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Letter to Editor OMICS International

How to Develop a Sensor System to Assess the Potential Risk of Running-related Injury of the Foot and Ankle?

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Letter to Editor

Long-term running and associated aerobic physical activities can reduce risks of health problems ranging chronic disease to early death. The economic burden of health-care systems due to the worldwide pandemic of physical inactivity was 67.5 billion dollars in 2013 [1]. Running-related musculoskeletal overuse injury of the lower extremities, known as a negative effect of running, is one of major factors that limits engagement in running. An epidemiological study reported that the incidence of running-related injuries of the lower extremities ranged from 19.4% to 79.3% for recreational and competition runners [2]. Furthermore, running-related injuries frequently occur on the foot and ankle including the lower leg, and the region-specific incidence ranged from 16.6% to 59.5%. Various types of running-related injuries such as tendinopathy, stress fracture and muscle strain occur on the common injured regions, and the potential risk differs among injuries [3]. A system for assessment of the potential risk of each running-related injury of the foot and ankle accurately needs to be developed for individual runners at a training field. Compact and inexpensive sensors such as an accelerometer are recently available to correct running-related data at a training field, but collectable data are limited. This problem can be resolved by the algorithm that accurately assess the potential risk of each running-related injury of the foot and ankle based on sensor data. Sensors with the developed algorithm can be used to assess the potential risk of each running-related injury of the foot and ankle at a training field by individual runners. This letter discusses steps in the development of a sensor system for assessment of the potential risk of each running-related injury of the foot and ankle.

The first step in a sensor system development is accurate assessment of the potential risk of each running-related injury of the foot and ankle. Overuse injuries result from repetitive micro trauma induced by large forces applied to injured regions [4]. The ground reaction force (GRF) and associated variables during running are frequently used to assess the potential risk of running-related injuries [5]. The GRF during running is well known to be approximately 1.5-3 times the body weight [5]. The GRF data can be accurately and directly collected by using the force platform system. The application point of the GRF is at the sole. The GRF and associated variables, therefore, are thought to be the potential risks of running-related injuries of the sole, such as stress fracture of metatarsal bones. The GRF, however, does not necessarily coincide with the forces applied to other regions of the foot and ankle because of the lever system of the joint [6]. This suggests that the GRF is not necessarily enough to accurately assess the potential risk of running-related injuries of the foot and ankle.

The forces applied to common injured regions of the foot and ankle are difficult to measure directly, because invasive techniques are required for direct measurement [7]. These forces, however, can be estimated by using the inverse or forward dynamics techniques. The forward dynamics technique is used to compute the kinematics of the system from the associated forces and moments of force. On the other hand, the inverse dynamics technique is used to compute the forces and moments of force from the associated kinematics of system. Both techniques require the GRF and position data of bony configurations, which can be collected by using the motion capture system. A limited number of studies computed the forces applied to common injured regions of the foot and ankle during running by using the forward [8] and inverse dynamics techniques [9]. These studies [8,9] showed that the forces applied to the Achilles tendon, calcaneus, talus and tibia reached 2.1-3.1 times the GRF. Furthermore, the trends and time history data of these forces did not coincide with the corresponding GRF value. These indicate that the potential risk of running-related injuries of the Achilles tendon, calcaneus, tibia, and talus cannot be assessed accurately based on the GRF but on the forces applied to the corresponding regions. Therefore, the first step in a sensor system development for assessment of the potential risk of each running-related injury of the foot and ankle can be resolved by the inverse and forward dynamics techniques.

The second step in a sensor system development is accurate estimation of the potential risk of each running-related injury of the foot and ankle by using sensor data. The inverse and forward dynamics techniques may be useful for accurate computation of the forces applied to common injured regions of the foot and ankle, but these techniques are thought to be inadequate for developing a sensor system. The force platform and motion capture systems are expensive, and less-portable systems must be used to collect data for forward and inverse dynamics techniques. These techniques, therefore, cannot be used at training fields by runners themselves but at the laboratory by researchers. For resolving this problem, a previous study developed the algorithm to estimate the force and associated parameters from sensor data [10]. The algorithm can be developed by examining the relationships among the force and sensor data. Regression analyses were traditionally conducted to examine the relationships among variables. Previous studies [10,11] reported that the correlation coefficients among the peak value of the GRF and the parameters collected from accelerometers, such as positive and negative peak values, and the corresponding difference values ranged from 0.14 to 0.98. These analyses require extraction of a single-selected value such as mean, peak, and given instantaneous values from continuous data for each variable. The accuracy of the algorithm developed by using regression analyses, therefore, depends on the variability of the subjectively selected values. Furthermore, the algorithm developed in a previous study [10] can estimate the GRF but not the forces applied to common injured regions of the foot and ankle.

A large sample size allows the use of vector-based pattern recognition techniques such as principle component analysis, independent component analysis, and support vector machines. Regression analyses examine the relationships among single-selected values of each variable, whereas the vector-based pattern recognition techniques can examine the relationships among variables of overall continuous data exhaustively [12]. These techniques were recently used in gait analysis to develop the algorithm to assess gait fall risk of elderly people from sensor data [13]. Previous study [14] reported that the vector-based pattern recognition technique improved the accuracy of the algorithm to estimate the minimum height of toe clearance, which is one of major parameter of gait fall risk, by 68% in comparison with the regression analyses. The vector-based pattern recognition techniques, therefore, have a potential to advance the development of the algorithm to estimate the forces applied to common injured regions of the foot and ankle based on sensor data. Few studies [12,15] used these techniques for running analysis, no study has developed the algorithm to estimate the forces applied to common injured regions of the foot and ankle from sensor data by using these techniques. The second step in a sensor system development for assessment of the potential risk of each running-related injury of the foot and ankle can be resolved by using the vector-based pattern recognition techniques.

In summary, this letter discussed the development of a sensor system for assessment of the potential risk of running-related injury of the foot and ankle. The following two steps are thought to be required: 1) first, the potential risk of each running-related injury of the foot and ankle should be accurately assessed by computation of the forces applied to corresponding injured regions, and 2) second, the algorithm to estimate the forces applied to injured regions from sensor data should be then developed. Compact and inexpensive sensors with the developed algorithm may be used at training fields by runners themselves. These two steps can be resolved by using the inverse and forward dynamics techniques, and the vector-based pattern recognition techniques, respectively.

References

1. Ding D, Lawson KD, Kolbe-Alexander TL, Finkelstein EA, Katzmarzyk PT, et al. (2016) The economic burden of physical inactivity: A global analysis of major non-communicable disease. Lncet 388: 1311-1324.
2. van Gent RN, Siem D, van Middelkoop M, van Os AG, Bierma-Zeinstra SM, et al. (2007) Incidence and determinants of lower extremity running Injuries in long distance runners: a systematic review. Br J Sports Med 41: 469-480.
3. Wilder RP, Sethi S (2004) Overuse injuries: Tendinopathies, stress fractures, compartment syndrome, and shin splints. Clin Sports Med 23: 55-81.
4. Armstrong RB, Warren GL, Warren JA (1991) Mechanicsms of Exercise-induced muscle fiber injury. Sports Med 12: 184-207.
5. Lieberman DE, Venkadesan M, Werbel WA, Daoud AI, D'Andrea S, et al. (2010) Foot strike patterns and collision forces in habitually barefoot versus shod runners. Nature 463: 531-535.
6. Biewener AA (1989) Scaling body support in mammals: Limb posture and muscle mechanis. Science 245: 45-48.
7. Finni T, Komi PV, Lukkarinemi J (1998) Achilles tendon loading during walking: application of a novel optic fiber technique. Eur J Appl Physiol 77: 289-291.
8. Almonroeder T, Willson JD, Kernozek TW (2013) The effects of foot strike pattern on Achilles tendon load during running. Ann Biomed Eng 41: 1758-1766.
9. Hashizume S, Yanagiya T (2017) A forefoot strike requires the highest forces applied to the foot among foot strike patterns. Sports Med Int Open 1: 37-42.
10. Charry E, Hu W, Umer M, Ronchi A, Taylor S (2013) Sutdy on estimation of peak ground reaction forces using tibial accelerations in running. Proceedings of IEEE International Conference on Intelligent Sensors, Sensor Networks and Information Processing.
11. Hennig EM, Milani TL, Lafortune MA (1993) Use of Ground reaction force parameters in predicting peak tibial accelerations in running. J Appl Biomech 9: 306-314.
12. Nigg BM, Baltch J, Maurer C, Federolf P (2012) Shoe midsole hardness, sex and age effects on lower extremity kinematics during running. J Biomech 45: 1692-1697.
13. Delahoz YS, Labrador MA (2014) Survey on fall detection and fall prevention using wearable and external sensors. Sensors 14: 19806-19842.
14. Santhiranayagam BK, Lai DTH, Sparrow WA, Begg RK (2015) A machine learning approach to estimate minimum toe clearance using inertial measurement unit. J Biomech 48: 4309-4316.
15. Maurer C, Federolf P, von Tscharner V, Stirling L, Nigg BM (2012) Discrimination of gender-, speed-, and shoe-dependent movement patterns in runners using full-body kinematics. Gait Posture 36: 40-45.