MARATHON STRIDE RATE DYNAMICS: A CASE STUDY

Michelle Norris, Ian C. Kenny, Ross Anderson,

Biomechanics Research Unit, University of Limerick, Limerick, Ireland

The purpose of this study was to investigate stride rate (SR) dynamics of a recreational runner participating in his debut marathon. Tibial accelerometry data obtained during a half marathon (R1) and marathon (R2) were utilised. SR data were extracted utilising novel computational methods and descriptive statistics were utilised for analysis of R2, and comparison of the first half of the marathon ($R2^{half}$) to R1. Results indicate that the participant employed comparable SR strategy in R1 and $R2^{half}$. For R2 a combined decreasing trend in SR and increased variance in SR from 30 km (R^2 =0.0238) was observed. Results indicate that the participant had the ability to maintain SR strategy for the first half of the marathon, however as fatigue onset occurred this ability decreased. Running strategies on SR during fatigue may be of future use to recreational runners.

KEY WORDS: Distance running, fatigue, gait, recreational, variability.

INTRODUCTION: The ability to maintain a coordinated running form and stride rate has previously been identified as a technique utilised by elite runners in order to be economical during distance running events (Coyle, 2007). Within this running form stride rate (SR) has been identified as a major contributing factor to running economy and overall run outcome, making it a parameter of great interest (Mercer, Dolgan, Griffin, & Bestwick, 2008). SR is believed to be affected by a number of variables such as muscle fibre distribution, anthropometrics and fatigue (Kyröläinen et al., 2000). Studies investigating SR changes during distance running have resulted in mixed conclusions. Kyröläinen et al. (2000) found an increase in SR during marathon running to combat neuromuscular fatigue whilst, Mizrahi, Verbitsky, Isakov, and Daily (2000) found a decrease in SR when inducing fatigue over a 30 minute running period. While results may be mixed, a common factor in much of the research investigating SR dynamics is that it has focused on trained athletes. However, due to an increasing number of recreational participants in distance running events this population is of growing interest. Recent research surrounding recreational runners has investigated step width alterations (Brindle, Milner, Zhang, & Fitzhugh, 2014), however there are no data, that the current authors are aware of, pertaining to stride rate, over a longitudinal period within this population. This study therefore aimed to investigate the stride rate dynamics, utilising a novel computational method, produced by a recreational runner when undertaking his first marathon. *Investigation one* aimed to identify if recreational runners are able to maintain previously utilised stride rate strategies when undertaking marathon distances. *Investigation two* aimed to identify the effect of fatigue. if any, on stride rate dynamics of a recreational runner, when completing his first marathon.

METHODS: **Participant and instrumentation:** Accelerometry data from 1 male, (age: 37 years, height: 1.81 m, mass 87 kg) recreational runner undertaking half marathon (12 week) and marathon (18 week) training programmes was utilised. There was a 6 week rest period between the completion of the half marathon run and the beginning of the marathon training programme. The participant was required to attach a tri-axial Shimmer 2r™ accelerometer (SHIMMER Ltd, Dublin, Ireland) to their anterio-medial distal tibia bi-laterally for each training run and the distance running events. Accelerometers were self- attached by the participant via a purpose built elastic strap with the sensor placed inward, toward the tibia, to prevent further movement. Prior to distribution a demonstration of sensor attachment was provided and sensors underwent static calibration following manufacturer 9DOF application methods. This calibration resulted in a coordination system which allowed for collection of medio-lateral acceleration in the x axis, vertical acceleration in the y axis and anterior-posterior acceleration in the z axis. When attached to the tibia a positive vertical acceleration was directed proximally, positive medio-lateral acceleration was directed laterally and positive anterio-posterior acceleration directed posteriorly. Data were sampled at 204.8 Hz (± 6 g, sensitivity range of 200 mV/g). Training comprised of 4 runs (3 short, 1 long run) per week for 12 weeks and 18 weeks of popular Hal Higdon novice distance running programmes. The participant also completed a weekly diary logging run information (distance, completion time) and rate of perceived exertion (RPE) (for each weekly long run and competitive runs). RPE was measured utilising the Borg 15-grade RPE scale (Borg, 1982), with 6 indicating very, very light perceived exertion and 20 indicating maximum exertion. Verbal feedback on race performance was provided post marathon.

Data analysis: Right leg accelerometry data from 2 runs (containing up to 14 million data points each) were analysed. Run 1 (R1) was a half marathon and run 2 (R2) was a marathon. For *investigation one* the first half of R2 was compared to R1. This phase of R2 was referred to as $R2^{half}$ (Table 1). Run time was calculated as a result of a standing period performed by the participant indicating run start and completion. Accelerometer run data were corrected for static tilt, calculated during the standing period, with x and z axis corrected to 0 m.s-2 and y corrected to 9.81 m.s-2. Medio-lateral accelerometry data were low-pass 2nd order reverse filtered at 2 Hz resulting in data representing the gross tibial acceleration pattern. Beginning and end of stride time was identified via a positive zero crossing, using a custom built LabView™ programme (National Instruments, Newbury, U.K.). Any stride above 1 s was eliminated as this was designated to be a walking step (Rowe et al., 2011). Run time was then broken into 1% epochs and stride rate (strides per minute) was calculated for each epoch. Predicted completion time (PCT) for half marathon and marathon times were calculated via the McMillan Running Calculator (McMillan 2014). Half marathon PCT was based off previous best 10km time and marathon PCT was based off previous best half marathon time. For *investigation two*, time to 21.1 km and 30 km distances were provided via race chip timing.

RESULTS: In *investigation one* the participant's modal SR was decreased for the first third of $R2^{half}$ when compared to the first third of R1 (83 vs 85) (Table 1). Both R1 and $R2^{half}$ then showed comparable increases in modal SR over the following two thirds of the distance.

Table 1. R1, R2 and $R2^{half}$ information.

	R1	R2	$R2^{half}$
Completion time (mins)	99.0	220.0	102.5
PCT (mins)	102.5	208.0	102.5
Difference PCT mins (%)	- 3.5 (- 3.4)	+ 12 (+ 5.8)	-
Modal SR (strides per min) (range) *1st Third*	85 (3)	85 (4)	83 (5)
Modal SR (strides per min) (range) *2nd Third*	85 (2)	86 (3)	85 (2)
Modal SR (strides per min) (range) *Last Third*	86 (3)	86 (11)	86 (3)
RPE	15	20	N\A

**PCT = Predicted Completion Time. SR = Stride Rate*

$R2^{half}$ also showed increased SR variance in the first third of the 21.1 km phase compared to the same period in R1, as identified via a larger vertical than horizontal data spread (Figure 1) and greater range (5 vs 3). Variance for the latter two thirds of R1 and $R2^{half}$ were comparable. Both R1 and $R2^{half}$ were within the participants PCT, however $R2^{half}$ completion time was greater than R1 (+3 mins).

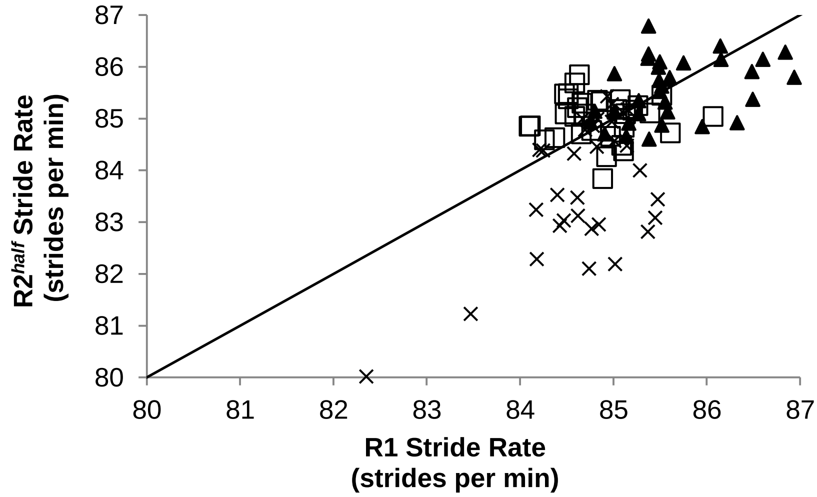

Figure 1. *Investigation one.* Comparison of 1% epoch stride rates for R1 and $R2^{half}$. Diagonal line inserted representing no change in stride rate between R1 and $R2^{half}$ at that % epoch. ✕= first third of run, □ = second third of run, ▲ = last third of run.

In *investigation two* whilst modal SR for R1 and R2 were comparable SR variance was greater in R2 across all run segments (thirds) (Table 1). The largest SR range was 11, which occurred in the last third of R2 and was much greater than the SR range during the last third of R1 (3). Strong correlation coefficients indicate SR increased linearly with % time ran for the first half of the marathon race (Start to 21.1 km, r = 0.81) (Figure 2). This SR was then maintained from 21.1 km to 30 km mark (r = 0.55). However, from 30 km - end of R2 a weak relationship was seen (r = 0.15).

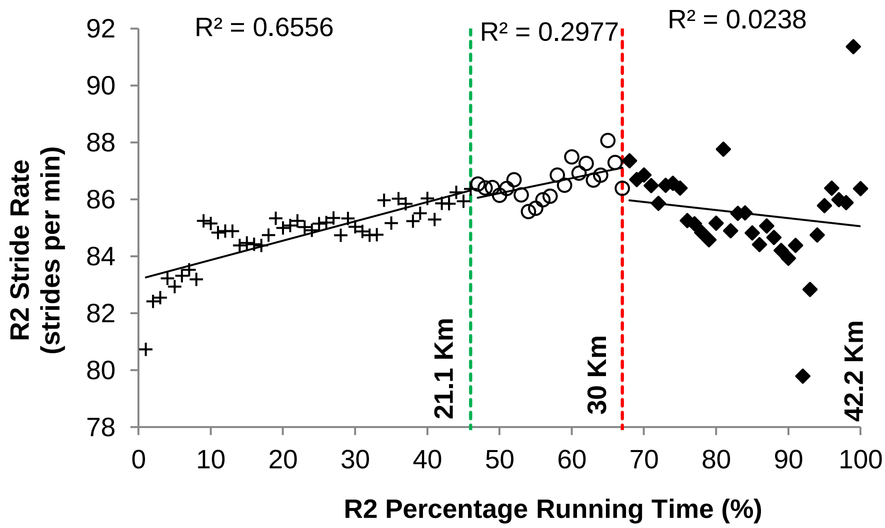

Figure 2. *Investigation two.* Stride rate at 1% time epochs for R2.

SR variance was also increased from 30 km - end of R2 (SR range = 11), compared to start to 21.1 km (SR range = 5) and 21.1 km to end (SR range = 2) indicating less SR consistency for the latter part of the race (Table 2). The participant indicated an RPE of 20 (maximum exertion) for R2 and verbally confirmed fatigue onset from 33.7 km to 38.6 km.

Table 2. ***Investigation two.*** **R2 stride rate utilising race chip timing information.**

	R2
Modal SR (strides per min) (range) ***Start - 21.1 km***	85 (5)
Modal SR (strides per min) (range) ***21.1 km - 30 km***	86 (2)
Modal SR (strides per min) (range) ***21.1 km - End***	86 (11)
Modal SR (strides per min) (range) ***30 km to End***	86 (11)

DISCUSSION & CONCLUSION: We first wished to investigate would the participant be able to maintain a previously utilised half marathon SR strategy in the first half of a marathon, and it is clear the participant was able to do so. Hunter and Smith (2007) stated that in a non-fatigued state runners adopted a preferred SR. This is close to their optimal SR which minimises metabolic cost, therefore optimising race performance. This theory supports that the SR strategy selected by the participant here is optimal, resulting in comparable successful completion times of the half marathon distance undertaken in R1 and $R2^{half}$ (99 mins and 102.5 mins). Our second investigation looked into the SR strategy utilised over the course of the marathon. Whilst the participant was able to maintain SR up to 30 km after this a decreasing trend in SR and increased variance in SR was identified. Whilst fatigue may have caused a decreasing trend in SR, fluctuations by the participant to combat this decrease may have further negative effect. As preferred SR is deemed to compromise the minimum amount of force exerted by the muscles and the minimum lower limb stiffness (Snyder & Farley, 2011) increased fluctuations in SR may result in shifting this compromise, compounding fatigue and metabolic cost. Whilst only one participant was utilised results may indicate that recreational runners have an ability to maintain stride rate strategy, for extended periods, during a novice marathon. Increasing knowledge on to optimal strategies to combat fatigue during distance running may be of use to recreational runners undertaking distance events.

REFERENCES:

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and science in sports and exercise, 14*(5), 377-381.

Brindle, R. A., Milner, C. E., Zhang, S., & Fitzhugh, E. C. (2014). Changing step width alters lower extremity biomechanics during running. *Gait & posture, 39*(1), 124-128. doi: http://dx.doi.org/10.1016/j.gaitpost.2013.06.010

Coyle, E. F. (2007). Physiological regulation of marathon performance. *Sports Medicine, 37*(4-5), 306-311.

Hunter, I., & Smith, G. A. (2007). Preferred and optimal stride frequency, stiffness and economy: changes with fatigue during a 1-h high-intensity run. *European journal of applied physiology, 100*(6), 653-661.

Kyröläinen, H., Pullinen, T., Candau, R., Avela, J., Huttunen, P., & Komi, P. (2000). Effects of marathon running on running economy and kinematics. *European journal of applied physiology, 82*(4), 297-304.

Mercer, J., Dolgan, J., Griffin, J., & Bestwick, A. (2008). The physiological importance of preferred stride frequency during running at different speeds. *Journal of Exercise Physiology Online, 11*(3), 26-32.

Mizrahi, J., Verbitsky, O., Isakov, E., & Daily, D. (2000). Effect of fatigue on leg kinematics and impact acceleration in long distance running. *Human movement science, 19*(2), 139-151.

Rowe, D. A., Welk, G. J., Heil, D. P., Mahar, M. T., Kemble, C. D., Calabró, M. A., & Camenisch, K. (2011). Stride rate recommendations for moderate intensity walking. *Medicine and science in sports and exercise, 43*(2), 312-318.

Snyder, K. L., & Farley, C. T. (2011). Energetically optimal stride frequency in running: the effects of incline and decline. *The Journal of experimental biology, 214*(12), 2089-2095.