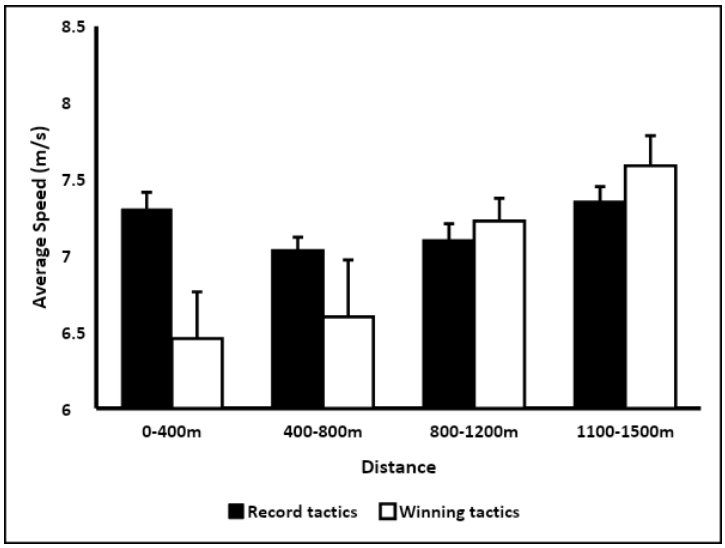

Figure 1. Average speeds obtained for 400m intervals of 1500m runs with record (R) vs. winning (W) tactics (n = 26).

The pacing characteristics of the first and second half-distance are summarized in **Figure 2**. On average, the first 800m was significantly slower than the last 700m both in R runs (7.16 ± 0.06 m/s vs. 7.24 ± 0.6 m/s, p < 0.05) and in W runs (6.52 ± 0.29 m/s vs. 7.39 ± 0.11 m/s, p < 0.05), with a more pronounced difference obtained for W runs.

However, although W runners completed the first interval much slower compared to R runners, they were only able to increase the pace slightly above that of R runners in the second interval. As reflected in the above reported standard deviations, W runners showed higher variability in pacing during the first half-distance than R runners did, but differences between the two groups leveled out during the second-half distance.

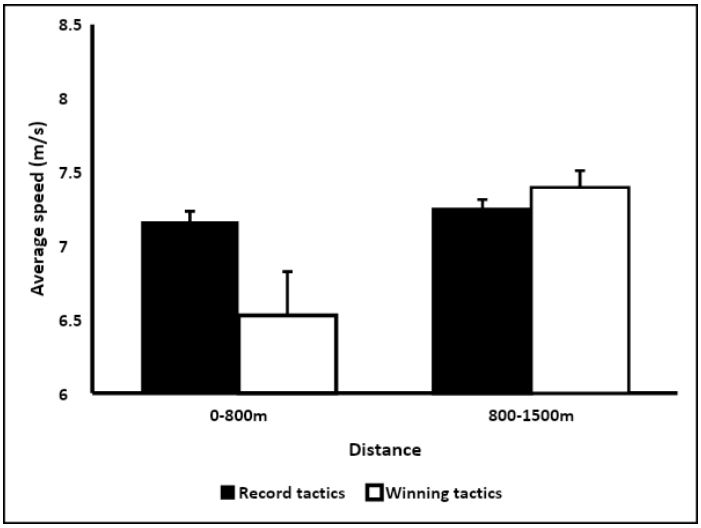

Figure 2. Average speeds obtained for the first and second half-distance of 1500m runs with record (R) vs. winning (W) tactics (n = 26).

As reflected in the sampled 13 athletes' paired differences in their field positions between the ends of two successive intervals, W runners showed a significant amount of position changes between 800m (4.79 ± 2.68) vs. 1200m (2.61 ± 2.63, p < 0.05), while no significant difference was found between either 400m vs. 800m or 1200m vs. the final positions. As to the individual athletes' final positions at R vs. W events, no significant difference was observed (1.76 ± 1.36 and 1.53 ± 0.77, respectively), while they showed significant differences between their R vs. W positions at 400m (3.15 ± 2.99 vs. 5.46 ± 3.15, p < 0.05).

The amount of cross-interval position changes was in all cases larger at W events than at R events, the largest difference observed for the 800m vs. 1200m measure (2.15 ± 2.64 for and 0.69 ± 0.94, respectively). This may be related to our earlier finding that medal-winning world championship finalists strive to increase their pace during the third lap.

800 m

The sampled top-ranking 800m runners showed significantly better time results and average race speed at R events (1:43.03 ± 0.54 sec, 7.76 ± 0.04 m/s, respectively) than at W events (1:44.28 ± 1.16 sec, 7.67 ± 0.08 m/s, respectively; $p < 0.05$ in both cases). Significant differences between the two groups were also found in terms of pacing and positioning within the field. **Figure 3** shows the pacing patterns of R and W runners composed of the average speeds obtained for the four 200m intervals in each group. The R runners showed steadily decreasing speed across the four intervals, with a significant difference between the first and second interval (8.16 ± 0.17 m/s vs. 7.76 ± 0.13 m/s, $p < 0.05$), the second and third interval (7.76 ± 0.13 m/s vs. 7.64 ± 0.10 m/s, $p < 0.05$), and the third and fourth interval (7.64 ± 0.10 m/s vs. 7.51 ± 0.16 m/s, $p < 0.05$). For the W runners, a significant average speed difference was found between the first and second interval (8.12 ± 0.23 m/s vs. 7.29 ± 0.67 m/s, $p < 0.05$) and the second and third interval (7.29 ± 0.67 m/s vs. 7.59 ± 0.15 m/s, $p < 0.05$), while there was no significant difference between the third and last interval (7.59 ± 0.15 m/s vs. 7.61 ± 0.25 m/s, *ns*). That is, the first interval was the fastest, directly followed by the slowest interval, and the runners steadily accelerated over the last two intervals. The highest standard deviations were obtained for the second interval. Comparing the two tactics, significant differences were also found between the average speeds of the second, third and last intervals. In both groups, the runners achieved the highest average speed during the first interval.

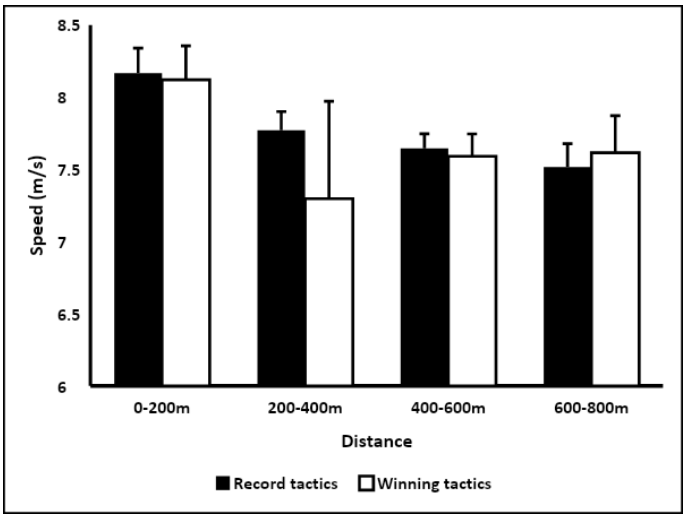

Figure 3. Average speeds obtained for 200m intervals of 800m runs with record (R) vs. winning (W) tactics (n = 144).

The pacing characteristics of the first and second half-distance are summarized in **Figure 4.** There was a significant difference between the R runners' first and second lap in terms of average speed (7.96 ± 0.11 m/s vs. 7.57 ± 0.09 m/s), indicating positive pacing, a comparable difference was also found for the W runners (7.73 ± 0.23 m/s vs. 7.59 ± 0.11 m/s). The R and W runners differed from each other in the average speed of the first but not the second lap. Interestingly, neither W nor R runners were able to increase the pace during the second lap.

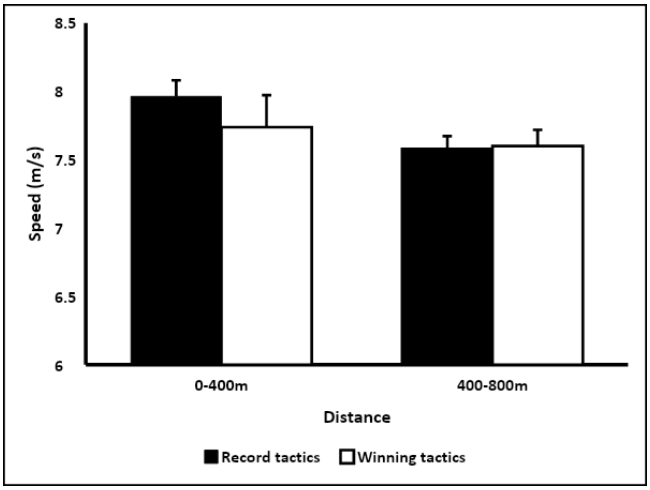

Figure 4. Average speeds obtained for the first and second half-distance of 800m runs with record (R) vs. winning (W) tactics (n = 144).

In terms of positioning, the R and W runners showed similar patterns. Specifically, no significant difference in instantaneous positions at 200m (4.88 ± 2.68 vs. 4.28 ± 2.39, respectively), 400m (4.43 ± 2.16 vs. 3.76 ± 2.15, respectively), or 600m (2.85 ±1.73 vs. 3.32 ± 1.93, respectively). Both R and W runners consistently improved their field positions throughout the race. In terms of overtaking, the R group showed a significant difference between the second and third interval (0.44 ± 1.23 vs. 1.62 ± 1.23) and also between the third and last interval (1.62 ± 1.23 vs. 0.81 ± 1.66). In both groups the runners were most active in terms of overtaking between the second and third interval.

The W runners showed no significant difference in the number of overtakes in the second and third interval (0.52 ± 1.65 vs. 0.44 ± 1.38), but there was a significant difference between the third and last interval (0.44 ± 1.38 vs. 1.32 ± 1.88). The largest number of overtakes clearly occurred in the last interval, which amount was significantly larger compared to any of the three preceding intervals, these latter showing no significant difference when compared to each other.. The difference between the R vs. W group in terms of overtakes was significant in the second and third intervals.

Discussion

Our results have shown that for top-ranking elite male 1500m runners pursuing record (R) tactics (i.e., aiming to achieve the best time result possible), show a pacing pattern that is more similar to that of longer distances (5000m; 10000m) than to that of the shorter 800m event (Tucker, Lambert & Noakes, 2006). That is, a fast initial interval is followed by steadily slower middle intervals, and then runners increase their speed at the end of the distance. Over the course of the race, the runners reach the highest speed in the first and last interval, which do not substantially differ from each other in average speed. This pattern forms a U-shaped speed curve (Casado et al., 2021b). The pacing of the fastest 1500m races follows a pattern similar to that associated with the mile world records (Noakes, Lambert & Hauman, 2008). R runners complete the second half-distance at the same or slightly higher speed than the first half-distance, that is, they employ a slightly negative pacing. This observation is in line with previous related findings (Foster et al., 1993; Foster et al., 2019; Bishop, Bonetti & Dawson, 2002; Thompson et al., 2004), which show that slightly negative pacing leads to the best times in endurance events of more than 2 minutes racing time.

At the 800m event, by contrast, runners are unable to maintain or increase their speed in the second part of the race. After a fast first 200m, each 200m interval becomes slower than the preceding interval by about 0.5 second on average. In the two-lap race, both R and W runners use positive pacing, the first lap being faster than the second lap. Since a significant average speed difference between W and R tactics was obtained for the first but not the second lap, we can conclude that it does not pay to run slowly in the early stages of the race if the goal is to achieve the fastest time possible, which is in line with Tucker's results (Tucker, Lambert & Noakes, 2006).

In the R sample of the present study, both 800m and 1500m runners were positioned directly behind the front runners. The sampled R runners tried to make as few position changes as possible, with overtakes timed for the last and penultimate laps in the 1500m races, while the most significant wave of overtaking occurred between 400m and 600m in the 800m race (González-Mohino et al., 2020).

In contrast with R runners competing at Grand Prix events, medal-winning Global Championship finalists pursue winning (W) tactics, that is, they they do not aim to achieve the best time result possible, therefore their pace is much slower in the first half-distance than during Grand-Prix races, which affects the final result, and this is true for both the 800m and 1500m events. They are unable to compensate for the time deficit accumulated in the first part of the distance, in line with the findings reported by Morton (2008), and Fukuba and Whipp (1999).

In the present study, the medal-winning 1500m W runners strived to complete the first two laps with the least possible energy investment, performing as few overtakes as possible, preferably positioned in the middle of the field. In the second half-distance, they started to increase their speed and tried to achieve a good position to start their final chase at the beginning of the last lap. During the race, their speed constantly increased from lap to lap and peaked during the last 400m (Aragón et al., 2015).

The 800m W runners sampled in the present study reached the highest speed in the first 200m interval, which was followed by a sudden slowdown and the lowest average speed between 200m and 400m, then the athletes gradually increased their pace during the last two stages, and started their final sprint after 600m (Hanley & Hettinga, 2018). It can be concluded that the main reason for the slower overall speed of W runners as compared to the 800m R runners is the significant slowdown during the second interval, when the pace is dictated by pacemakers.

Conclusions

In the 800m and 1500m track races, the largest differences between the Record Tactics (which are typical of Grand Prix races), and the Winning Tactics (which are typical in Global Championship Finals) are found in the first half-distance, both in terms of pacing and positioning. In the 800m race, the best times are achieved with positive pacing, where the time result of the first lap is consistently better than the second lap by about 2 seconds. This positive pacing pattern is constituted by the fact that the speed is constantly decreasing across the 200m intervals, with each 200m interval being slower than the previous one by 0.5 second on average. At the 1500m event, the best times are run with a steady or slightly negative pacing, with the first half-distance being slower

than the second half-distance by about 1%. The average speed of 400m laps follow an U-shaped curve, with the first and last laps similarly fast and the middle two laps consistently slower. In W runs as compared to R runs, the first half-distance is significantly slower, while the number of field position changes is significantly higher. The time deficit accumulated at the beginning of the distance cannot be compensated for in the second part of the race, thus W runs are generally associated with poorer time results. To be successful in middle-distance running, runners need to be comfortable with both R and W tactics, and so both tactical behaviors should be practiced in training and preparation for races.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abbiss, C. R., & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports medicine (Auckland, N.Z.)*, *38*(3), 239–252. https://doi.org/10.2165/00007256-200838030-00004

Amo, J., Planas-Anzano, A., Zakynthinaki, M., & Ospina-Betancurt, J. (2021). Effort distribution analysis for the 800 m race: IAAF World Athletics Championships, London 2017 and Birmingham 2018. *Biomedical Human Kinetics, 13*(1), 103–110. https://doi.org/10.2478/bhk-2021-0013

Aragón, S., Lapresa, D., Arana, J., Anguera, M. T., & Garzón, B. (2015). Tactical behaviour of winning athletes in major championship 1500-m and 5000-m track finals. *European Journal of Sport Science*, *16*(3), 279–286. https://doi.org/10.1080/17461391.2015.1009494

Bishop, D., Bonetti D., & Dawson, B. (2002). The influence of pacing strategy on &OV0312;O2 and supramaximal kayak performance. *Medicine &Amp; Science in Sports &Amp; Exercise*, *34*(6), 1041–1047. https://doi.org/10.1097/00005768-200206000-00022

Casado, A., & Renfree, A. (2018). Fortune Favors the Brave: Tactical Behaviors in the Middle-Distance Running Events at the 2017 IAAF World Championships. *International Journal of Sports Physiology and Performance*, *13*(10), 1386–1391. https://doi.org/10.1123/ijspp.2018-0055

Casado, A., García-Manso, J. M., Romero-Franco, N., & Martínez-Patiño, M. J. (2021a). Pacing strategies during male 1500 m running world record performances. *Research in sports medicine (Print)*, *29*(6), 593–597. https://doi.org/10.1080/15438627.2021.1878459

Casado, A., González-Mohíno, F., González-Ravé, J. M., & Boullosa, D. (2021b). Pacing Profiles of Middle-Distance Running World Records in Men and Women. *International Journal of Environmental Research and Public Health*, *18*(23), 12589. https://doi.org/10.3390/ijerph182312589

Casado, A., Hanley, B., Jiménez-Reyes, P., & Renfree, A. (2021c). Pacing profiles and tactical behaviors of elite runners. *Journal of Sport and Health Science*, *10*(5), 537–549. https://doi.org/10.1016/j.jshs.2020.06.011

Casado, A., Moreno-Pérez, D., Larrosa, M., & Renfree, A. (2019). Different psychophysiological responses to a high-intensity repetition session performed alone or in a group by elite middle-distance runners. *European journal of sport science*, *19*(8), 1045–1052.

Filipas, L., Nerli Ballati, E., Bonato, M., La Torre, A., & Piacentini, M. F. (2018). Elite Male and Female 800-m Runners' Display of Different Pacing Strategies During Season-Best Performances. *International Journal of Sports Physiology and Performance*, *13*(10), 1344–1348. https://doi.org/10.1123/ijspp.2018-0137

Foster, C., de Koning, J. J., Thiel, C., Versteeg, B., Boullosa, D. A., Bok, D., & Porcari, J. P. (2019). Beating Yourself: How Do Runners Improve Their Own Records?. *International journal of sports physiology and performance*, 1–4. Advance online publication. https://doi.org/10.1123/ijspp.2019-0261

Foster, C., Snyder, A. C., Thompson, N. N., Green, M. A., Foley, M., & Schrager, M. (1993). Effect of pacing strategy on cycle time trial performance. *Medicine and science in sports and exercise*, *25*(3), 383–388.

Foster, Carl & de Koning, Jos & Hettinga, Florentina & Lampen, J & Dodge, C & Bobbert, Maarten & Porcari, John. (2004). Effect of Competitive Distance on Energy Expenditure During Simulated Competition. *International Journal of Sports Medicine*, *25*(3), 198–204. https://doi.org/10.1055/s-2003-45260

Fukuba, Y., & Whipp, B. J. (1999). A metabolic limit on the ability to make up for lost time in endurance events. *Journal of Applied Physiology*, *87*(2), 853–861. https://doi.org/10.1152/jappl.1999.87.2.853

González-Mohíno, Fernando & Santos del Cerro, Jesus & Renfree, Andrew & Yustres Amores, Inma & Gonzalez Rave, Jose Maria. (2020). The Relationship Between Tactical Positioning and the Race Outcome in 800-M Running at the 2016 Olympic Games and 2017 IAAF World Championship. Journal of Human Kinetics. 71. 299-305. 10.2478/hukin-2019-0090.

Hanley, B., & Hettinga, F. J. (2018). Champions are racers, not pacers: an analysis of qualification patterns of Olympic and IAAF World Championship middle distance runners. *Journal of Sports Sciences*, *36*(22), 2614–2620. https://doi.org/10.1080/02640414.2018.1472200

Hanley, B., Stellingwerff, T., & Hettinga, F. J. (2019). Successful Pacing Profiles of Olympic and IAAF World Championship Middle-Distance Runners Across Qualifying Rounds and Finals. *International Journal of Sports Physiology and Performance*, *14*(7), 894–901. https://doi.org/10.1123/ijspp.2018-0742

Hettinga, F. J., Edwards, A. M., & Hanley, B. (2019). The Science Behind Competition and Winning in Athletics: Using World-Level Competition Data to Explore Pacing and Tactics. *Frontiers in Sports and Active Living*, *1*. https://doi.org/10.3389/fspor.2019.00011

Hettinga, Florentina & Edwards, Andrew & Hanley, Brian. (2019). The Science Behind Competition and Winning in Athletics: Using World-Level Competition Data to Explore Pacing and Tactics. Frontiers in Sports and Active Living. 1. 10.3389/fspor.2019.00011.

Kelemen, B., Benczenleitner, O., Tóth, L.(2022). Are 800-m runners getting faster? Global competition performance trends between 1999 and 2021. *Journal of Physical Education and Sport (JPES), Vol. 22 (issue 9), Art 284,* pp. 2231-2237, September, 2022 online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051

Martin, D.E., Coe, P.N. (1997). Better training for distance runners*. 2nd ed. Champaign, IL: Human Kinetics.*

Morton, R. H. (2008). A new modelling approach demonstrating the inability to make up for lost time in endurance running events. *IMA Journal of Management Mathematics*, *20*(2), 109–120. https://doi.org/10.1093/imaman/dpn022

Noakes, T. D., Lambert, M. I., & Hauman, R. (2008). Which lap is the slowest? An analysis of 32 world mile record performances. *British Journal of Sports Medicine*, *43*(10), 760–764. https://doi.org/10.1136/bjsm.2008.046763

Pugh L. G. (1971). The influence of wind resistance in running and walking and the mechanical efficiency of work against horizontal or vertical forces. *The Journal of physiology*, *213*(2), 255–276. https://doi.org/10.1113/jphysiol.1971.sp009381

Renfree, A., Casado, A., Pellejero, G., & Hanley, B. (2020). More Pace Variation and Pack Formation in Successful World-Class 10,000-m Runners Than in Less Successful Competitors. *International journal of sports physiology and performance*, *15*(10), 1369–1376. https://doi.org/10.1123/ijspp.2019-0852

Renfree, A., Martin, L., Micklewright, D., & St Clair Gibson, A. (2014). Application of decision-making theory to the regulation of muscular work rate during self-paced competitive endurance activity. *Sports medicine (Auckland, N.Z.)*, *44*(2), 147–158. https://doi.org/10.1007/s40279-013-0107-0

Renfree, Andrew & Casado, Arturo. (2018). Athletic Races Represent Complex Systems, and Pacing Behavior Should Be Viewed as an Emergent Phenomenon. Frontiers in Physiology. 9. 10.3389/fphys.2018.01432.

Sandford, G. N., Pearson, S., Allen, S. V., Malcata, R. M., Kilding, A. E., Ross, A., & Laursen, P. B. (2018). Tactical behaviors in men's 800-m Olympic and World-Championship medalists: A changing of the guard. *International Journal of Sports Physiology and Performance*, *13*(2), 246–249. https://doi.org/10.1123/ijspp.2016-0780

St Clair Gibson, A., De Koning, J. J., Thompson, K. G., Roberts, W. O., Micklewright, D., Raglin, J., & Foster, C. (2013). Crawling to the finish line: why do endurance runners collapse? Implications for understanding of mechanisms underlying pacing and fatigue. *Sports medicine (Auckland, N.Z.)*, *43*(6), 413–424. https://doi.org/10.1007/s40279-013-0044-y

Thiel, C., Foster, C., Banzer, W., & De Koning, J. (2012). Pacing in Olympic track races: Competitive tactics versus best performance strategy. *Journal of Sports Sciences*, *30*(11), 1107–1115. https://doi.org/10.1080/02640414.2012.701759

Thompson, K. G., MacLaren, D. P., Lees, A., & Atkinson, G. (2004). The effects of changing pace on metabolism and stroke characteristics during high-speed breaststroke swimming. *Journal of Sports Sciences*, *22*(2), 149–157. https://doi.org/10.1080/02640410310001641467

Tucker, R., Lambert, M. I., & Noakes, T. D. (2006). An Analysis of Pacing Strategies During Men's World-Record Performances in Track Athletics. *International Journal of Sports Physiology and Performance*, *1*(3), 233–245. https://doi.org/10.1123/ijspp.1.3.233