COMPARISON OF ACCELEROMETRY STRIDE TIME CALCULATION METHODS

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The purpose of this study was to investigate how a newly proposed method of stride time calculation, utilising data filtered at 2 Hz, compared to previous methods. Tibial accelerometry data for 6 participants completing half marathon running training were collected. One run was selected for each participant at random, from which five consecutive running strides were ascertained. Four calculation methods were employed to derive each stride time and results were compared. No significant difference was found between methods (p=1.00). The absolute difference in stride time, when comparing the proposed method to previous methods, ranged from 0.000 seconds to 0.039 seconds. Filtered data could offer a simplified technique for stride time output during running gait analysis, particularly when applied during automated data processing for large data sets.

KEY WORDS: Analysis, data processing, gait, running, sensor.

INTRODUCTION: The use of low cost portable sensors, such as accelerometers and gyroscopes, has become increasingly popular in running gait analysis over the last number of years (Higginson, 2009). Within running gait analysis tibial sensor attachment has been identified as superior in identifying lower limb acceleration patterns as it close to the area of interest (Mathie, Coster, Lovell, & Celler, 2004). This attachment allows for identification of running gait parameters such as stride frequency and ground contact time. Of these parameters, stride frequency, and therefore stride time, has been identified as a major contributing factor to running economy and overall run outcome, making it a parameter of great interest (J. Mercer, Dolgan, Griffin, & Bestwick, 2008). Stride time is defined as “time elapsed between the first contacts of two consecutive foot falls of the same foot expressed in milliseconds” (Beauchet et al., 2011, p. 2), and numerous methods have been previously utilised to identify this parameter within tibial accelerometer data during running. Purcell, Channells, James, and Barrett (2006) identified the minimum value along the medio-lateral axis as occurring at the beginning of ground contact time or foot strike. J. A. Mercer, Bates, Dufek, and Hreljac (2003) identified the minimum value before the absolute maximum value in the longitudinal axis as the beginning of foot strike. However, the ability to accurately and efficiently identify stride time from accelerometer data streams utilising these methods can be difficult. Due to erroneous noise and varied running patterns multiple fluctuations within data may lead to false results. Also, at increased accelerometer recording rates large data file size can lead to inefficient parameter output time. However, the current study aimed to investigate if accelerometer data filtered at 2 Hz could use an identifiable trend point to accurately identify stride time. It is believed smoothed data may produce comparable, accurate results to previous methods, whilst also being more efficient and reliable as it would not be as heavily influenced by erroneous data.

METHODS: **Participants and instrumentation:** Accelerometry data from 6 (1 male, 5 female) recreational runners (age: 33.5 ± 5.8 years, height: 1.66 ± 0.08 m, mass: 71.1 ± 12.2 kg) undertaking a half marathon training programme was utilised. Participants were required to attach a tri-axial Shimmer 2r^{TM} accelerometer (SHIMMER Ltd, Dublin, Ireland) to their anterio-medial distal tibia bi-laterally for each training run, in a half-marathon training programme, and the event itself. Accelerometers were self- attached by the participants 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 per week for 12 weeks of a popular Hal Higdon half marathon ‘novice’ programme. **Data analysis:** One right leg run (containing up to 7 million data points) was chosen at random for each participant (n=6). Run time was calculated as a result of a standing period performed by the subject 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 ms^2 and y corrected to 9.81 ms^2. Preliminary data processing was performed for all files using a custom built LabView^{TM} programme. Within run time, data containing 6 subsequent impact peaks were chosen at random from within the file. A total of 4 stride time calculation methods, the proposed method (*Method 1*) and three previously utilised methods, were compared (Figure 1). *Method 1* was custom designed and proposed that medio-lateral accelerometer 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 via a custom built LabView^{TM} programme. *Method 2* identified heel contact as the minimum acceleration value before the absolute maximum (peak impact) in the vertical axis of the tibia (J. A. Mercer et al. (2003)). *Method 3* identified the peak or transient in the vertical axis of the tibia as heel strike occurrence (Mizrahi, Verbitsky, Isakov, & Daily, 2000). *Method 4* identified the beginning of contact time as the maximum value in the medio-lateral axis. This method is similar to that used by (Purcell et al., 2006) however it has been adapted to suit our coordinate system. Accelerometer placement, antero-medial distal tibia, was the same for all methods except method 3 where placement was on the tibial tuberosity. Stride time data for method 1 were calculated via LabView^{TM} whilst methods 2 - 4 and comparison analyses were calculated via Excel. As running stride time was of interest any stride above 1 second duration was excluded as this was designated to be a walking step (Rowe et al., 2011). For statistical analysis all stride times were grouped via method (30 trials for 4 methods). A repeated measures analysis of variance (ANOVA) was performed across the 4 methods, using Excel.

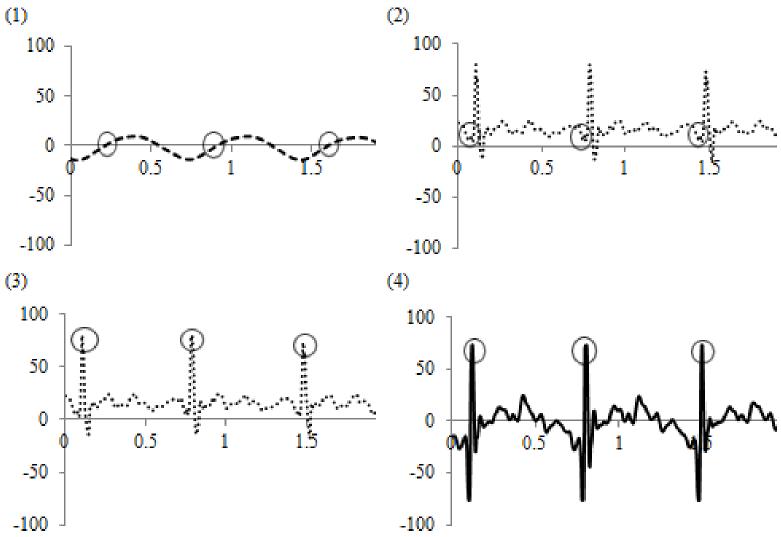

Figure 1. Acceleration patterns (ms^2) for a representative running trial. Identification of beginning/end of stride times for methods 1, 2, 3 and 4 as identified by the circle.

RESULTS: Results showed that there was no significant difference between methods to derive stride time $F(3,87) = 0.03$, $p = 1.00$. Comparison of individual stride times across methods was also undertaken (Table 1). All methods employed compared favourably resulting in low standard deviations. The standard deviation of stride time across all four methods ranged from a minimum of 0.002 seconds to 0.017 seconds. When comparing the proposed method (Method 1) to previously identified methods the greatest difference in stride time occurred with Subject 4, strides 4 and 5, both of which resulted in a difference of 0.039 seconds between Methods 1 and 3. Method 1 also resulted in no difference in stride time on numerous occasions (n = 7) when compared to previously utilised methods.

Table 1

Stride time (s) calculations for all subjects. [a] indicates the greatest difference in stride time, whilst [b] indicates no difference in stride time, compared to proposed method 1. The greatest and least SD values are also denoted in bold.

Participant 1

	Method					
Stride	**1 - *2Hz Filter (s)***	**2 - *Min in Y (s)***	**3 - *Max in Y (s)***	**4 - *Max in X (s)***	**Average *(s)***	**SD *(s)***
1	0.728	0.718	0.708	0.713	0.717	0.009
2	0.718	0.723	0.728	0.722	0.723	0.004
3	0.722	0.717	0.717	0.723	0.720	0.003
4	0.703	0.718	0.713	0.713	0.712	0.006
5	0.723	0.718	0.728	0.722	0.723	0.004

Participant 2

	Method					
Stride	**1 - *2Hz Filter (s)***	**2 - *Min in Y (s)***	**3 - *Max in Y (s)***	**4 - *Max in X (s)***	**Average *(s)***	**SD *(s)***
1	0.693	0.684	0.683	0.689	0.687	0.005
2	0.689	0.688	0.694	0.688	0.690	0.003
3	**0.693**[b]	0.698	**0.693**[b]	0.694	0.694	**0.002**
4	0.689	0.679	0.683	0.683	0.684	0.004
5	0.693	0.703	0.699	0.698	0.698	0.004

Participant 3

	Method					
Stride	**1 - *2Hz Filter (s)***	**2 - *Min in Y (s)***	**3 - *Max in Y (s)***	**4 - *Max in X (s)***	**Average *(s)***	**SD *(s)***
1	**0.708**[b]	**0.708**[b]	**0.708**[b]	0.703	0.707	**0.002**
2	0.698	0.684	0.693	0.688	0.691	0.006
3	0.708	0.718	0.713	0.713	0.713	0.004
4	**0.703**[b]	**0.703**[b]	0.698	**0.703**[b]	0.702	**0.002**
5	0.698	**0.698**[b]	**0.698**[b]	0.703	0.699	**0.002**

Participant 4

	Method					
Stride	**1 - *2Hz Filter (s)***	**2 - *Min in Y (s)***	**3 - *Max in Y (s)***	**4 - *Max in X (s)***	**Average *(s)***	**SD *(s)***
1	0.708	0.703	0.718	0.737	0.717	0.015
2	0.708	0.718	0.703	0.679	0.702	0.**017**
3	0.713	0.688	0.703	0.703	0.702	0.010
4	**0.703**[a]	0.728	0.718	**0.742**[a]	0.723	0.016
5	**0.708**[a]	0.693	0.689	**0.669**[a]	0.690	0.016

Participant 5

Stride	Method 1 - *2Hz Filter (s)*	2 - *Min in Y (s)*	3 - *Max in Y (s)*	4 - *Max in X (s)*	Average *(s)*	SD *(s)*
1	0.718	0.698	0.708	0.708	0.708	0.008
2	**0.698**[b]	0.708	**0.698**[b]	0.693	0.699	0.006
3	**0.703**[b]	0.688	**0.703**[b]	**0.703**[b]	0.699	0.007
4	**0.674**[b]	0.684	**0.674**[b]	0.679	0.677	0.005
5	0.718	0.723	0.732	0.723	0.724	0.006

Participant 6

Stride	Method 1 - *2Hz Filter (s)*	2 - *Min in Y (s)*	3 - *Max in Y (s)*	4 - *Max in X (s)*	Average *(s)*	SD *(s)*
1	0.923	0.957	0.938	0.942	0.940	0.014
2	0.942	0.913	0.913	0.908	0.919	0.016
3	0.938	0.952	0.952	0.947	0.947	0.007
4	0.933	0.938	0.938	0.938	0.936	**0.002**
5	**0.942**[b]	0.947	**0.942**[b]	0.952	0.946	0.005

DISCUSSION & CONCLUSION: The proposed method offers a simple and accurate technique for stride time output in running gait analysis for large data sets. This method could allow for real time stride derivement possibly less effected by erroneous noise. Along with this the ability to output running stride parameters promptly could also allow for the development of a real time automated feedback system based on the consistency or fluctuations of stride time. In data post processing this method could allow for quick and accurate stride time output for extensive data sets, allowing researchers more efficient use of time to investigate information which occurs within these stride time epochs. This would be useful for runner and researchers alike as it could glean information related to both health and performance.

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