Original Research

A Description of Variability of Pacing in Marathon Distance Running

THOMAS A. HANEY JR.† and JOHN A. MERCER‡

Department of Kinesiology and Nutrition Sciences, University of Nevada, Las Vegas, NV, USA

‡Denotes professional author, †Denotes graduate student author

ABSTRACT

Int J Exerc Sci 4(2) : 133-140, 2011. The purpose of this study was twofold: 1) to describe variability of pacing during a marathon and 2) to determine if there is a relationship between variability of pacing and marathon performance. Publically available personal global positioning system profiles from two marathons (Race 1 n = 116, Race 2 n = 169) were downloaded (http://connect.garmin.com) for analysis. The coefficient of variation of velocity (Velcov) was calculated for each profile. Each profile was categorized as finishing in under 3.9 hours, between 3.9 and 4.6 hours, or longer than 4.6 hours. Linear and quadratic lines of best fit were computed to describe the relationship between marathon finish time and Velcov. A 2 (Race) x 3 (bin) analysis of variance (ANOVA) was used to compare the dependent variable (Velcov) between races and the marathon bin finish times. Velcov was not influenced by the interaction of finish time bin and Race (p>0.05) and was not different between races (Race 1: 16.6 ± 6.4%, Race 2: 16.8 ± 6.6%, p>0.05). Velcov was different between finish time categories (p<0.05) for each race such that Velcov was lower for faster finish times. Using combined data from both races, linear (marathon finish time = marathon finish time = 0.09Velcov + 2.9, R^2 = 0.46) and quadratic (marathon finish time = -0.0006 Velcov 2 + 0.11 Velcov + 2.7, R^2 = 0.46) lines of best fit were significant (p<0.05). Slower marathon finishers had greater variability of pace compared to faster marathoner finishers.

KEY WORDS: Fatigue, pace strategy, running economy

INTRODUCTION

During endurance running events, there are many factors that can influence the pace of the runner. For example, changes in terrain, elevation, environmental temperature, and fatigue can all influence the pace that can be maintained. Likewise, a runner may strategize to maintain a constant (e.g., target pace) or variable pace (e.g., run-walk strategy). Understanding variability of pacing may lead to a better understanding of factors that influence marathon performance and help runners either complete a marathon successfully or improve race performance. Specifically, the intriguing aspect of investigating variability of pace is that the runner, theoretically, selects a pace to maintain homeostasis. However, if the wrong pace is selected (e.g., too fast) fatigue will result and the runner will slow down or possibly not finish the distance event.

Variability in pacing has been studied in respect to short- and middle-distance running (e.g., 3,000 m to 10 km) (1, 2, 4, 5, 6, 7, 9, 10). These studies have mostly focused on the influence of pacing on metabolic measures related to performance but some studies do provide insight into variability of pacing. For example, Billat (2) reported that the coefficient of variation in velocity was 1%-5% during a 3000 m run. Cottin et al. (4) demonstrated that fatigue did not increase variability of velocity during a distance run (1280 m). Despite research like this, there is only limited research on the variability of pace during long distance events such as a marathon.

Ely et al. (5) reported that elite runners completing a marathon had very little change in 5 km pace during a marathon – suggesting low variability of pace. It makes sense that elite runners attempt to maintain a constant pace throughout the marathon. Likewise, Lambert et al. (8) reported that the top-ten runners completing a 100 km ultra-marathon race had less changes in pace than runners finishing between 11th and 77th place. Although it makes sense to study pacing strategies of elite athletes, the majority of marathon participants are non-elite runners. Information on pacing strategies for this population would be helpful in designing appropriate training programs, for example. Therefore, the purpose of this study was to describe the variability of pacing during a marathon for non-elite runners. A second purpose was to determine if there is a relationship between variability of pacing and marathon performance for this same population. It was hypothesized that there is a non-linear relationship between variability of pace and marathon performance in a such that slower runners will experience less variation in pace compared to mid-range finshers. Faster runners attempting to maintain a pace throughout the race will also have less variability of pace compared to mid-range finishers.

METHODS

Participants

Velocity data during a marathon were obtained by downloading publicly available global position system (GPS) data from the Garmin Connect web page. Each data set included at least: marathon location, marathon date, speed, and position data. A total of 311 GPS profiles from 2 races (Las Vegas and San Diego marathons) were downloaded for analysis. These races were selected due to the number of GPS profiles available via Garmin Connect. Subject-specific descriptive information (e.g., age, gender, height, weight, or ethnicity) were not available. The study was determined to be exempt from requiring consent from human subjects since de-identified secondary data were used.

Protocol

All GPS profiles were inspected prior to analysis and it was determined that 26 profiles were not suitable for analysis resulting in 285 profiles (116 for Race 1, 169 for Race 2) used for analysis. Profiles were removed either due to large gaps in the GPS profile or the presence of negative velocity values. Of the 285 profiles, 13 had additional data beyond the finish line evident by a dramatic drop in velocity as well as extension of the position data beyond the finish line. Data beyond the finish line location (as determined by position coordinates) were removed from the profiles. Two (2) profiles from Race 1 and 11 files from Race 2 were edited for this reason. All GPS profiles used for analysis were resampled to yield the same sample rate (0.15 Hz) using a custom program (Matlab, Mathworks, Version 6.1).

Variability of pacing was determined by calculating the Coefficient of Variation of velocity (Velcov). The velocity data in the GPS profile were used to calculate Velcov using the formula:

$$\mathrm{Vel}_{\mathrm{cov}} = \frac{vel_{stdev}}{vel_{mean}} \bullet 100$$

Where:
velstdev = the standard deviation of velocity over the duration of the marathon.
velmean = the average velocity over the duration of the marathon.

Marathon finish time was determined by identifying the last time in the data set. Each marathon finish time was placed into one of three finish time bins: Bin 1: < 3.9 hrs, Bin 2: 3.9 – 4.6 hrs, Bin 3: > 4.6 hrs. These bins were defined in order to have a similar number of data sets per bin.

Statistical Analysis
Descriptive statistics were calculated for Velcov and marathon finish time for each race. Frequency distributions of marathon finish time and Velcov per race were generated with Velcov data tested for normality (Kolmogorov-Smirnov test; SPSS 17.0).

A 2 (Race) x 3 (bin) analysis of variance (ANOVA) was used to compare the dependent variable (Velcov) between races and the marathon bin finish times. Post-hoc tests (least square difference) were computed if the omnibus F-ratio was found to be significant to compare Velcov between bins. Non-parametric tests were used in the case that the data were not normally distributed. Finally, linear and quadratic regression lines were generated predicting marathon finish time from Velcov using all 285 data sets.

RESULTS

The frequency distributions of Velcov and for marathon finish time for each race are presented in Figure 1. Velcov was 16.9 ± 6.4% and 16.8 ± 6.6% for Race 1 and Race 2 (Table 1). Marathon finish time was 4.27 ± 0.80 hours for Race 1 and 4.40 ± 0.86 for Race 2. The range of Velcov was 30.0% for Race 1 vs. 40.2% for Race 2.

It was determined that Velcov was not normally distributed for either Race 1 or Race 2 ($p<0.01$). Non-parametric tests and parametric tests were conducted with both analyses yielding identical results.

Velcov was not influenced by the interaction of Race and bin ($p>0.05$) and was not different between Races (Race 1 16.6 ± 6.3%; Race 2 16.7 ± 6.5%; Table 1; $p>0.05$). Velcov was influenced by bin finish time ($p<0.05$). Using post-hoc tests, it was determined that Velcov was lower in Bin 1 vs. Bin 2 ($p<0.05$), lower in Bin 1 vs. Bin 3 ($p < 0.05$), and lower in Bin 2 vs. Bin 3 ($p<0.05$) for both races (Table 1).

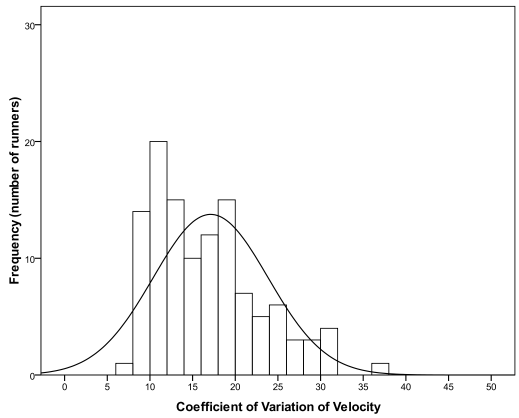

Figure 1A. Race 1.

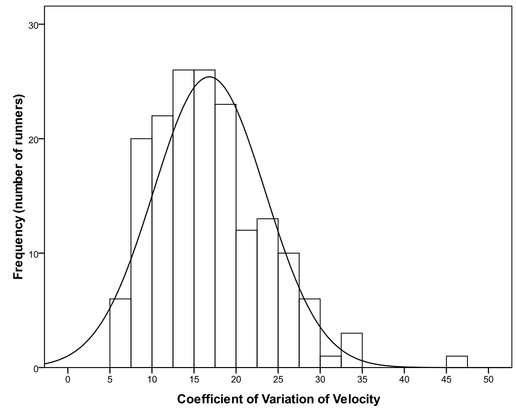

Figure 1B. Race 2.

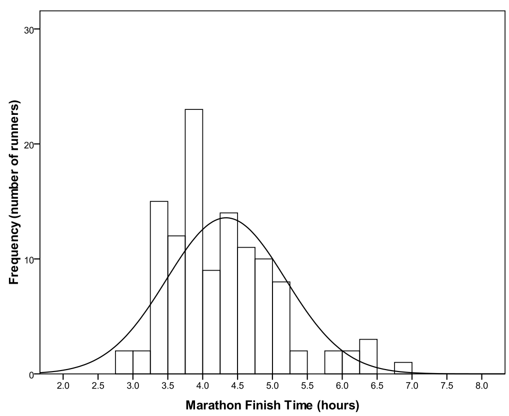

Figure 1C. Race 1.

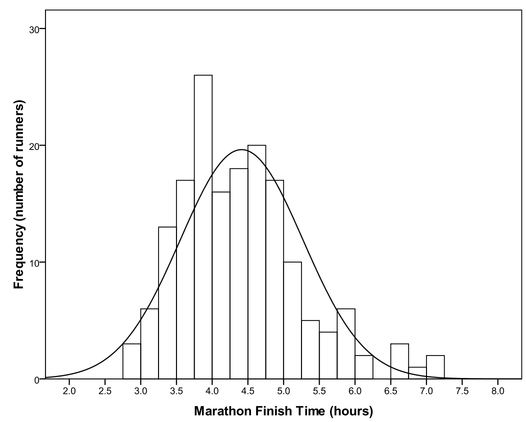

Figure 1D. Race 2.

Figure 1. Frequency of Velcov for Race 1 (Figure 1 A) and Race 2 (Figure 1 B) as well as marathon finish time for Race 1 (Figure 1C) and Race 2 (Figure 1D).

Table 1. Means and standard deviation for coefficient of variation of velocity (Velcov) and marathon finish times per bin and per race ('n' is the number of observations for the specific race and/or bin).

		Race 1	Race 2
Bin 1: <3.9 hrs	*n*	44	56
	Vel_{cov} (%)	13.2 ± 4.6*	12.3 ± 3.5
Bin 2: 3.9-4.6 hrs	*n*	36	50
	Vel_{cov} (%)	15.9 ± 5.5**	15.1 ± 5.2
Bin3 : >4.6 hrs	*n*	36	63
	Vel_{cov} (%)	21.5 ± 6.1	22.2 ± 6.0
Total	*n*	116	169
	Vel_{cov} (%)	16.6 ± 6.4	16.8 ± 6.6
Finish time (hrs)		4.27 ± 0.80	4.40 ± 0.86

Note: * Bin 1 was different than Bin 2 and Bin 3; ** Bin 2 was different than Bin 3 for each race ($p<0.05$).

Marathon time was not influenced by an interaction of Race and bin ($p>0.05$) and was not different between Races (Table 1; $p>0.05$). Marathon time was different between bins ($p<0.05$) with Bin 1 containing the fastest times and Bin 3 the slowest.

Both linear and quadratic regression lines predicting marathon finish time from Velcov were significant (Figure 2, $p<0.05$).

Linear:
Marathon finish time = .09•Velcov + 2.9, R2 = 0.46

Quadratic:
Marathon finish time = -0.0006•Velcov 2 + 0.11•Velcov + 2.7, R2 = 0.46

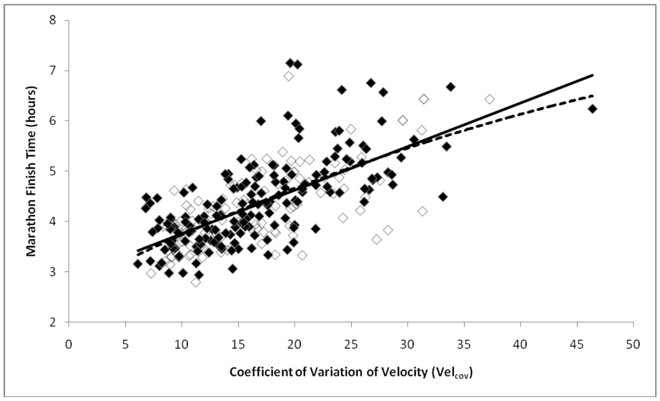

Figure 2. Velcov across marathon finish time. Velcov increased as marathon time increased for Race 1 (open symbols) and Race 2 (filled symbols). Both the linear (solid line) and quadratic (dashed line) lines of best fit were significant ($p<0.05$; linear: R2 = 0.46, quadratic R2 = 0.46).

DISCUSSION

This study set out to describe the variability of marathon pace for non-elite runners. Using 285 GPS data sets from two different marathons, it was determined that the Velcov was 16.7 ± 6.5% for marathon finish times of 4.35 ± 0.84 hours. A second goal of this study was to determine if there was a relationship between marathon finish time and Velcov. We approached this purpose two ways. First, we placed each marathon finish time in a specific bin (i.e., < 3.9 hours, 3.9 – 4.6 hours, > 4.6 hours) and compared Velcov between bins for each race. Using this approach, we determined that Velcov was different between marathon finish times such that Velcov was greater for slower finish times for both races. The second approach we used was to build linear and quadratic regression lines to predict marathon finish time from Velcov. Using this approach, we determined that both linear and quadratic lines fit the data (R2 = 0.46 for both lines) such that Velcov increased with slower marathon finish times. Originally, we hypothesized that the slower marathon times would have less variability of pace than the average marathon finish time. Based upon the two approaches we took, it seems that this was not the case and instead variability of pace continued to increase with slower marathon finish times.

There are minimal published data on variability of pacing in running endurance events. The few studies that have reported variability of pacing have either been of shorter distances (e.g., 2) or of elite runners (e.g., 5, 8). For example, Billat (2) reported that Velcov of middle- and long-distance running to be in the range of 1%–5% for 3,000 m to 10 km for competitive runners. Inspection of the data reported by Ely et al. (5) indicates that the marathon race winners had low variability of pacing (approximately less than 20 s difference between 5 K splits) as did the 100th place finishers (range of about 3 minute difference between fastest and slowest 5 K splits). Lambert et al. (8) observed Velcov as low as 5.4% for the top ten finishers of a 100 km ultra-marathon race and as high as 19.6% for the 61st-67th place finishers. In the present study, variability of pace was greater (16.7 ± 6.5%) compared to Billat (2) and Ely et al. (5) but comparable to some of the data presented by Lambert et al. (8). The reason for the difference between studies is likely related to the level of competitive athlete studied. In our case, the subjects were not elite runners. Considering all 285 data sets, the mean marathon finish time was 4.35 ± 0.84 hours. Given the result that Velcov was influenced by marathon time, it does makes sense that the Velcov will be higher among non-competitive marathon distance runners compared to elite marathoners with finishing times under 3 hours. For example, using the linear and quadratic regression equations, Velcov would be between 3.04% (quadratic) and 3.00% (linear) for a 3 hour marathon.

A personal GPS device is a convenient tool to use to monitor race pace. However, the GPS device does contain some noise in the signal and we had to discard 26 profiles from analysis due to different errors in the signal. We considered that Velcov may have been influenced by the noise in the signal and therefore we smoothed the data set using a low-pass filter (4th order, zero phase-lag, cutoff frequency = 0.15/4 Hz) to remove any high frequency noise (e.g., intermittent high-velocity spikes). The smoothed data sets were then compared using the same statistical procedures as the original data and it was determined that the outcome of the analysis was the same regardless of which data sets were used. Therefore, we concluded that the noise did not influence the outcome of the study.

Changes in elevation may have an effect on Velcov since runners tend to change their velocity while running up or downhill. The influence of elevation changes on Velcov was not examined in this study. The elevation profiles for each race are illustrated in Figure 3 and are normalized to the starting elevation in order to emphasize the change in elevation (vs. the actual elevation). From this illustration, it seems that the changes in elevation were not dramatic between races or even within a race which coincides with our observation that variability of pace was not different between races. Nevertheless, it is hypothesized that races with either more frequent or greater changes in elevation would result in a greater Velcov than what was observed in this study.

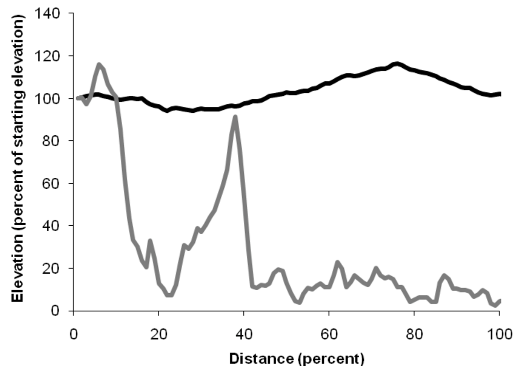

Figure 3. Elevation profiles for the Las Vegas and San Diego marathons. Elevation data are normalized to the starting elevation (Las Vegas ~665 m; San Diego ~80 m) in order to emphasize the change in elevation (vs. the actual elevation).

There does seem to be a relationship between Velcov and marathon time since Velcov was different across the marathon finish time bins for each race and because the data were fit with both linear and quadratic regression lines. Lambert et al. (8) also observed an increase in variability of pace with longer finishing times during a 100 km race. It makes sense that Velcov is low for fast marathon (5) or ultra-marathon (8) times since runners are trying to maintain as fast a velocity possible over the entire distance in an attempt to achieve a faster finishing time. Large Velcov over the course of the race would mean the runner is undergoing large changes in velocity which would seem detrimental to elite marathon performance. It also makes sense that Velcov is greater for slower marathon times since the runner does not have the same physical capacity as the elite marathon runner to maintain a consistent pace. For example, a runner who ran for a period of time but then needed to walk to recover from the exertion would have a greater Velcov then a runner who could maintain a consistent pace over the same period of time. However, it is not clear why Velcov continued to increase for longer marathon times (i.e., >4.6 hrs). Originally, it was thought that these runners would have low variability of pace since the capacity to achieve a fast pace would be lower and therefore any change velocity in velocity would also be lower. For example, if a runner was trying to maintain a 13 min/mi pace (about a 5 hour 40 minute marathon) had to walk their pace may only change slightly to 15 min/mi while walking. However, if a faster runner trying to maintain an 8 min/mi pace (about a 3 hour 30 min pace) had to walk, the change in pace would be much larger. Instead, it seems that greater variability in pace is detrimental to marathon performance. This might mean that runners with slower marathon times had more frequent vs. larger changes in pace compared to faster runners. That being said, the importance of a quadratic regression equation fitting the marathon finish time - Velcov relationship is that there would be a maximum of this function. However, in the case of the quadratic regression equation that best fit the data, the maximum of the parabola would occur at Velcov 92% with a marathon finish time of 7.74 hours. Although we had a few observations above or near a 7 hour marathon time, the greatest Velcov was under 50%. Therefore, it seems unlikely that a plateau or decrease in Velcov would be observed even if longer marathon times were studied.

The linear or quadratic regression equations explained 46% of the variance in marathon finish time by variability of pace. This obviously means that there is a wide range of possible values of Velcov for a given marathon finish time. Nevertheless, it seems that a greater variability of pace is associated with slower marathon performance. That being said, there might be some advantages to using a more variable pace (e.g., run-walk strategy) that are overlooked in this analysis. For example, it might be that using a planned variable pace which includes specific intervals of running followed by specific intervals of walking may allow a runner to minimize the impact of fatigue in a way that the marathon can be successfully completed. We did not attempt to separate planned run-walk strategies in this analysis even though we suspect that some of the profiles do reflect this approach.

We suspect that variation of pace is related to fitness and/or fatigue. For example, Cade et al. (3) reported that 11 of 21 marathoners studied adopted a walk/run/walk pacing strategy in the last six miles due to high body temperature and/or lower levels of blood glucose. Although we did not examine variability of pace at different sections of the marathon, there might be some value in determining if pace varies within a race. To gain some insight into this, we fit each velocity vs. time profile with a linear line of best fit. Both races had velocity vs. time slopes that were negative (Race 1: -0.10±0.1 m/s/s; Race 2: -0.13±0.1 m/s/s); meaning that, on average, runners slowed their pace over the course of the marathon. We compared the slopes between races and bins and determined that there was no difference in slope between races or bins. This is an indication that the amount of slowing of pace was independent of the actual pace maintained. Future research is needed to determine if the amount of variation in pace is different for different stages of the race.

Most marathon training programs target maintaining a specific pace during the 26.2 miles. We observed that non-elite marathon runners change their pace in such a way that those with slower marathon finish times had more variability of pace than those with faster finish times. We also observed that, on average, runners slow their pace over the course of the marathon. For runners interested in achieving a faster marathon performance, he/she would likely benefit by training at low variability of pace. However, many marathoners may simply want to complete the event vs. achieve a fast marathon time and it is important to match training specificity with the marathon goal. In this case, the training regimen of slower runners should include increased variability of pace.

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