Effects of fatigue on ground reaction forces measured through embedded sensors in football shoes during a constant velocity run: a preliminary study

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1. Introduction

Football is the most popular sport around the world and it is also known as one of the most injury-prone sport. Most of football injuries (thigh strains, knee/ankle sprains) occur without any contact with another player and injury incidence is greater at the end of matches and during overloaded weeks (Bengtsson et al. 2013; Ekstrand et al. 2011). Thus, fatigue and excessive training load have been identified as major risk factors. However, most of research in this field has not been conducted in ecological conditions, due to the lack of a portable device allowing to measure performance parameters, i.e. in situ ground reaction forces (GRFs). Recently, the use of inertial measurements units (IMUs) to estimate these GRFs has gained interest among professional football clubs and federations (Buchheit and Simpson 2016). However IMUs have shown poor or limited validity during team sport activities or football-specific tasks, reducing training load/fatigue quantification accuracy (Halson 2014; Jennings et al. 2010)

Consequently, efficiency of injury prevention programs appears limited, and the number of muscle injuries in football is still growing (Ekstrand et al. 2016). The purpose of this study was thus to measure fatigue in situ during an exhaustive run performed on a football ground through instrumented football shoes.

2. Methods

2.1. Subjects

Three amateur football players (mean ± SD: age, 23,2 ± 0.5; height, 1.78 ± 0.06 m; body mass, 72 ± 7,5 kg). Participant inclusion criteria were based on regular practice of football (once a month or more) and on an absence of lower limb injury within the last 6 months before the start of the study. Participants provided written-informed consent before taking part in this study. This study was approved by the Academic Research Ethics Committee (Université Paris-Saclay, 2020-170).

2.2. Material

Subjects were fitted with a commercially available football shoe (Nike® Tiempo Legend VIII Pro SG) equipped with six instrumented studs (Phyling, France) recording vertical GRFs in situ. Each stud has a measurement range of 3500N and a measurement accuracy of ±1% of the applied force. Data acquisition system (Phyling, France) was composed of a portable acquisition system (weight =230 g) worn by subjects in a custom lightweight sport vest (Apex Vest – STATSport®). Shoe was connected to the data acquisition system thanks to a wire that passed inside subjects' joggers. The sampling frequency was 1000 Hz.

2.3. Testing procedure

Subjects performed an exhaustive run at a constant velocity corresponding to 90% of VO2max. Subjects were required to run around a 200 m oval-shaped track in the middle of a turf football pitch. Subject's velocity was controlled by audio signals given every 20 m. This experiment was conducted on a synthetic turf (EuroField TT +45). This turf follows the EN 15330-1 and NF P90-112 standards and is in conformity with the French football federation regulation.

2.4. Data analysis

Data analysis was conducted on Python (3.9). Beginning of each step was defined as the moment were measured force exceeded 50 N (Cavanagh and Lafortune 1980). Although current vertical force was measured in reference to the shoe, there was no post processing to compare data with vertical force measured in an absolute reference frame. Force data were normalized by body weight to allow inter-subjects comparison. Kinetics parameters (impact and propulsive force peak, rate of decline after these peaks, loading rate and mean force value) and temporal parameters (contact and swing times, step frequency) were averaged for all steps. Statistical analysis (paired sample t-tests and Cohen's d) was conducted (JASP 0.14.1) to find differences between the 'non-fatigue' condition and the 'fatigue' condition, corresponding to the first and last 15% of the run, respectively.

3. Results and discussion

Mean time to exhaustion was 620 ± 91 s and mean number of steps analysed per subject was 868 ± 170. Impact

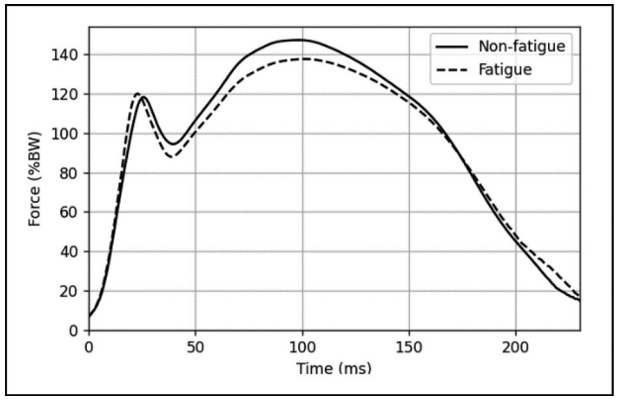

Figure 1. Example of mean GRFs patterns for one subject between the two conditions.

peak ($p = 0.52–0.82$) did not change significantly between the two conditions. Propulsive peak ($p < 0.05$, effect sizes =0.22–0.44), rate of decline after this propulsive peak ($p < 0.001$, effect sizes =0.42–0.48) and mean force value ($p < 0.05$, effect sizes =0.25–0.36) decreased significantly in all subjects in the fatigue condition. Contact time ($p < 0.05$, effect sizes =0.27–0.98) and step frequency increased ($p < 0.001$, effect sizes =0.65–1.30) among two subjects whereas swing time also decreased for these two subjects ($p < 0.001$, effect sizes =0.82–2.27) (Figure 1).

The main result of this study was the decrease in propulsive peak and the following slope. Repetitive ground impacts might induce a decrease in the capacity to store energy during stretch-shortening cycles (SSC) as the fatigue occurs (Komi 2000; Nicol et al. 1991). This loss of efficiency during SSC might lead to a less efficient and longer propulsive phase. Consequently, propulsive peak and rate of decline after this peak would significantly decrease with fatigue. Step frequency raise (and constant speed imposed to subjects) might imply a shorter stride length, which is also an indicator of this loss of performance. Similar results were found during an exhaustive run performed on a track field for which velocity was imposed (Rabita et al. 2011).

4. Conclusion

While some parameters did not vary in the same way among subjects, specific biomechanical adjustments induced by a fatiguing run can be detected in situ with a pair of football shoe instrumented with force sensors. Further research is needed to determine how these parameters may now be used to prevent football-induced injuries. More subjects will take part in this study in the upcoming weeks.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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