CHANGES IN RUNNING GAIT PARAMETERS DURING A 161 KM TRAIL RACE

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The current study examined changes in running speed and technique during a 161 km trail race and their relationship to performance. Sixteen participants were video recorded during continuous running for each of the five 32 km loops of the race. Participant's stride length (SL), stride rate (SR), and speed were calculated. Lap and finish times were also collated from the race results. All variables changed significantly during the race (i.e. Speed↓, Lap time↑, SL↓ and SR↓). Increased consistency in stride rate and length across the five laps, as well as speed, correlated positively with performance. Increased stride length in laps one, two and four correlated positively with performance. Results indicated that fatigue during the race decreased both speed and SL. Better performers ran faster with a longer SL and were able to maintain their initial speed for longer.

KEY WORDS: Stride Length, Stride Rate, Pacing.

INTRODUCTION: Trail running has become an increasingly popular activity worldwide. Many high profile trail races are now ultra-marathon distances (any distance longer than a traditional marathon or > 42.2 km, such as a 50k or 100k foot race). In 1998, there were only 21 ultra-marathons of varying ultra-distances in North America; however, by 2008, there were 53 161 km ultra-marathon competitions alone in North America (Hoffman, Ong & Wang 2010). Despite the exponential increase in races and number of ultra-runners, little is known about factors affecting how these competitors choose to complete ultra-races. For instance, pacing strategy is essential to manage and/or postpone the detrimental effects of fatigue. A number of measurable factors can contribute to pacing strategy, such as running speed, which might be the most obvious and easily managed variable related to exhaustion. Gait parameters typically related to running speed are stride rate and stride length. With the above facts in mind, gait parameters during ultra-marathons have received limited research attention. To our knowledge, Kasmer et al. (2013) were the first to publish research related to foot strike pattern and gait parameters during a 161 km ultra-marathon. They assessed change in variables at three points during the race and subsequently related them to performance and muscle fatigue. The current study adds to the aforementioned research variables in that we investigated the change in running speed and gait parameters over five points of a 161 km ultra-marathon and related them to performance.

METHODS: Sixteen race participants (4 females, 12 males, Mean ± SD Age = 44.19 ± 8.15 years) volunteered in response to a blanket survey sent to all registered race participants before the 2013 Rocky Raccoon 161 km footrace held in Huntsville State Park in Texas, USA. Participants in the race were required to sign a race waiver, and current researchers assumed all participants were in good health. The current study was approved by the Institutional Review Board of the research team's university.
Participants were observed running a 161 km footrace that consisted of five identical laps of 32 km. Participants were observed at 27 km, 59 km, 91 km, 123 km and 155 km. The course consisted of trail running on double and single track trails generally considered to have low elevation change at roughly 1680 m ascent and descent; hills were not higher than 31 m. The race had a cutoff time of 30 hours, requiring the majority of runners to perform a portion of the race at night wearing headlamps. Current researchers placed no controls on the participants.
Two Panasonic HX-DC10 (Panasonic Corporation, Kadoma, Osaka, Japan) cameras recording at 60 Hz in 1080p were set up at one relatively flat location. One camera was

aimed perpendicular to the trail with two reflective stakes in view to indicate a 1 meter reference parallel to the trail, for scaling purposes. The second camera was placed parallel to the trail such that the participants' bib number could be viewed for identification purposes. During the night portion of the data collection, multiple battery-operated lights were aimed to illuminate the recording area. Participants were encouraged pre-race to ignore the cameras and run naturally through the recording zone.

Post-race, a researcher analyzed two strides, which were averaged for the participant per lap, for stride length and time utilizing Kinovea (v 0.8.15, Kinovea open source project, www.kinovea.com). per participant and averaged the two samples per lap. Stride length was defined as the distance measured between first and second initial contact of the left foot; stride time defined as the time between the contacts. Lap times and overall race times as well as race placement were retrieved from the race results for analysis.

A one-way repeated measures ANOVA was used to compare the differences across laps for the dependent variables of lap time, speed while in the camera view, stride length, and stride rate. Significance was set at $p < 0.05$. A Greenhouse-Geiser correction factor was used when the assumption of sphercity was violated. When significant main effects were detected, a Bonferoni corrected pair-wise comparison was performed. Correlations of the overall finish time (s) to number of laps completed, standard deviation of lap times, stride rate and length, and average speed for the race were also performed. In addition, for each of the five laps: speed while in the camera view; stride length; and stride rate; were correlated to overall finish time (s) using a Pearson bivariate correlation analysis.

RESULTS & DISCUSSION: The change in measured variables across five laps is shown in Figure 1. All variables changed significantly across laps.

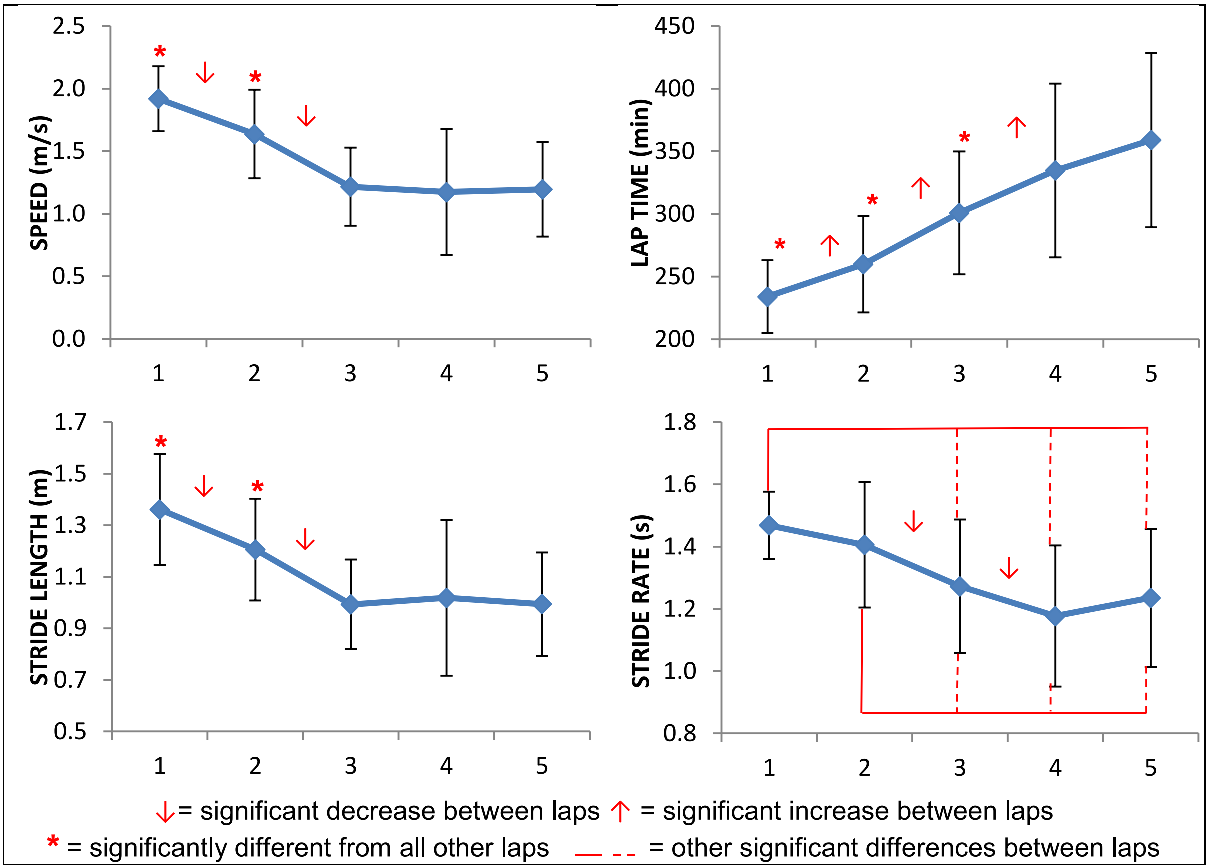

Figure1. Change in running technique and speed across 5 laps

The relationships between gait parameters and performance across the five laps are detailed in Table 1. The following variables, measured across the entire race, were significantly correlated ($p < 0.01$) with finish time (s) and included: number of laps run (r=-0.716**), standard deviation of lap times (r=0.722**), standard deviation of stride rate (r=0.668**), standard deviation of stride length (r=-0.506*), and average speed (r=-0.829**).

Table 1
Relationship between running technique and finish time (s) across all laps

	Lap1	Lap2	Lap3	Lap4	Lap5
Speed (m/s)	-.507*	-.671**	-.562*	-.734**	-0.413
Stride Length (m)	-.582*	-.655**	-0.345	-.637**	-0.387
Stride Rate (stride/s)	.259	-.300	-.345	-.494	-.280

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

Lap time, running speed, and all recorded gait parameters changed significantly during the five laps of the event. Lap time increased significantly between laps one to four followed by a non-significant increase in lap time between laps four and five or the closing loop. Running speed and stride length followed a similar pattern with significant decrease between laps one, two and three. Running speed and stride length remained relatively constant between laps three, four and five. Stride rate decreased from lap one to four with significant decreases reported between laps two, three and four. A slight increase was seen between laps four and five but was not significant.

Similar changes in gait parameters were reported by Kasmer et al. (2013). They reported a significant decrease in stride length between 16.5 km and 90.3 km. This has also been reported in previous work over shorter distances (Hausswirth et al., 1997; Townshend et al., 2010). Decreases in stride length and frequency have been previously associated with increases in fatigue (Landers et al., 2011; Girard et al., 2013) and strongly related to a decrease in running speed (whereby running speed = stride length X stride rate). A significant increase in stride rate was also reported by Kasmer et al. (2013) between 90.3 km and 161.1 km. This has also been reported previously at the end of a 24 hour foot race (Morin et al., 2011a) and 3 hours following completion of an 166 km ultra-marathon when runners were tested pre and post-race (Morin et al., 2011b). Interestingly Edwards et al. (2009) suggested that a 10% increase in stride frequency may decrease the probability of stress fractures by 3– 6%. It is however more likely that the significant increase in stride rate reported by Kasmer et al. was due to the proximity of the observation point (250 m from the finish), where runners attempted to produce a last surge to the line resulting in increased stride frequency.

The second purpose of the current study was to investigate the relationship between running speed and the gait parameters and each participant's finish time. A number of variables correlated significantly with finish time. Logically, speed in laps one, two, three and four were significantly correlated with finish time. Those who ran faster in laps one to four finished sooner. There was a non-significant negative correlation between speed and finish time for lap five, indicating speed on the final lap may be less influential towards race finish time. Stride length was also negatively correlated with finish time for laps one, two and four. Lambert et al. (2004) reported that faster runners in a 100 km foot race were better able to maintain their initial speed for a longer distance before slowing. Perhaps the faster finishers in the current study were better able to maintain their initial speed in laps one to four explaining the significant correlation with finish time during these laps. The correlations calculated for stride length indicated that the faster finishers may be maintaining their speed by manipulating stride length as opposed to stride rate, which had no significant correlations with finish time.

Interestingly, the standard deviations of lap time and stride rate were both positively correlated with finish time, indicating that runners with consistent lap splits and stride rate finished faster. The standard deviation of stride length displayed a significant negative correlation with finish time. This is consistent with Lambert et al. (2004) who reported that faster runners in a 100 km race ran with fewer changes in speed. This consistency is likely to stem from controlling stride rate as opposed to stride length which shows less consistency in the better performers. Despite stride rate also serving as an important contributor to faster performances, stride length is equally important to maintain, per the results of this study.

CONCLUSION: Running speed and running gait parameters in the current study are reported to change significantly across a 161km trail race. Fatigue is thought to decrease running speed along with moderating effects on stride rate and length. For instance, increased speed and stride length correlated significantly with decreased finish time, as did consistency in stride rate for each lap. Potentially, this illustrated that better performers ran faster with a longer stride length, consistent stride rate, and were able to maintain their initial speed longer. In the end, it's highly probable that greater ultra-running experience and enhanced training parameters react cooperatively to balance the aforementioned variables.

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Acknowledgement

The research team would like to thank all participants in this research study, the race organiser Joe Prusaitis, the race volunteers and the grounds staff at Huntsville State Park. The research team would also like to acknowledge the College of Health Sciences and Professional Studies, Northern Michigan University for funding this research project. The research team would also like to acknowledge the Physical Education & Sport Sciences Department in the University of Limerick for the use of their video recording equipment during data collection.