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Increased variability of lap speeds differentiate medallists and non-medallists in middle distance running and swimming events

Original Investigation

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Abstract

Purpose: Previous literature has presented pacing data of groups of competition finalists. The aim of this study was to analyse the pacing patterns displayed by medallists and non-medallists in international competitive 400-m swimming and 1500-m running finals.

Methods: Split times were collected from 48 swimming finalists (four 100-m laps) and 60 running finalists (4 laps) in international competitions between 2004 and 2012. Using a cross sectional design, lap speeds were normalised to whole race speed and compared to identify variations of pace between groups of medallists and non-medallists. Lap speed variations relative to the gold medallist were compared for the whole field.

Results: In 400-m swimming the medallist group demonstrated greater variation in speed than the non-medallist group, being relatively faster in the final lap ($p<0.001$; moderate effect) and slower in laps one ($p=0.03$; moderate effect) and two ($p>0.001$; moderate effect). There were also greater variations of pace in the 1500-m running medallist group compared to the non-medallist group with a relatively faster final lap ($p=0.03$; moderate effect) and slower second lap ($p=0.01$; small effect). Swimming gold medallists were relatively faster than all other finalists in lap 4 ($p=0.04$) and running gold medallists were relatively faster than the 5th to 12th placed athletes in the final lap ($p=0.02$).

Conclusions: Athletes that win medals in 1500-m running and 400-m swimming competitions show different pacing patterns from non-medallists. End spurt speed increases are greater with medallists, who demonstrate a slower relative speed in the early part of races but a faster speed during the final part of races compared to non-medallists.

Keywords:

Sports performance; pacing; medallist; middle distance.

Introduction

Pacing is defined as the distribution of effort over an exercise bout[1] to allow for the best possible completion time for a given activity.[2] Pacing patterns have been shown to have faster initial and final lap pace in 1 mile running world record events with 30 of the 32 world record times showing an 'end spurt'[3] which has been identified as being between 1200-1300m of the race.[4] Compared to 1500-m running, a milder end-spurt has been reported in 400-m swimming[5] with a fast start that may be accounted for by the dive and 15m underwater stroke.[6,7] Comparisons between 1500-m running and 400-m swimming do not exist in the literature but may be useful to contrast pacing patterns of middle distance events with similar net energetics. The current 400-m men's freestyle swimming world record is 220.07s[8] and the current 1500-m men's running world record is 206.0s,[9] suggesting that the energetics of both events are similar and derived primarily from the aerobic energy system.[10,11]

Recently modelled performances of 800-m runners, 200-m swimmers and 1500-m speed skaters demonstrate that pacing patterns are different for these events despite very similar net energetic requirements.[12] A key aspect of this research was the development of models that include the forces of drag and friction which differ between skating, running and swimming. The study recommended that 200-m swimmers, who experienced the highest drag, keep to an even pace whereas 800-m runners should start faster. There is some evidence to suggest that in running, although the ability to achieve a fast overall time is important, so is tactical positioning throughout the race.[13] Similarly tactical positioning at intermediate stages of middle distance races was a found to be a significant factor in finishing position at the London Olympic Games.[14] In swimming athletes are not in close physical proximity so pacing patterns should focus on an optimal individual performance[15] although there could be some tactical advantages in drafting behind a competitor[16] whilst avoiding waves created by them.[17]

There have been calls for high level competition data to be used to investigate pacing in the real world and outside of laboratory conditions.[14,18] An investigation into pacing differences in world class middle distance competitions would add to the theoretical basis developed by others for shorter events.[12] In a recent review article,[15] many examples of parabolic pacing patterns in longer duration events were reported, however the difference between medallists and non-medallists was not investigated. Whilst some literature has identified differences in pacing profiles based on finishing position by splitting finishers into quartiles [13] or by comparing groups of finalists and semi-finalists[5], there is a need to define pacing patterns that are successful enough to win a medal which is often the target for elite athletes and their funding agency. This information could be used by coaches and athletes in these events when preparing training strategies and racing plans. Therefore the aim of this study was to analyse the pacing patterns displayed by medallists and non-medallists in international competitive 400-m swimming and 1500-m running finals.

Methods

Data Collection

Data were collected from international competitions between 2004 and 2012 in men's 400-m swimming and 1500-m running events. In total 48 performances were analysed from six international 400-m freestyle swimming final competitions which is one more event than has previously been reported as being needed to ensure reliability.[19] 50m split times from the final in each championship were included from the European Championships in 2006, 2010 and 2012, the World Championships in 2007 and 2011 and the Commonwealth Games in 2006. Data was freely available in the public domain from the Omega Timing results service (www.omegatiming.com) and was anonymised before publication. Due to effects of full body swim suits on speed[20] a preliminary assessment of data from events in 2008 and 2009 when polyurethane suits were legal was carried out. This suggested that pacing patterns were altered, in particular a significantly faster 3rd lap was seen during these years (absolute mean time 57.24 ± 0.75 with a polyurethane suit vs. 57.75 ± 0.59 s with a standard suit; p=0.02) and therefore data from the 2008 Olympics and the 2009 World Championships were excluded, despite others finding no interaction between pacing pattern and suit use.[6] For 1500-m running, video recordings were obtained from public websites of 5 athletics final events which is the number of events reported to ensure a reliable sample[19]. Videos were included from the 23rd and 24th Olympiads (Athens 2004 and Beijing 2008), the International Association of Athletics Federations (IAAF) World Championships in 2009 and 2005, and the European Athletics Championships in 2010. Videos were only used when a static camera view of the start/finish line existed as athletes crossed the line on every lap during the final of the 1500-m event. In total 60 performances were analysed from these five events. A static camera view of the start/finish line was not available for the IAAF 2011 or 2007 World Championships or the European Athletics Championships in 2006. The videos were uploaded into Dartfish TeamPro v5 (Dartfish, Switzerland) and each athlete's lap times measured using a frame by frame playback method.[21]

Ethical Approval

The data used were obtained from publicly available websites and therefore ethical approval to collect secondary data was given by the Northumbria University Health & Life Sciences ethics committee. All data was anonymised upon addition to the database and it was ensured that no individuals could be identified from the reporting of the results.

Data Analysis

Lap times for both running and swimming events were divided by the lap distance to provide lap speed ($m.s^{-1}$). Overall race speed was calculated so that each lap speed could be expressed as a percentage of the overall race speed, also known as normalised speed[7]. Lap speeds for 100-m portions of the 400-m swimming race are presented to allow for easy comparison to 1500-m running. Lap speeds in both running and swimming were not normally distributed. Normalised speed for each lap in medallists and non-medallists were compared using a Mann Whitney test. Lap times relative to the gold medallist were compared for each finishing position using a Kruskal-Wallis tests for each lap and followed up where necessary by Mann Whitney tests to isolate differences between the gold medallist and the rest of the field. Statistical significance was set at $p<0.05$. Cohens *d* effect size was calculated for all significant differences using the pooled standard deviation as the denominator and the difference between group means as the numerator.[22] Effect size was classified as trivial (<0.2), small (>0.2-0.6), moderate (>0.6-1.2) and large (>1.2-2.0).[23]

Results

The normalised speeds for medallist and non-medallist groups in each lap and sport are described in figure 1. Medallists in 1500-m running had greater variation in speed than non-medallists with a faster lap four (110.2 ± 2.8% vs. 107.9 ± 3.5%, p = 0.03, *d* = 0.70 moderate) and slower lap two (92.7 ± 1.8% vs. 93.8 ± 2.1%, p = 0.01, *d* = 0.54 small). In absolute terms medallists were 0.22 $m.s^{-1}$ faster in lap four and 0.01 $m.s^{-1}$ slower in lap two. In laps one and three the normalized speed of the medallist and non-medallist groups did not differ from each other (lap one 96.9 ± 3.1% vs. 98.1 ± 3.5%, p = 0.13; lap three 101.3 ± 3.4% vs. 102.0 ± 3.2%, p = 0.28) and absolute speeds were 0.01 $m.s^{-1}$ and 0.02 $m.s^{-1}$ faster in the medallists in these laps respectively. In 400-m swimming the medallist group also had greater variation in speed than the non-medallists group. The medallists in swimming had a faster normalized speed in lap four (101.8 ± 1.7% compared to 100.5 ± 1.2%, p ≤ 0.01, *d* = 0.93 moderate) than non-medallists and relatively slower speeds in laps one (102.2 ± 1.2% compared to 103.1 ± 1.1%, p = 0.03, *d* = 0.75 moderate) and two (97.7 ± 0.8% compared to 98.2 ± 0.6%, p < 0.001, *d* = 0.78 moderate). Normalized speed in swimming was not different between the groups in lap three (98.5 ± 1.0% vs. 98.4 ± 0.6%, p = 0.63). Comparison of the absolute speeds in these laps show that medallists were 0.01 $m.s^{-1}$, 0.01 $m.s^{-1}$, 0.02 $m.s^{-1}$ and 0.05 $m.s^{-1}$ faster during laps 1, 2, 3 and 4 respectively. Lap speed varied to a greater extent in running medallists (with a range of 91- 115% of overall pace) compared to swimming medallists (a range of 97-105% of overall pace).

Figure 1 near here.

In 1500-m running there were significant differences in speed in lap four between finishing positions when calculated relative to the gold medallist (p < 0.01), but no differences were observed in laps one, two or three (Figure 2). Post hoc analysis identified that positions 5 to 12 had significantly lower speed relative to the gold medallist on lap four (p = 0.02 to 0.005) and on average were 0.26 $m.s^{-1}$ slower than gold medallists in absolute speed. In swimmers there were no differences in speed relative to the gold medallist in lap one, however there were differences in laps two, three and four (p = 0.02, 0.002 and ≤0.01 respectively, Figure 2). Post hoc analysis show that gold medallists were significantly faster than 6th to 8th place on lap two (p = 0.04 to 0.002; 0.01 $m.s^{-1}$ faster on average), 4th to 8th place on lap three (p = 0.04 to 0.002; 0.02 $m.s^{-1}$ faster on average) and 2nd to 8th place on lap four (p = 0.04 to 0.002; 0.06 $m.s^{-1}$ faster on average). It was also found that silver medallists were significantly faster than the gold medallists on lap 2 (p = 0.04) by 0.01 $m.s^{-1}$.

Figure 2 near here.

Discussion

The main finding of this study is that performance in the final lap in 1500-m running and 400-m swimming can differentiate between medallists and non-medallists. The last lap showed the largest differences in absolute, normalized and relative speed between the medallists and non-medallists. The success associated with a more pronounced end-spurt in both disciplines suggests that medallists were able to call on reserves of energy not available to non-medallists three-quarters of the way through the race. This may have been possible due to a lower physiological disturbance in the medallists at this stage of the race which in turn may be due to their faster VO_2 kinetics, a greater critical speed and possibly a greater aerobic capacity, meaning they produce a slower rise in the slow component and take longer to attain their VO_2max.[24]

Our findings show that the pacing pattern which characterises a winning race performance is different to that which characterises a world record performance as improvements in the 1-mile male running world record has been attributed to a relatively more even pacing pattern.[25]

This may be an effect of the use of pace-makers who are often deployed in world record attempts. In swimming, the end-spurt seen in this study was pronounced and saw gold medallists on average swim a faster final 100-m than first 100-m including the dive start whilst all other finishing positions averaged a slower final 100-m than their first 100-m. Gold medal swimmers were significantly faster than all other swimmers during the final lap. In separating swimmers by finishing position, the current study has added to previous work[5] finding a greater 'end-spurt' in medallists and showing that this differentiates them from non-medallists (the lap four speed of the medallists increased from the previous lap by 1.2% more than the speed increase in non-medallists at the same point in the race). In both events a more conservative initial speed that allowed for increases later on appears to be associated with success, however athletes will need mental confidence and physical talent in order to put these strategies into practice.

International 400-m swimmers demonstrated a u-shaped speed curve[26] during the competitions analysed. The fast start can be accounted for by the dive start and underwater component where speeds of over 3.5m.s^{-1} can be achieved from a grab dive start,[27] twice the average race speed seen in this study. In international competition swimming medallists, particularly gold medallists, seem to exhibit a different pacing pattern during finals than non-medallists which disagrees with others who report similar patterns for 400-m swimming finalists albeit with small individual differences.[5,28] In swimmers in this study the medallists were swimming below their mean velocity in the first half of their race whereas non-medallists were swimming above it indicating the importance of having the ability to increase speed at the end of the race as suggested previously.[29] The first half of the race may be the time when more successful swimmers conserve energy and spare their anaerobic capacity for use later on and by doing so may help them to better finishing positions.[30] Conversely those swimmers who swim faster over the initial stages seem unable to sustain the necessary speed to compete for medal positions in the latter race stages.

The 1500-m runners demonstrated a j-shaped speed curve,[26] speeding up in laps three and four after slowing in lap two, which is similar to previous literature for the same race distances.[3,4] Absolute and relative speeds in lap four were higher than all other laps for each finishing position emphasising the importance of final lap speed for every finisher in this event. Running performances showed greater variation in lap speed during a race compared to swimmers as previously found.[19] All runners had a greater relative speed in the second half of the race compared to swimmers. The swimmers had a greater relative speed in the first half than runners and overall produced a more evenly paced pattern during races. Runners share the same lane and therefore are more concerned with tactical considerations,[14] drafting benefits[31] and their opponents' pace, whereas swimmers are able to adopt a more consistent[19] self-selected race pattern, are less spatially affected by their opponents and are exposed to greater drag forces as speeds in the water increase.[32]

The current study employed independent statistical tests even though some individual athletes appear in more than one finishing position in different races. Athletes with more than one appearance were removed from the data set to see if this would affect the findings however only minor differences were found in the analysis of normalised lap speeds between medallist and non-medallist groups and there were no differences in the relative to gold medallists analysis. It was thought that it was more ecologically valid to include all athletes to ensure that the lap speeds for each finishing position were as complete as possible. Independent statistics are also less likely to produce a type I error than dependent statistics and as such are a more conservative option. This study included data from one race per calendar year from the Olympic, World or European championships to try and ensure that the pacing patterns described were indicative of those at the highest level of performance. It is acknowledged therefore that competitive elite level performances in other competitions were not included for comparison from the 2004-2012 period and may show alternative pacing patterns.

Practical applications to coaches and athletes.

- Athletes in 400-m swimming and 1500-m running events need to be able to increase their speed during the final lap of the race to maximise their chances of winning gold.
- As long as athletes stay in touch with their opponents, adopting a conservative speed in the early stage of 400-m swimming and 1500-m running finals might result in a more successful race performance because absolute speed can be increased by a greater margin in the final lap.

Conclusion

Previous research has used international competitive data to show pacing profiles adopted by international finalists, information which is useful for aspiring athletes. This study extends this approach by showing how pacing patterns can differentiate between successful and unsuccessful finalists in terms of medal success. To win a medal in both 400-m swimming and 1500-m running it appears necessary to vary pace during the race by adopting a more conservative pace in the early stages to allow for a relatively greater increase in speed at the end of the race.

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Figure Headings

Figure 1: Differences between sports in normalised speed for medallists and non-medallists in 1500-m running and 400-m swimming. * Medallists significantly faster than non-medallists; # Non-medallists significantly faster than medallists.

Figure 2: Lap times relative to the gold medallist for each lap in the 1500-m run and 400-m swim.
*Significantly slower than the gold medallist; # significantly faster than the gold medallist.