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Similarities and differences in pacing patterns in a 161 and 101 km ultra-distance road race

Running title: Pacing profiles of ultra-runners

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ABSTRACT

The purpose of this study was to establish and compare the pacing patterns of fast and slow finishers in a tropical ultra-marathon. Data were collected from the Craze Ultra-marathon held on the 22nd and 21st of September in 2012 and 2013, respectively. Finishers of the 161-km (N=47) and 101-km (N=120) categories of the race were divided into thirds (Group A-C) by merit of finishing time. Altogether, 17 and 11 split times were recorded for the 161-km and 101-km finishers, respectively and used to calculate the mean running speed for each distance segment. Running speed for the first segment was normalized to 100, with all subsequent splits adjusted accordingly. Running speed during the last 5 km was calculated against the mean race pace to establish the existence of an end spurt. A reverse J-shaped pacing profile was demonstrated in all groups for both distance categories and only 38% of the finishers executed an end spurt. In the 101-km category, in comparison to group B and C, group A maintained a significantly more even pace (p = .013 and .001, respectively) and completed the race at a significantly higher percent of initial starting speed (p = .001 and .001, respectively). Descriptive data also revealed that the top five finishers displayed a "herd-behaviour" by staying close to the lead runner in the initial portion of the race. These findings demonstrate that to achieve a more even pace, recreational ultra-runners should adopt a patient sustainable starting speed, with less competitive runners setting realistic performance goals while competitive runners with a specific time goal to consider running in packs of similar pace.

KEYWORDS

Ultra-marathon, Ultra-endurance, Ultra-run, Ultra-runners, Pacing strategy, Extreme heat

INTRODUCTION

Fatigue or the acute impairment of exercise performance, leading to an inability to maintain desired velocity (28), is a major challenge for runners competing in an endurance race. Well-trained athletes utilize specific pacing strategies in an attempt to delay the onset of fatigue and optimize overall performance (9).

Pacing can be defined as the distribution of work or pattern of energy expenditure of an individual to achieve his/her performance goal (8). From a physiological perspective, it is believed that a 'teleoanticipatory system' regulates pacing during long-duration exercise (11, 37), in which the brain anticipates the endpoint of exercise and changes the exercise intensity accordingly to prevent or minimise the disturbance of physiological homeostasis (17, 21).

Traditionally, three basic pacing profiles (positive, negative and even pacing) have been observed during different exercise tasks and conditions (9). A positive pacing profile is one whereby a runner's speed gradually declines throughout the duration of the event (2). It has been shown that the adoption of a positive pacing strategy results in an increased oxygen consumption (VO_2) (33) and greater accumulation of fatigue-related metabolites (34) during the early stages of exercise. These changes might have provided the necessary cues to reduce the exercise intensity and adopt a positive pacing profile so as to maintain physiological homeostasis (19). Conversely, a negative pacing profile occurs when there is an increase in speed over the duration of the event (2). Engagement of this pacing strategy improves endurance exercise performance by reducing the rate of carbohydrate utilization (1) and lowering VO_2 (29) early on in the exercise task. Finally, an even pacing profile is the maintaining of a constant submaximal exercise intensity throughout the event (2) and tends to manifest in the race characteristics of highly-trained endurance athletes (5). The theoretical support for such a strategy is primarily based on mathematical laws of motion, which indicate that frequent variations in pace can result in a greater percentage of the power generated to overcome fluid (i.e., air or water) resistance rather than producing forward motion (10).

These three profiles have been derived from research examining differences in performance (based on split times) during the first and second halves of a race (2). Such an approach is a relatively simple analysis and provides limited insight of one's overall pacing strategy. Contemporary studies have shown that runners naturally choose a start speed that is substantially greater than the mean speed of the race. They then progressively reduce speed during the race until approximately 90% of the entire distance has been completed before increasing the intensity to produce a so-called end spurt (18, 23, 36). This results in a parabolic-shaped pacing – U-, J- or reversed J-shaped profile (2).

Pacing is well documented during athletic competitions ranging from 800-m race to the marathon (30, 36) but not frequently studied in ultra-marathons. This could be attributed to the variety of mechanisms identified as contributors to fatigue as running distances increase, making a systematic experimental approach difficult (20).

Lambert et al. (16) attempted to better understand pacing strategies by studying the race times of elite ultra-runners participating in the 100-km IAU World Challenge to determine the variations in speed changes between faster and slower runners. The authors concluded that the faster ultra-runners ran with less variation in running speed, sustaining their initial pace for longer distances into the race than slower runners. A decade later, Knechtle, Rosemann, Zingg, Stiefel and Rüst (15) presented similar findings of top 100-km runners finishing the ultra-marathon at a high percent of their initial pace. Similarly, Parise and Hoffman (23) examined the differences in how runners of various abilities pace themselves over different ambient temperatures in the 100-mile Western States Endurance Run. They captured a reverse J-shaped pacing profile in all their subjects racing regardless of finishing time or ambient conditions. Hoffman (13) went on to examine pacing of the top five runners in 24 editions of the same race and concluded that the fastest times are achieved when speed fluctuations are limited .

The optimal pacing strategy for performance in ultra-marathons of different lengths remains unclear. Theoretically, an even-pacing strategy is believed to be ideal for long duration events in a stable environment. However, ultra-marathons are often conducted under dynamic external conditions (i.e., varying altitudes, ambient temperatures) (5, 22). Moreover, the handful of pacing studies conducted on ultra-marathons so far, utilized a homogenous group of elite to well-trained athletes. Thus, the findings may not be representative of a more heterogeneous population of ultra-marathons finishers of lower performance levels. In light of the rising popularity of ultra-marathons, the purpose of this study was to establish and compare the pacing patterns of fast and slow finishers in a tropical ultra-marathon. We hypothesized that (i) a reverse J-shaped pacing profile will be observed in both fast and slow finishers (ii) the fastest runners will display fewer variations in running speed and slow down lesser than the rest and (iii) majority of the finishers will have an end spurt in the last distance segment of the race.

METHODS

Experimental Approach to the Problem

This descriptive field study occurred at the Craze Ultra-marathon held in Singapore on the third weekend of September in 2012 and 2013 on a relatively flat road course. Runners from the 161-km and 101-km categories are allowed 32 h to complete the race. Eight checkpoints (CP) offering a variety of food and beverages are positioned along a relatively flat 80.5-km loop making up the route. Runners attempting the 161-km would turn back at CP8 (80.5-km mark) while those in the 101-km category would turn back at CP5 (50.5-km mark). Distance markers are available at every 5-km intervals except for the first and last 10 km of the race. In both years, the course was identical and the general weather conditions were similar, with the temperature at the start being 26 to 28° C, night lows of 24 to 26° C, and daily highs of 34 to 35° C. Humidity ranged from 65% to 98% with no rain or wind. Generally, all runners were exposed to temperature above 30° C between 9 am to 7 pm while humidity remained above 90% through the night from 11 pm to 7am, making the race progressively more challenging as the duration increases. By analysing the split times of all the finishers and the changes in race positions of the top five runners, the current study aimed to provide important insight into the similarities and differences in pacing patterns between fast and slow recreational ultra-runners as well as the practices of the top few finishers.

Participants

To increase the sample size, data were collected from two consecutive years (2012 and 2013) of an ultra-marathon. A total of 47 runners (out of 128) and 120 runners (out of 150) completed the 161-km and 101-km race in both years, respectively. The data of 22 runners were excluded from the analysis due to missing split times. In order to assess the influence of absolute performance level on pacing strategy displayed, runners were further divided into three groups (A-C) by merit of finishing time: fastest one-third (A), middle one-third (B) and slowest one-third (C). The study was approved by the Research and Ethics Committee for the Faculty of Health Sciences, University of Cape Town and subjects were informed of the benefits and risks of the investigation prior to providing informed consent through electronic means.

Procedures

A total of 17 (12, 21.5, 30, 39, 50.5, 65, 70, 80.5, 91, 96, 110.5, 122, 131, 139.5, 149, 156 and 161 km) and 11 (12, 21.5, 30, 39, 50.5, 62, 71, 79.5, 89, 96 and 101 km) distance segments were available for the 161-km and 101-km categories, respectively. A CP was located at every segment except the last. Split times for all CPs were recorded with chronometry (System Stopwach S149-4A00, Seiko, Tokyo, Japan). Two assistants were stationed at each CP and 5 km from the finish line to record the arrival and departure times of each runner. The last 5 km was chosen on the basis of research identifying that an end spurt occurs when a task is 95% complete, irrespective of length of task (4, 6). The finish times were subsequently obtained from the event organiser. The time taken between CPs was calculated from the point of departure from the previous CP to the point of arrival of the present CP.

Analysis of running speed

Mean running pace (km/h) for each distance segment was then calculated using each runner's segment split times. The mean absolute race pace (km/h) was calculated using each runner's finish time. Due to the possible accumulation of long bouts of rest at the CPs, thus negatively affecting the race pace, a separate mean pace “without (w/o) rest” (km/h) was calculated by dividing the race distance with only each runner’s time taken to run all the distance segments. Coefficient of variation (CV) for the race pace w/o rest was also calculated.

To establish an end spurt for each individual, running speed during the last 5 km was calculated against the mean race pace w/o rest according to the following equation (18):

Percentage off mean race pace

= [(Mean speed for 5 km – Mean race pace w/o rest) / (Mean race pace w/o rest)] x 100

where a positive value represents an end spurt. A group is deemed to have achieved an end spurt when the overall mean speed of the last 5-km split is significantly faster than the overall mean race pace.

‘Normalized’ running speed for each runner’s distance segment was calculated by assigning the first segment running speed to 100%. All the subsequent splits were adjusted accordingly. Subsequently, the mean normalized speed was derived for each group at each distance splits, and the line of best fit between distance and normalized speed was determined for them.

Statistical Analysis

The data were analyzed using version 20 of the SPSS software package (SPSS Inc., Chicago, Illinois, USA). One way ANOVA and Tukey post hoc follow-up tests were used to identify differences across groups while an independent *t* test and a one-sample *t* test were used to assess the differences in average race paces and speed over the last 5 km against the overall average speed within each group, respectively. For binary data, a Chi-square analysis with a post hoc conversion of the residual to a Z-score was used to detect differences across groups. The level of significance was set at $P < 0.05$ (Z-score > 1.96) and data are presented as mean ± SD. No statistical analysis was done for the data of the top five finishers of both distance categories due to limited sample size.

RESULTS

The mean race time for all the 161-km finishers was 29:01 ± 3:14 (hh:mm), with an average race pace of 5.6 ± 0.8 km/h. The fastest time recorded was 19:24 (hh:mm) and the slowest time was 31:55 (hh:mm). The performance characteristics of each group (A to C) are shown in Table 1. Tukey-post hoc tests indicated that runners in group A finished the 161-km race significantly faster than those in group B (p = .001) and group C (p = .001). The mean race paces w/o rest of groups B and C were also significantly faster than their overall mean absolute race pace (p = .001 and .001, respectively). There were no differences between the three groups with respect to age, CV or number of runners with an end spurt.

**Table 1 about here

The mean race time for all the 101-km finishers was 21:18 ± 3:35 (hh:mm), with an average race pace of 4.9 ± 0.4 km/h. The fastest time recorded was 14:01 (hh:mm) and the slowest time was 29:04 (hh:mm). The performance characteristics of each group (A to C) are shown in Table 2. The mean race paces w/o rest of all the groups were also significantly faster than their overall mean absolute race pace (p = .003, .001 and .001, respectively). Tukey post hoc tests indicated that runners in group A finished the 101-km race significantly faster and ran with a significantly lower CV than those in group B (p = .001 and .013, respectively) and group C (p = .001 and .001, respectively). Runners in group B also finished the race significantly faster and and ran with a significantly lower CV than those in group C (p = .001 and .018, respectively). Group C, however, had a significantly greater number of runners with an end spurt than group A or B (Z-score = 3.00). The mean race paces w/o rest of all the groups were also significantly faster than their overall mean absolute race pace (p = .003, .001 and .001, respectively). There were no differences between the three groups with respect to age.

**Table 2 about here

Figure 1 illustrates mean running speed across 17 distance segments of the 161-km course and 11 distance segments of the 101-km course for groups A-C, respectively. Pacing demonstrated a reverse J-shaped profile in all the groups for both distance categories. Overall in the 161-km category (left column), runners in group A ran faster than group B and C in 13 and 15 of the 17 segments, respectively. Runners in group B were faster than group C in only 1 of the 17 segments. Overall in the 101-km category (right column), runners in group A ran faster than group B and C in 9 and 11 of the 11 segments respectively. Runners in group B were also faster than group C in 9 of the 11 segments. No end spurt was detected for both distances when the analysis was done at group level.

**Figure 1 about here

In the 161-km category, runners who finished in group A, B and C, completed the entire race at running speeds within 40, 42 and 44% of their initial starting speed respectively (Figure 2 -- left column). The slopes of the normalized running speeds ranged from -0.26 ± 0.07 to -0.29

± 0.07 (groups A to C) (Table 1). There were no significant differences between the 3 slopes, suggesting that all the groups were slowing down evenly. In the 101-km category, runners who finished in group A, B and C, completed the entire race at running speeds within 34, 42 and 45% of their initial starting speed respectively (Figure 2 – right column). The slopes of the normalized running speeds ranged from -0.34 ± 0.18 to -0.50 ± 0.22 (groups A to C) (Table 2). The slope of group A was significantly lesser than the slopes of group B and C (*P* = .001 and .001, respectively), indicating that runners in group A ran at a more even pace compared to groups B and C. Figure 3 shows the combined graphs of groups A-C for both 161-km and 101-km finishers. From a descriptive point of view, Figure 4 and Figure 5 show mean of speeds and positions of all editions for the top five runners at each CP for both 161-km and 101-km categories.

**Figure 2 about here

**Figure 3 about here

**Figure 4 about here

** Figure 5 about here

DISCUSSION

The main findings of the study were that (i) pacing patterns during a 161-km and 101-km ultra-marathon remained consistent across different performance categories (ii) in the early portion of the race, top finishers tend to follow the leading runner while slower competitive finishers tend to form small packs with runners of similar pace (iii) faster finishers ran with fewer changes in speed than the slower finishers in the 101-km category and (iv) finishers remained conservative in their pacing over the last segment of the race when proximity to the end point is not known due to the absence of distance markers

Performance

In the 161-km category, finish times ranged from 25 h to 31.5 h across the three groups. This is a lot slower than the pacing study of Parise and Hoffman (23), whose participants in the fastest and middle one-thirds of the cohort ran a 100-mile race over a tougher mountainous terrain in under 22 h and 24 h, respectively. In the 101-km category, the finish times ranged from 17.5 h to 25 h across the groups. This is also slower than the timings established in the ultra-marathon literature where elite ultra-runners are able to complete the 100-km distance in 6.5 – 10 h (16) while well-trained athletes can do so in about 12 h (14). Although the high thermal load (temperature and humidity) experienced in both years of data collection would adversely affect the race performance and pacing (38), it is clear that the bulk of our participants were merely moderately-trained athletes who aimed to simply finish the event. This is affirmed by the absence of differences between the finish times of groups B and C in the 161-km category which bordered on the event's cut-off duration of 32 h.

Pacing pattern

According to the current data, there are general trends toward a reduced-speed, positive-pacing (fast – slow) pattern, resulting in a reverse J-shaped pacing profile regardless of performance or race distances. This is in agreement with the first hypothesis. Most runners completed the first quarter of the race relatively quickly and slowed progressively until the last CP, before picking up speed again (Figure 1). This pacing profile was also demonstrated in earlier ultra-marathon studies, with distance ranging from 100 km (25) to 161 km (23). A fast start in the less competitive / experienced runners [Figure 1 (L-R) – Group C] might simply reflect performance goals that are unrealistic and too ambitious while the top few might be chasing after the leader. For the remaining competitive participants [Figure 1 (L-R) – Groups A and B], their rate of perceived exertion (RPE) might be lower than anticipated during the start due to race excitement or the absence of fatigue, causing them to adopt a fast pace (26). After which, these runners might go on to form packs with those they find are running at similar pace during the course of the race and attempt to sustain that intensity for as long as possible. Indeed, Hanley (12) confirmed that most athletes running in packs during the IAAF World Half Marathon Championships were not actually in the lead group. A closer inspection of the data (results not shown) revealed that in the 161-km and 101-km categories, our participants were racing in packs of 5 and 10, respectively.

Although no physiological parameters were measured during the event, the rapid decline in speed after the first quarter of the race could be a result of cardiovascular strain due to the high thermal load (temperature and humidity approximately 32° C and 65%, respectively) imposed on the runners. Indeed, Périard, Cramer, Chapman, Caillaud and Thompson (24) showed that self-paced exercise in climatic conditions similar to this study led to the utilization of a progressively greater percentage of peak aerobic capacity during the development of thermal and cardiovascular strain for a given workload. Thus, exercise intensity in the heat was reduced in order to allow one to continue exercising at the physiological limit.

Generally, faster ultra-runners tend to display lesser variations in running speed (reflected via their mean CVs) than slower runners in distances ranging from 100 km to 161 km (13, 16). Such behaviour can be seen in our 101-km finishers, with the faster groups having a significantly lower CV (*P* = .013 and .001, respectively) than their slower opponents (Table 2). 101-km finishers in group A also slowed down significantly lesser (*P* = .001) than groups B and C (Figure 3). This is in line with the findings of Lambert, Dugas, Kirkman, Mokone and Waldeck (16) although their best 100-km runners ended the race within 15% of their starting speed while our fastest finishers could only achieve it within 34%. Interestingly, no differences exist in the CVs or decline in speed among the 161-km groups (Table 1 and Figure 3, respectively) despite group A finishing the race significantly faster than the rest (*P* = .001). Thus the second hypothesis can be partially rejected as only the fastest runners in the 101-km category had fewer variations in running speed and slowed down lesser than the remaining 101-km finishers.

It is interesting to note that all three groups in both categories increased their running speeds relative to the previous segment upon departure from the last CP [Figure 2 (L-R) – segment 15 and segment 9]. A similar trend was observed by Knechtle, Rosemann, Zingg, Stiefel and Rüst (15) in their analysis of pacing strategy in male elite 100 km ultra-runners where most of the runners achieved a negative (slow – fast) pacing over the last segment (23.3 km) of the race. Despite this increase in speed, only 38% of our large sample of ultra-runners could execute an end spurt in the last 5-km split, with the majority (N = 18) in Group C of the 101-km category (Table 2), hence disproving the third hypothesis that majority of the finishers will demonstrate an end spurt. This is also significantly larger (Z-score = 3.00) than the number of runners with an end spurt in groups A and B of the same distance category, respectively.Tucker (35) proposed that during the regulation of exercise intensity, a conscious

RPE (the verbal manifestation of the integrated physiological and psychological cues) is continually matched to a subconscious "template" RPE. The ignorance of one's proximity to the end point could potentially prevent the correct interpretation of afferent feedback from numerous physiological systems, resulting in a mismatch between the template and conscious RPE, with the latter to be un-interpreted. The overall effect will be to reduce or maintain the work rate. However, should the athlete be informed that the end of exercise is approaching, it is expected that the work rate, in this case running speed, will increase. Thus, the accurate knowledge of the distance between the last CP and the end point (12 km) would cause an increase in speed for the next distance segment. However, the absence of distance markers for the last 10 km would void the runners of subsequent information of their progress and proximity to the end. Overtime, this lack of feedback could restore the uncertainty in the runners and render them unwilling to increase speed further, hence the low number of end spurts.

Top five finishers

A reverse J-shaped pacing profile was observed for all the top five finishers in both distance categories (Figures 4 and 5 - bottom). This result is surprising given that top finishers of 100-km ultra-marathons were able to display more even pacing than less successful competitors (15, 25). A much slower start is required to achieve an even-pacing profile, which has been suggested to be the best for prolonged activity. Indeed, general performance benefits such as reduced rates of glycogen depletion, lower excessive oxygen consumption and ultimately a superior race time are associated with a slow starting speed (2). The "herd-principle" of following the leading runner at the beginning of the race might shed light on the actions of the top five runners in both categories (3). This model of herd behaviour suggests that when faced with a range of possible decisions (i.e., whether to follow the fastest runner or stick to own pace) individuals will pick the option that would result in the most positive affective response. To achieve this, an accurate assessment of both benefit and risk incurred by the potential actions has to be made and this is usually done via a rational or experiential approach (7). However, when decisions making is complex, using an overall affective impression (experiential) is easier and more efficient than performing a rational analysis of the various options available (31). Hence, runners are likely to select muscular work rates based on behaviour of rivals while giving less weighting afferent information pertaining to their personal physiological status. While our top five runners (both categories) did not run closely as a pack in the initial portion of the race, the lead runner was within sight for most of them. This can be demonstrated by the narrow differences in the spectrum of speeds maintained within the group in the early part of the race (Figures 4 and 5 - bottom). In fact, the second and third runners were usually just five to eight min behind the lead runner while the rest attempted to close the distance gap. This lasted for 21.5 km (CP 2) before the time gap between the lead and second runner widened considerably to about 20 - 30 min. It should be noted that the first split time was only available from the 12-km mark (CP 1) while subsequent splits were captured at every 9 to 15-km intervals. Future research should incorporate higher resolution data (i.e., 5-km splits for the first half of the race) to capture any potential pack running behaviour among the top ultra-runners.

A recent study by Hoffman (13) revealed that winners from 24 editions of a 161-km ultra-marathon did not always lead the race throughout, but remained relatively close behind the leading runners at the beginning of the race before taking the lead in the middle half , and then avoided slowing down as much as the other top runners in the later stages of the race. However, we failed to observe such a pattern consistently in the top five finishers of both distance categories in 2012 and 2013. Winners of the 161-km race took the lead early or immediately from the start of the race (Figures 4 and 5 - top) while those in the 101-km event adopted a conservative strategy and only overtook the second finisher very late into the race (Figure 5 - top). The aggressive pacing strategy of the 161-km victors might be attributed to their confidence in the ability and fitness to maintain a fast pace, which could be reflected in their reasonably good finish times of 19.4 h and 22.4 h, respectively. We acknowledge that two editions of the race might be insufficient to generalize adequate meaningful practices of the top finishers and that more years of data should be included.

The outlier winner

It is noteworthy that the 2012 winner of the 101-km event displayed atypical pacing characteristics compared to the other top finishers in both distance categories. This participant was able to maintain an even pacing profile for 8 of the 11 distance segments (total 73 km), with speed kept at a narrow range of 7.2 km/h to 7.9 km/h before speeding up considerably for the last 5 km of the race. The decline in speed at segment 5 and 6 (Figure 5 – bottom left) coincided with running along an unshaded path during the hottest period of the day. This is not surprising since it is well-documented that increased ambient temperature can disrupt the even pacing patterns of faster runners. A study of marathon finishers on a flat course indicated that the fastest runners maintained an even pace under cool conditions but slowed down in the second half of the race under hot conditions (6). The mean CV of 6.3% across the first 10 distance segments (Segment 11 was excluded in the calculation as the end spurt would inflate the mean overall CV severely) was comparable to the mean CV (5.4%) displayed by the top 10 elite ultra-runners in the 100 km IAU World Challenge (16). This figure is also much lower than the mean CV (16.3%) measured over the same segments of the remaining top 10% 101-km finishers in both years. These findings concur with earlier studies that faster athletes display more even pacing than less successful competitors in distances ranging from 100-km ultra-marathon (25) to marathon running (27), suggesting that similar mechanisms pertaining to regulation of intensity influence the strategy utilized in endurance activities of varying durations. The absence of the 'herd principle', as evidenced by the runner's adoption of a low starting speed instead of keeping up with the faster runners (7.3 km/h vs 8.6 km/h of the other top 4 101-km finishers in 2012), combined with an unusually large end spurt of 62% above his mean race pace, is possibly the result of an overly conservative race strategy. His reluctance to increase his pace could be attributed to a high and low perception of risk and benefits, respectively (26). As periods of uncertainty during closed-loop exercise decrease with proximity to the end point (32), it might have been deemed safe to finally run faster, thus explaining the large end spurt of the runner. In fact, he only overtook the lead runner somewhere along the last 5 km of the race.

In summary, findings presented in this paper agree with previous research that sub-elite ultra-runners of varying performance levels tend to adopt a reverse J-shaped pacing profile. This might be attributed to unrealistic performance goals or running in packs of similar (yet unsustainable) pace in the initial portion of the race. Faster 101-km finishers also displayed fewer variations in their running speeds and slowed down lesser than their weaker competitors. A herd behaviour of following the leader was present in the top finishers and that the eventual winner need not be the leading runner at all times.

PRACTICAL APPLICATIONS

Results from this descriptive field study of pacing involving ultra-runners of varying fitness levels seems to suggest that adopting a patient sustainable starting speed is recommended. Less competitive / experienced runners aiming to just finish the ultra-marathon can benefit from having realistic performance goals while competitive runners with a specific time goal in mind can consider running in packs of similar pace. The latter group is also strongly discouraged from switching pace under the external influence of others early in the race. Judging from the severe decline in pace during the hottest period of the race, we also recommend athletes competing in ultra-marathons held in hot and humid conditions to practice adequate heat acclimatization before the event.

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FIGURE LEGENDS

Fig 1 Mean pace across each segment of the 161-km (left column) and 101-km (right column) courses for each cohort. *, ^ and + indicate a statistically significant difference ($P < .05$) for Group A vs. Group B and C, Group A vs. Group C, and Group B vs. Group C, respectively. Dotted line represents overall mean race pace of the group.

Fig 2 Normalized running speed of runners from the 161-km (left column) and 101-km (right column) courses for each cohort. The line of best fit for each group mean is shown in bold.

Fig 3 (L-R) Lines of best fit for 161-km and 101-km categories of normalized running speed vs. distance. * indicates a statistically significant difference ($P < .05$) for Group A vs. Group B and C.

Fig 4 Global pacing comparisons among the top five finishers of the 161-km race. Top: Race positions based on checkpoint. Bold circle represents same arrival time at the checkpoint by two runners. Bottom: Speed comparisons among the top five finishers. Thick bold line represents mean pace across each segment of the 161-km courses (standard deviation bars removed for clarity). Dotted line represents overall mean race pace of the five runners. Legend reflects overall race position. All data are from 2012 – 2013 editions. Abbreviations: CP, Checkpoint.

Fig 5 Global pacing comparisons among the top five finishers of the 101-km race. Top: Race positions based on checkpoint. Bold circle represents same arrival time at the checkpoint by two runners. Bottom: Speed comparisons among the top five finishers. Thick bold line represents mean pace across each segment of the 101-km courses (standard deviation bars removed for clarity). Dotted line represents overall mean race pace of the five runners. Legend reflects overall race position. All data are from 2012 – 2013 editions. Abbreviations: CP, Checkpoint.

Table 1 Performance Characteristics of the 161-km Finishers (Mean ± SD)

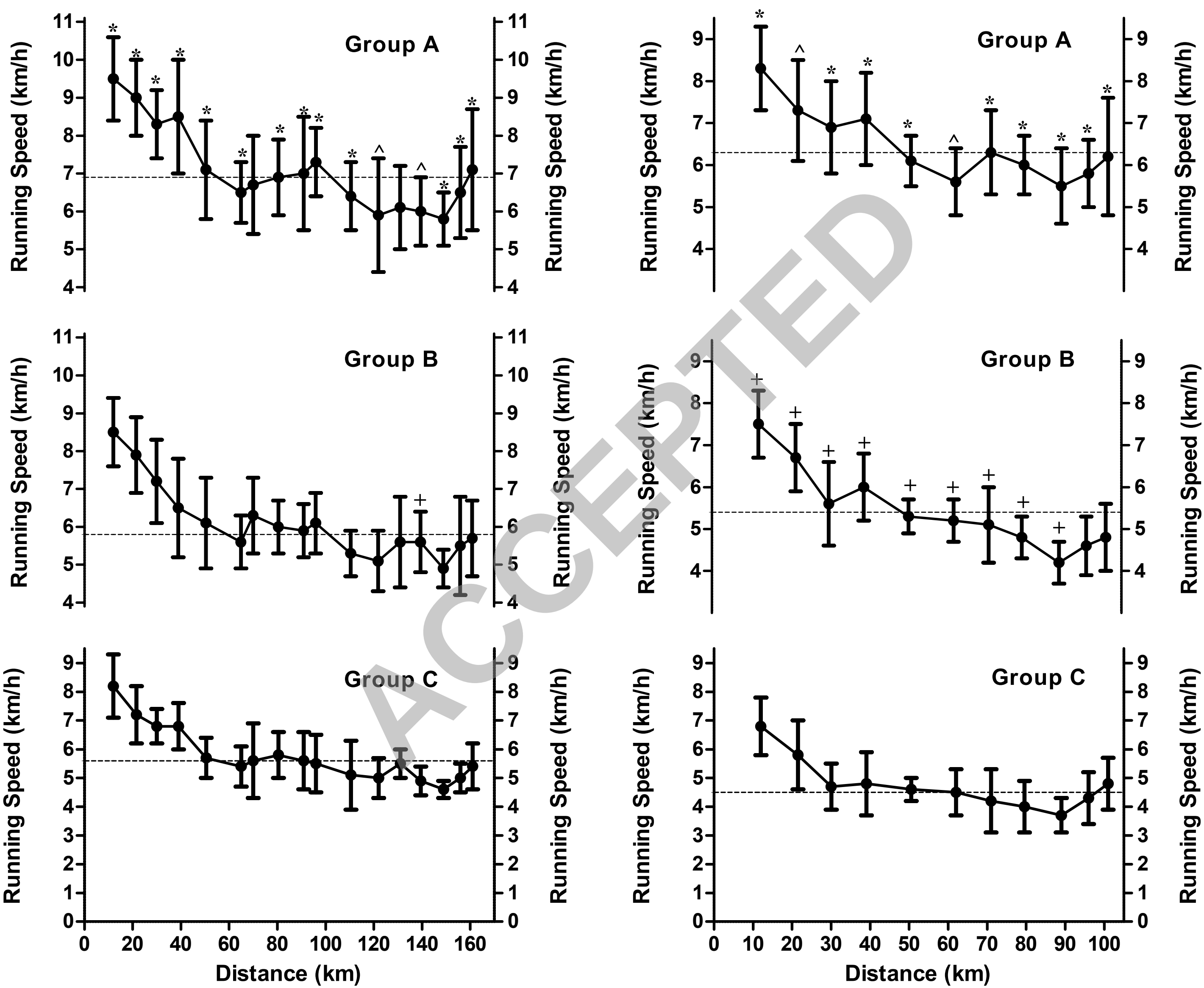
	Group		
	A (n = 16, 2 women)	**B (n = 16, 4 women)**	**C (n = 15, 2 women)**
Age (y)	40.3 ± 6.4	41.9 ± 7.0	41.0 ± 8.0
Finish Time (hh:mm)	25:20 ± 2:56 ^{B,C}	30:20 ± 00:45	31:34 ± 00:14
Pace W rest ($km \cdot h^{-1}$)	6.4 ± 0.8 ^{B,C}	5.3 ± 0.1	5.1 ± 0.1
Pace W/O rest ($km \cdot h^{-1}$)	6.9 ± 0.8 ^{B,C}	5.8 ± 0.2*	5.6 ± 0.2*
Overall CV (%)	19 ± 5.3	20.4 ± 6.0	21.1 ± 4.0
Normalized Slope	-0.26 ± 0.07	-0.28 ± 0.10	-0.29 ± 0.07
Runners with end spurt	7	5	5

Abbreviations: W, with; W/O, without; CV, coefficient of variation; 1st, first; 2nd, second; No., number.
* and capital superscript letters denote *P* < .05 within and between groups, respectively.

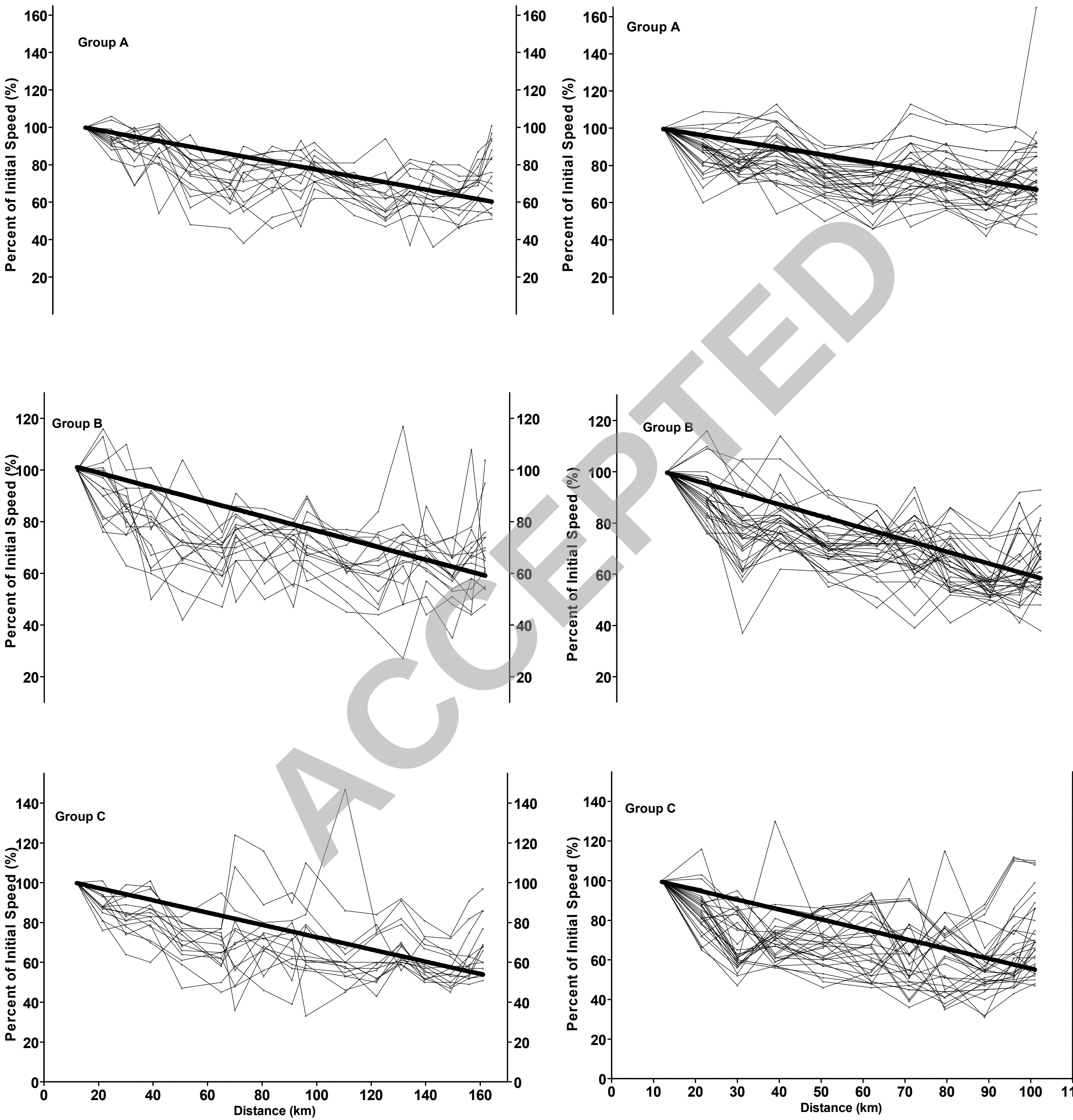
Table 2 Performance Characteristics of the 101-km Finishers (Mean ± SD)

	Group		
	A (n = 33, 4 women)	**B (n = 34, 8 women)**	**C (n = 31, 5 women)**
Age (y)	39.4 ± 7.8	41.7 ± 9.0	39.0 ± 9.4
Finish Time (hh:mm)	17:25 ± 01:41^{B,C}	21:22 ± 00:45^{C}	25:22 ± 02:01
Pace W rest (km·h^{-1})	5.9 ± 0.6 ^{B,C}	4.7 ± 0.2^{C}	4.0 ± 0.3
Pace W/O rest (km·h^{-1})	6.3 ± 0.6*^{,B,C}	5.3 ± 0.3*^{,C}	4.5 ± 0.4*
Overall CV (%)	17.1 ± 5.7 ^{B,C}	21.0 ± 4.3 ^{C}	24.7 ± 6.2
Normalized Slope	-0.34 ± 0.18 ^{B,C}	-0.46 ± 0.14	-0.50 ± 0.22
Runners with end spurt	13	5	18^{A,B}

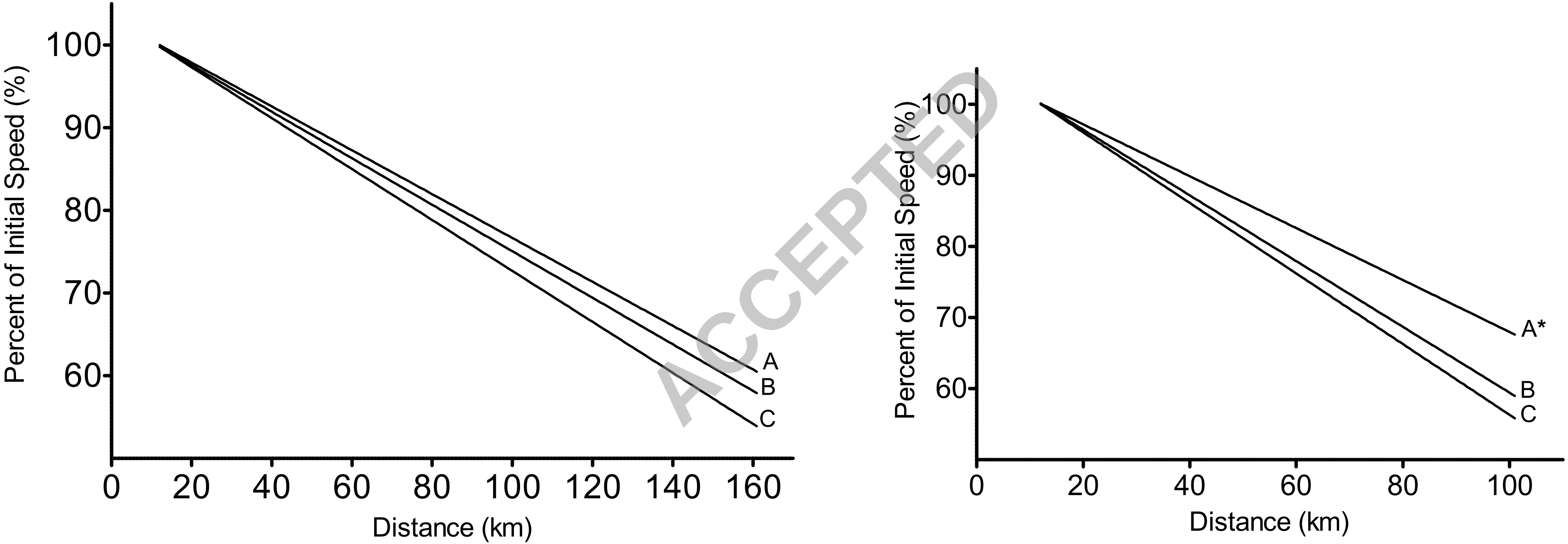
Abbreviations: W, with; W/O, without; CV, coefficient of variation; 1st, first; 2nd, second; No., number.
* and capital superscript letters denote *P* < .05 within and between groups, respectively.



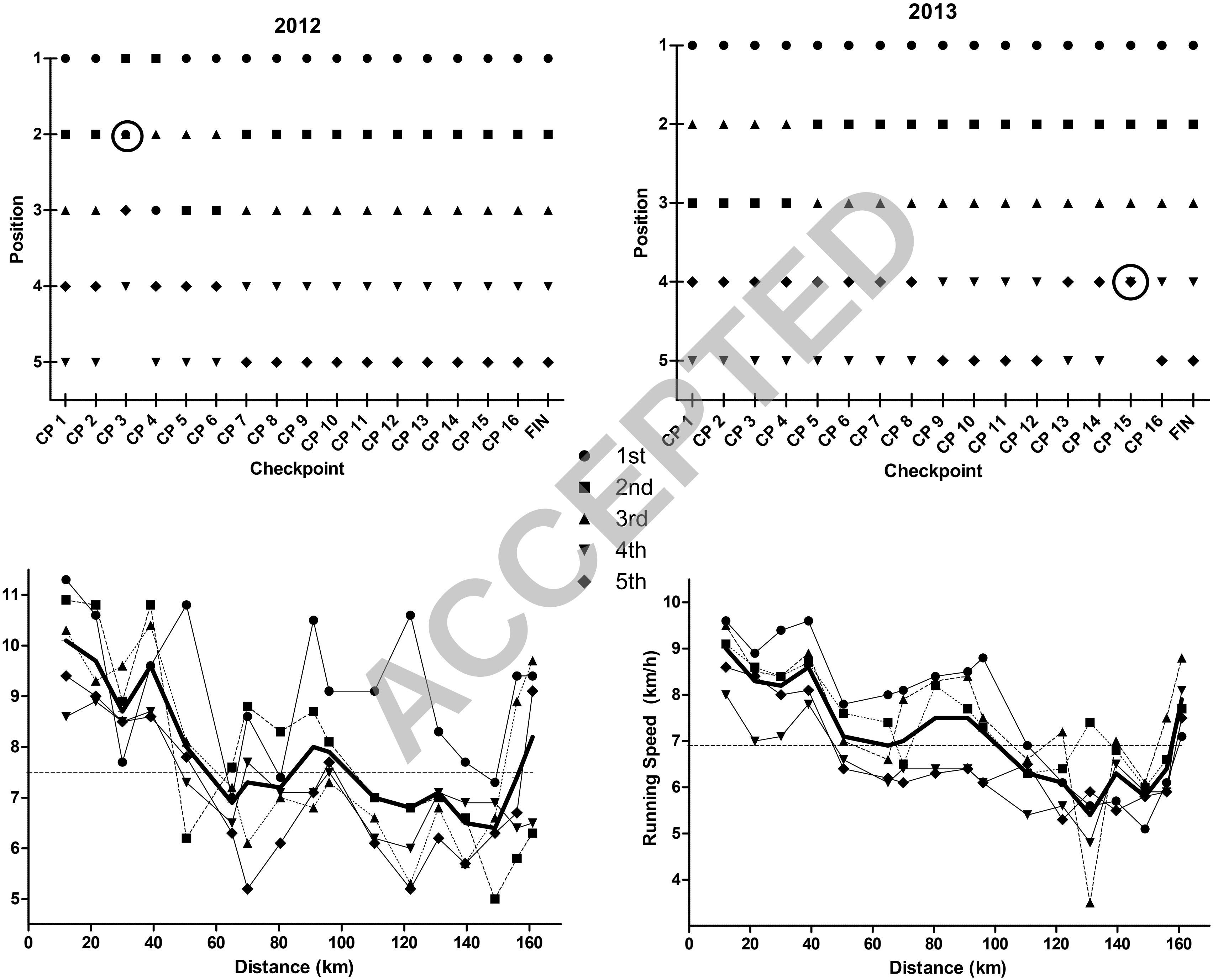
Group A
Group A
Group B
Group B
Group C
Group C
Running Speed (km/h)
Distance (km)
ACCEPTED

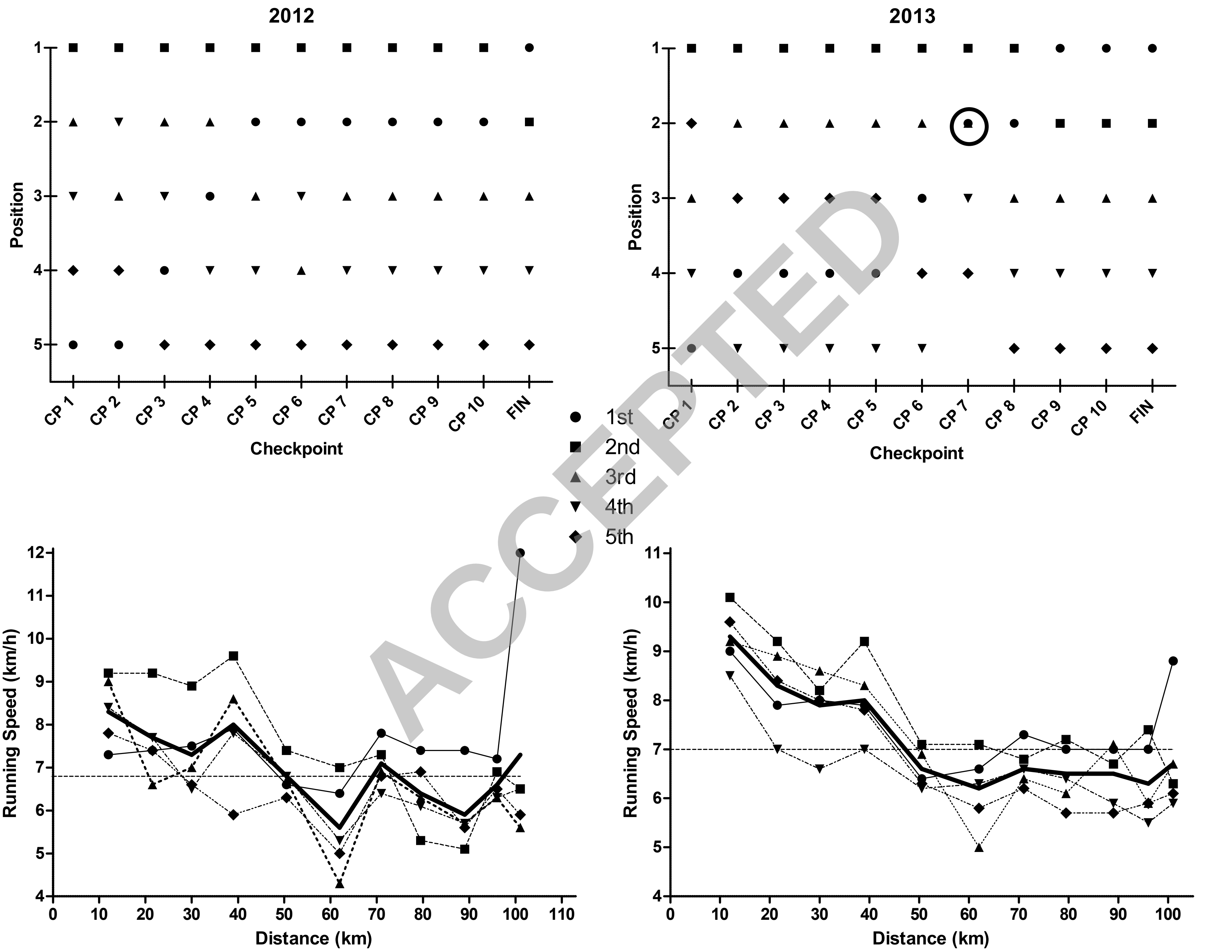


Group A
Group A
Group B
Group B
Group C
Group C
Percent of Initial Speed (%)
Distance (km)



Percent of Initial Speed (%)
100
90
80
70
60
0
20
40
60
80
100
120
140
160
Distance (km)
A
B
C
Percent of Initial Speed (%)
100
90
80
70
60
0
20
40
60
80
100
Distance (km)
A*
B
C


2012
2013
Position
Checkpoint
CP 1
CP 2
CP 3
CP 4
CP 5
CP 6
CP 7
CP 8
CP 9
CP 10
CP 11
CP 12
CP 13
CP 14
CP 15
CP 16
FIN
1st
2nd
3rd
4th
5th
Running Speed (km/h)
Distance (km)


2012
2013
Position
Checkpoint
CP 1
CP 2
CP 3
CP 4
CP 5
CP 6
CP 7
CP 8
CP 9
CP 10
FIN
1st
2nd
3rd
4th
5th
Running Speed (km/h)
Distance (km)
ACCEPTED