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CONFERENCE PAPER

An assessment of mediolateral knee and ankle acceleration as an indicator of fatigue

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ABSTRACT

Lower limb injuries in football (soccer) are caused by a lack of muscle strength and fatigue. The mediolateral acceleration of the knee and ankle was measured during a simple running exercise using 25 elite football players over a full playing season (26 weeks). Each run was compared using acceleration skewness comparing base line and fatigue. Most (79%) participants exhibited significant changes ($0.002 < p < 0.044$) in left-ankle acceleration skew, and 55% ($0.0003 < p < 0.045$) in right-ankle acceleration skew. Recording ankle and knee accelerometer data and analysing for skewness offers a potential detection method for fatigue assessment.

Keywords: accelerometer, joint stability, knee, ankle, football

INTRODUCTION

Injuries occur in all sports but this is particularly common in sports involving running, quick direction changes, jumps etc, typically found in ball based team sports. Professional and amateur football associations are concerned about the effects on player wellbeing, player performance and match time minutes.[1]

The definition of fatigue poses difficulties during match play because of the individuality of each athlete. A correlation between ankle sway velocity and the level of fatigue has been reported[2] and also knee joint position and fatigue.[3] The monitoring of fatigue becomes extremely important as the ankle and knee are two of the most affected areas[1] according to the percentage of injuries in football. Prolonged physical activity results in metabolic muscle fatigue and weakened proprioception. These impairments increase the risk of musculoskeletal injuries[4].

A combination of voluntary and reflex control of muscles in knees and feet are used to maintain stability during walking. Whilst proceeding in the direction of motion, the knee and foot muscles are also coordinated to minimise the horizontal and vertical displacement of the body's centre of mass. When muscles become fatigued they have impaired ability to generate force. This is believed to induce an adaptation in the level of muscle activity. Indeed, it is known that knee and ankle flexion increases after runners become fatigued.[5-9]

Several studies report measurements of fatigue during running.[5-9] Kinematic variables were

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compared at the beginning and end of the running on a treadmill.[5] Plantarflexion, ankle inversion and eversion were observed to increase with running time.[6] In addition fatigue may cause muscle imbalances and alteration of joint stability[7] and the maximum angular velocities of knee flexion and ankle flexion increased after ankle fatigue. Runners tested before and after a fatigue protocol[8] showed an acute decrease in muscle strength capacity of the knee extensors and flexors which occurs about the knee and ankle before and after foot impact. The foot motion of runners equipped with shoe-based inertial measurement units was analysed.[9] The range of foot motion in the sagittal plane increased in the final phases of 10 km long running races.

This paper describes an investigation of a fatigue detection method for sports involving running. While heart rate is a common variable describing the fitness quite precisely[10], the analysis of data recorded during a simple exercise with accelerometers fixed to the athlete's knees and ankles may provide a method for detecting fatigue to assist managing the risk of injuries. The results were obtained with the assistance of a professional football (soccer) team.

MATERIAL AND METHODS

25 professional football players participated in this study (Ethics approval 2015/865). The athletes were monitored over 26 weeks of the competitive season 15/16. The physical dimensions of each player such as age, weight and height were recorded. During the season the fitness and conditioning manager provided information about current and previous injuries and activities including strengthening and conditioning regimes.

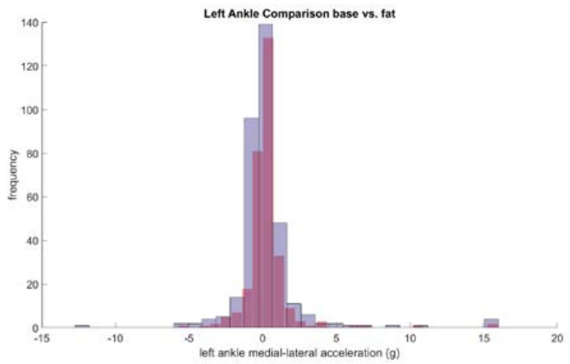

Figure 1 – Left ankle acceleration distribution for one player showing the change between base line measurements (4.92 - blue) and fatigue measurements (-0.517 - red).

The players were asked to run through a coordination ladder of 10 meters length three times at a default speed of 50% of their maximum speed. Every run was taken in the same direction, so the players had to walk around the ladder back to the start where they occupied a static stance before starting again. This coordination task was also performed following a very intensive field training session.

The data was recorded with Sabel® wireless inertial sensors. One of these sensors was fixed to the lateral side of each knee, and to the lateral side of the ankle respectively, using strapping tape. The sensors measured the acceleration amplitude in three directions – mediolateral, anteroposterior and craniocaudal. The mediolateral axis was of main interest.

The data was split in single runs. Secondly, the skewness of the mediolateral acceleration during each run was calculated. Paired T tests were performed in many variations between ankles and knees as well as baseline and fatigue conditions.

RESULTS

Table 1 – Percentage changes in mediolateral skewness for knees and ankles before and after fatigue for all players.

Base-fatigue change	Left ankle	Right ankle	Left knee	Right knee
Percentages %	79.2	54.5	75	75

A significant change in the skewness between base line and fatigue, ankle and knee, was common through the recorded data (Figure 1). The right ankle of 55% of all participating athletes changed skewness between base line and fatigue significantly. A significant change in left and right knee skewness between baseline and fatigue occurred in 75% ($0.0001 < p < 0.047$/ $0.001 < p < 0.049$) of the data. Particularly significant was the change of left ankle's skewness where 79% ($0.002 < p < 0.044$) of the participant's left ankle changed between base line and fatigue significantly (Table 1).

DISCUSSION

This work was designed to assess the influence on fatigue on the knee and ankle mediolateral acceleration during running. It is shown that the individuality of every player makes it always difficult to define fatigue adequately. There are several other mental and physiological causes/ reasons which may affect fatigue but these factors were ignored in this study. The mediolateral ankle acceleration could be used as a reliable and assistant support for the real time detection of fatigue in training or even in a game according to the high percentage of players that suit the method of skewness observation.

CONCLUSION

Every player showed a significant change in skewness in either a knee or an ankle joint independent of previous injuries when they are fatigued compared to baseline. Especially the skewness of the mediolateral acceleration of the athlete's ankle was remarkable and can be considered as a reliable indicator of fatigue. From the 25 players, 79% exhibited a significant change in mediolateral acceleration skewness of the left ankle with fatigue. The dominant leg as well as lower limb injuries did not affect the results. Because only 3 players showed a slight relation between the ankle-knee skewness, this result was not considered to be useful. In routine measurements the accelerometers could be positioned in the player's socks with minimal risk of impact injury.

The results of this study can be used for:

- The rapid assessment of player fatigue during training
- The fitness level of players can be monitoring during the season
- Warning indications for potential injury onset can be developments of each player individually.

REFERENCES:

1. Haegglund, M., Waldén, M., Bahr, R., Ekstrand, J, (2005). Methods for epidemiological study of injuries to professional football players: developing the UEFA model, *British Journal of Sports Medicine, 39(6),* 340-346.
2. Harkins, K. M., Mattacola, C. G., Uhl, T. L., Malone, T. R., McCrory, J. L., (2005). Effects of 2 ankle fatigue models on the duration of postural stability dysfunction, *Journal of Athletic Training,* 40(3), 191-194.
3. Hiemstra, L. A., Lo, I. K. Y., Fowler, P. J. (2001). Effect of fatigue on knee proprioception: Implications for dynamic stabilization, *Journal of Orthopaedic & Sports Physical Therapy, 31(10),* 598-605.
4. Borotikar, B. S., Newcomer, R., Koppes, R., McLean, S. G. (2008). Combined Effects of fatigue and decision making on lower limb landing postures: Central and peripheral contributions to ACL injury risk, *Clinical Biomechanics*, 23(1), pp. 81-92.
5. De Lucca, L., Melo, S. I. L. (2012). Relationship between running kinematic changes and time limit at vVO_{2max}, *Brazilian Journal of Kinanthropometry and Human performance, 14 (4),* Florianópolis.
6. Ryu, J. (2003). The effect of fatigue caused by running time on the kinematic parameters of the lower uncertainty, *Proc. 8th Biennial. Conference of the Canadian Society of Biomechanics*, 316 - 317.
7. Kellis, E., Liassou, C. (2009). The effect of selective muscle fatigue on sagittal lower limb kinematics and muscle activity during level running, *Journal of Orthopaedic & Sports Physical Therapy*, 39(3), 210 – 220.
8. Kellis, E., Zafeiridis, A., Arimidis, I. G.(2011), Muscle coactivation before and after the impact phase of running following isokinetic fatigue, *Journal of Athletic Training*, 46(1), 11-19.
9. Medina, E. Palomares, N., Page, A., Banzuelo-Ruiz, B. (2015), Analysis of kinematic patterns in runners. An approach based on inertial sensors and functional data analysis, *Proc. 33rd Int. Conf. Biomechanics in Sports*.
10. Grant, C. C., Murray, C., Janse van Rensburg, D. C., Fletcher, L. (2013). A comparison between heart rate and heart rate variability as indicator of cardiac health and fitness, *Frontiers in Physiology, 4,* 139-143.