A new approach to running style analysis using a pressure-sensitive insole device: a small step towards injury prevention

Valorisation

This thesis validated a pressure-sensitive insole device designed to measure spatiotemporal parameters during running. A subsequent case-control study to identify associations of biomechanical risk factors with running-related injury was performed, followed by an observational study to assess running style in varying running conditions. The device used throughout the thesis was at the prototype stage of development. Strike index, centre of pressure trajectory and temporal parameters were calculated from the raw data. The outcome of these studies has enhanced our understanding of the device's potential and its limitations, highlighting areas for further development. A spinoff company to commercialise the pressure-sensitive insole device was created at the end of 2014, and is currently developing the next generation prototype, with a view to finalising a marketable product by the end of 2015. Future versions of the Runalyser should be able to measure the absolute amplitudes and impulses of pressure and force. Being able to reliably measure these parameters continuously and in the natural environment of the runner will be of great interest to researchers and clinicians alike. The work carried out in this thesis, and relating to the advances in understanding of the technological capabilities of the device, are a result of the excellent collaboration between Maastricht University, the Luxembourg Institute of Health and TNO Eindhoven.

1) Social and economic relevance of research results

This thesis put forward several new aspects of running analysis among recreational runners. The first stage of the work carried out ensured that the pressure insole used could reliably measure strike index and spatiotemporal parameters independently and no matter what type of running style the runner uses. This required extensive testing of many different running styles to develop an analysis algorithm capable of providing accurate results in all conditions. At a population level, the accurate measurement of such parameters is of great interest, especially to the recreational long distance runner. It is estimated that 50% of runners sustain an injury related to running annually, incurring huge medical and social welfare costs. Until now, no system has been developed which is capable of continuous monitoring of training parameters as well as biomechanics of running. Although the Runalyser is still at a development stage, future versions of the device will be able to gather such data in the runner's natural environment. Making this device commercially available will stimulate economic growth through creating job opportunities in research and development in various countries. Providing recreational runners, who in general are very susceptible to overuse injuries, with a means of monitoring their training and biomechanics with a view to prevent injury, could save governments vast spendings in medical treatment and social welfare costs. Additionally, preventing overuse injuries will ensure reduced

dropout rates of people participating in regular physical activity and help to improve overall quality of life of the general population.

2) Target groups who find interest in the research results

Running as a recreational sport and physical activity has boomed during the last 40 years. It has become a sporting activity adopted by both the young and old, the active and previously inactive, the experienced and novice. This is a result of the recognition of the health benefits of regular cardiovascular training. However, increases in participation numbers also led to a parallel increase in injury numbers. Since the 1970s, researchers have tried to identify the risk factors associated running injuries, and tried to shed some light on ways of reducing this risk. Until now, no conclusive evidence of identifiable risk factors has emerged, particularly within biomechanical analyses of running. Several reasons are behind this slow progress in running injury prevention. One is that biomechanical analyses are time consuming and require a large amount of resources to perform. Expensive force plates and motion analysis systems are the main instrument types employed until now, which need to be carefully installed, calibrated and operated by experienced and skilled lab technicians in a laboratory setting. Preparing the runner for testing can be laborious and often requires more than one tester. Once everything is prepared, there is no guarantee that the runner can perform habitual running, as the laboratory setting is different to the habitual running environment, where injuries most often occur. The constraints related to laboratory testing of biomechanical parameters have meant that studies until now have been limited to low numbers of test subjects (often not exceeding 20 subjects) and rarely incorporate a prospective follow-up. Associations of biomechanical variables with injury are often speculative therefore, and true relationships are yet to be determined. A tool which is valid and reliable, readily available, easy to use and with the capacity to record and store large quantities of data would be a huge advantage in running injury prevention research. Such a tool could be distributed among hundreds of runners and can be used in each runner's habitual running environment, providing researchers with representative data and a direct link to training and biomechanical progressions in the build-up to injury occurrence. Findings emerging from such studies would contribute to, and further our current understanding of, biomechanical risk factors of running injuries. Such information would be very useful to sports doctors and medical professionals within the field of running. A system specially developed to collate data from injured runners, identify risky behaviour or risky biomechanical patterns and provide timely warnings and training alternatives would be of great use to such physicians. This also goes for physiotherapists and coaches wishing to keep track of their patients and athletes. Indeed, both performance and health status can be

monitored and data can be available to all parties instantly via the internet and social media applications. Finally, the leisure time and top end athletes alike can benefit greatly from such a device. Not only through their entourage making use of the device and associated applications, but through real-time feedback on their running style, pace, impact distributions and magnitudes etc., athletes can adapt their training and running pattern to maximise their performance and reduce the risk of sustaining an overuse injury.

3) Into which concrete products, services, processes, activities or commercial activities will your results be translated and shaped?

The Sports Medicine Research Laboratory of the Luxembourg Institute of Health began a collaboration with TNO Eindhoven, The Netherlands in 2011, within the framework of this PhD project. At the time there was already talk of taking the Runalyser prototype to the next stage of development. After three years of research on running using the Runalyser, a start-up company was founded and a next generation prototype has been under development since December 2014. The results of this thesis have contributed to the knowledge and understanding of the capabilities and requirements of a pressure insole device for the commercial market. The variables tested in the studies presented in the thesis currently feature in the next generation prototype. Further, through extensive testing of hundreds of runners over the years, we were able to compile lists of features to be improved upon, as well as suggestions for future design and materials to be employed in the production. Concretely, the marketable product will consist of a pair of pressure-sensitive insoles, a pair of microprocessors to be attached to each running shoe, a wrist watch for real-time feedback and data storage and a software application.

4) Innovative aspects of the research and Runalyser

This thesis has attempted to put forward a pressure-based device for plantar measurements as a reliable means of quantifying the foot strike pattern by way of the strike index. In addition, reliable algorithms for temporal parameter measurements as well as strike index measurement have been developed and submitted to the Benelux Office for Intellectual Property to be date-stamped as proof of creation as an i-Depot. Although this does not offer legal protection, it does guarantee proof of conception on a given date, by a given party. This is a product of the work carried out within the framework of the PhD project, and is the property of the Sports Medicine Research Laboratory of the Luxembourg Institute of Health.

The device allowed for continuous measurement of multiple, consecutive steps during running, which is often not the case in biomechanical studies. Generally the use of force plates mounted in a laboratory-based runway limit the measurement of consecutive steps. The development of instrumented treadmills (with force measurement integrated) have facilitated this, however it is a very expensive solution. A portable pressure-sensitive insole device is a much cheaper solution, and overcomes many measurement restraints associated with treadmills and laboratory-based testing. This advantage allowed our research to apply an analysis method new to running and unique to injury prevention research. However, when it comes to overuse injuries, it is exactly this long-term observation of possible risk factors which is necessary, to observe whether changes (or lack thereof) in certain parameters can be associated with injury development. This thesis provides a comprehensive methodology to combine the use of pressure insoles and detrended fluctuation analysis to better understand the fluctuations in running style and how this may relate to injury occurrence. This analysis was originally used to assess correlative patterns of the heartbeat, has recently been applied in running analysis. It is still a new concept in running, and chapter 4 of this thesis is the second study to compare stride-to-stride correlative patterns between previously injured and uninjured runners.

5) Implementation and commercialisation planning

A spinoff company was founded in December 2014, by one of the developers of the original prototype. Since then, the project has gained momentum and is entering into the first test stage of the new prototype. This stage is heavily research-oriented, with a view to distribute multiple devices to a cohort of runners, to begin the long awaited research into biomechanics, prospective follow-up and injury monitoring. The device will again be validated (as several changes to the hardware and software have been made since the last validation study), ensuring its suitability for a scientific, medical and consumer market. By the end of 2015, sales of the device will be open to the general public, and the company will start generating revenue, and look to invest in continued improvements of the product. Such improvements will largely be due to the findings of the validation and prospective studies on injury risk factor identification. The end product is envisaged to incorporate techniques developed, and findings observed as a result of the research presented in this thesis.