

A COMPARISON OF FOOT STRIKE EVENTS USING THE FORCE PLATE AND PEAK IMPACT ACCELERATION MEASURES

Niamh Whelan, Robin Healy, Ian Kenny and Andrew J Harrison

Biomechanics Research Unit, University of Limerick, Limerick, Ireland

A popular method for measuring initial contact (foot-strike) during running is the force platform. It has been proposed that the foot contact events can be estimated using peak impact related accelerations of the leg using accelerometers. Various studies have been conducted to compare force platform and accelerometer methods in walking and running. The aim of this study was to develop a method for identifying peak impact accelerations in the anterior-posterior axis using the Delsys Trigno System during running and compare this with initial contact via force plates. Seven national and international sprinters completed runs across a force platform with an accelerometer fixed to their shin. The results showed the acceleration of the anterior-posterior axis approximated foot-strike within ± 0.017 s of the foot-strike event detected by the force plate.

KEY WORDS: foot-strike, accelerations, force plate.

INTRODUCTION: Force platforms provide a valid method for measuring initial contact (foot strike) during running. The use of force platforms however, is not practicable for outdoor situations as they are fixed in the ground and are therefore non-portable. Recent developments in wireless inertial sensors may enable the determination of key events in running gait outside of a laboratory environment. Accelerometers are useful for field based testing as they are portable, lightweight, and can be used for an extended periods (Kavanagh et al., 2006). Various studies have used force plates and accelerometers to try determine foot contact events during walking and running (Lee, Mellifont & Burkett 2010, Auvinet, Gloria, Renault, & Barrey 2002, Sinclair, Hobbs, Protheroe, Edmundson & Greenhalgh 2013) and sprinting (Purcell, Channells, James & Barrett 2005). Purcell et al., (2005) developed and tested a method for determining foot ground contact time during the acceleration phase of maximal sprinting using data obtained from a force plate and an accelerometer. Contact time was determined using the minima of the anterior-posterior axis accelerations and on the X and Z axis accelerations which experienced a local minima and maxima respectively around the event of toe off. Lee et al., (2010) used an inertial sensor placed on the sacrum to examine stride, step and stance durations at various walking and running frequencies. Tibial accelerations were examined in the anterior-posterior direction to identify foot-strike events. Acute positive peaks in anterior-posterior acceleration indicated foot-strike. The results indicated there was less than 0.020 s difference between force plate and accelerometer identified foot-strike events, indicating a strong agreement between both methods.

The main aim of this study was to develop a method for identifying peak impact accelerations using the Delsys Trigno System during running and comparing the timing of this event with the initial contact on the force plates. This study is intended to provide a basis for future studies using accelerometers to identify key events during maximal sprinting and to detect simultaneous muscle activations and accelerometry using the Delsys Trigno system during sprinting.

METHODS: Seven national and international sprinters (three males, four females) with a mean age of 22.3 (± 2.2) year; stature 169 (± 10.87) cm; and body mass 60 (± 8.93) kg participated in this study. All participants were injury free and completed one testing session. The study was approved by the local university research committee and written consent was obtained from all participants.

Testing Protocol: All participants completed a standard warm up followed by a series of familiarisation trials prior to the testing. Participants then completed 10 runs at up to 50% of maximum effort across a force platform over a distance of 10 metres. The participants were

instructed to make contact with the force plate with their right foot while maintaining their normal running stride (i.e. not alternating stride to make contact with the force plate). Therefore the starting point for each subject was different depending on stride length. Each run was followed by a 30 s recovery.

Instrumentation: For the testing protocol a Delsys Trigno Wireless EMG System Natick MA, USA and an AMTI force plate (OR6-5, Advanced Mechanical Technology, Inc., Watertown, MA, USA) were used to obtain ground reaction force and accelerometer data. The force platform sampling frequency was 1000 Hz while the accelerometer sampled at 148.15 Hz. Both systems were synchronised using an external source Delsys Trigger Module (SN: 1345). Due to the differences in sampling rate between the systems, there was an expected delay between the two systems of up to 7 ms. A Delsys Trigno Wireless triaxial accelerometer device was secured to the participant's leg (anterior tibia) to record the tibial accelerations during the running trials, see Figure 1.

Data Analysis: The force plate data were analysed to determine the instant of foot contact. This was determined by finding the point in time where there was a rapid increase in the vertical ground reaction force above a threshold of 5 N. Previous research has indicated that a minor anterior acceleration peak (i.e. peak impact acceleration) occurs close to the foot-strike event and a major peak occurs soon after toe off (Purcell et al., 2005). All three axes were analysed but the Z axis (anterior-posterior) data provided the most appropriate indicator when compared to the force plate and was also the easiest to identify the peak accelerations. The Z axis accelerometer data was filtered using a low pass Butterworth filter with a frequency cut off (fc) of 10 Hz and the time the peak acceleration occurred was recorded and compared to the force plate data. The average maximum and minimum difference between the times on the force plate foot-strike event and the peak impact accelerations via the tibial-mounted accelerometer were calculated. An interclass correlation coefficient and a Pearson R calculated together with Bland and Altman (1986) limits of agreement (LoA) to determine the levels of agreement between the peak impact acceleration and foot-strike events.

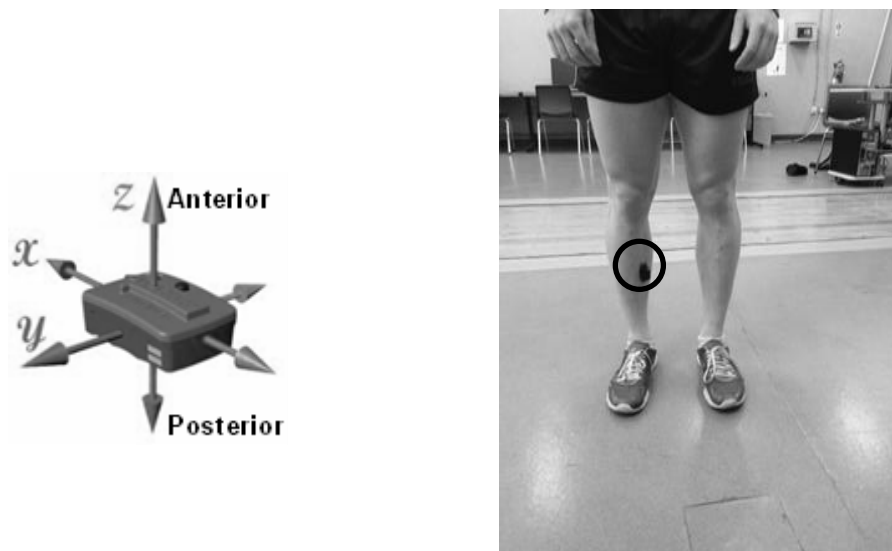


Figure 1: Trigno wireless 4-channel sensor triaxial accelerometer and EMG and sensor placement on the tibialis anterior (arrow on sensor was pointing upwards).

RESULTS:

Table 1: Average minimum, maximum, Upper LoA, Lower LoA, Intraclass Confidence Interval and Pearson R comparisons of force plate and accelerometer data

Average Maximum Differences (s)	Average Minimum Differences (s)	Upper Limits of Agreement	Lower Limits of Agreement	Intraclass Correlation Coefficient	Pearson R
0.015	-0.017	0.038	-0.0123	>0.99	0.999

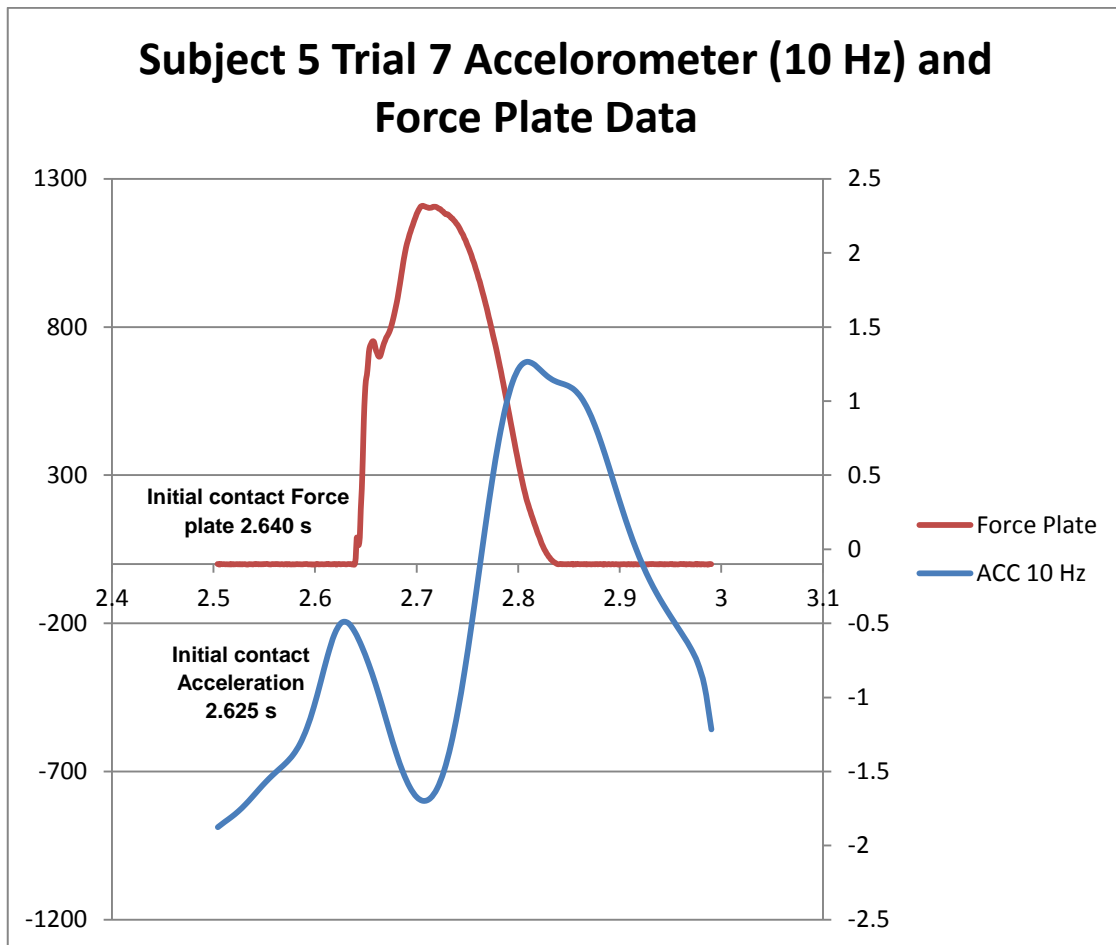


Figure 1: Exemplar graph illustrating accelerometer data and force plate data for subject 5.

The interclass correlation coefficient and the Pearson R value (see table 1) indicates a strong correlation between the approximation of foot strike and the foot contact on the force plate. Figure one shows the anterior-posterior (Positive = anterior movement), accelerometer data filtered at 10 Hz. The graph shows a large acceleration forward as the foot lands (heel strike); and as the foot comes off (Toe off) there is second peak acceleration forward. Initial contact according to the force plate was 2.640 s and 2.625 s according to the accelerometer-based method (difference of 0.015 s)

DISCUSSION: The purpose of this study was to develop a method for determining or approximating foot-strike during running using an accelerometer device (Delsys Trigno Wireless). The results show that the use of accelerometers provides a means to reliably determine peak tibial impact accelerations in a laboratory setting. The data demonstrate that peak tibial impact acceleration provides a very good approximation to foot impact with average maximum and minimum differences of -0.017 to +0.015 s. In analysis of running gait, peak tibial impact acceleration may be used to normalise the gait cycle data. The ICC and Pearson R values of >0.99 indicate that there are very high correlations between the force plate foot-strike event and peak impact acceleration in the anterior-posterior axis. These data show that the accelerometer based peak impact reading provides close estimates of initial contact/foot-strike during running. While the peak impact acceleration may not be an identical event to foot-strike, it does occur regularly in the gait cycle and occurs within 20 ms of the foot-strike event. The data in this experiment agrees closely with the findings of Purcell et al, (2005). According to Purcell et al., (2005) the level of agreement increased with running speed, this is due to the association of larger accelerations being generated with increased speed. While previous studies consider the minima and maxima accelerations of the anterior-posterior axis (Purcell et al., 2005; Auvinet et al., 2002), the minor peak before the subsequent major peak in anterior-posterior acceleration was an easily identifiable event when compared to the force plate vertical ground reaction force. The second purpose of this study was to develop a method of determining an approximation of a foot-strike event to aid with future studies in which subjects will be maximally sprinting. It should be borne in mind that while this event may not exactly coincide with foot-strike, it generally provides a useful approximation to this event. Therefore in practical situations, running gait cycles could be effectively normalised using consecutive peak tibial impact acceleration events rather than consecutive foot-strikes.

CONCLUSION: This study found that a single accelerometer positioned on the anterior tibia provided an effective technique to identify key events in the running gait cycle. The peak impact acceleration approximated foot-strike to within ± 0.017 . The findings from this study provide a means of key gait event data collection and analysis outside the laboratory.

REFERENCES:

- Auvinet, B., Gloria, E., Renault G. & Barrey, E. (2002). *Runners stride analysis comparison of kinematic and kinetic analyses under field conditions*. Journal of Science & Sport, 17: 92-94
- Bland JM, Altman DG (1986). *Statistical methods for assessing agreement between two methods of clinical measurement*. Lancet, 327 (8476): 307–10.
- Kavanagh, J.J., Morrison, S., James, D.A. & Barrett. R. (2006) *Reliability of segmental accelerations measured using a new wireless gait analysis system*. Journal of Biomechanics, 39: 2863-2872
- Lee J.B., Mellifont R.B. & Burkett, B.J. (2010). *The use of single inertial sensor to identify stride, step, and stance durations of running gait*. Journal of Science and Medicine in Sport, 13: 270-273
- Purcell, B., Channells, J., James, D. & Barrett, R. (2005). *Use of accelerometers for detecting foot-ground contact time during running*. In: Nicolau, D.V. (Ed), Proceedings of SPIE 6036, BioMEMS and Nanotechnology II, 603615, Brisbane, Australia, December 11, 2005.
- Sinclair, J., Hobbs, S.J., Protheroe, L., Edmundson, C.J., & Greenhalgh, A. (2013). *Determination of gait events using an externally mounted shank accelerometer*. Journal of Applied Biomechanics; 29(1):118-22.