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Wearing Electronic Performance and Tracking System Devices in Association Football: Potential Injury Scenarios and Associated Impact Energies †

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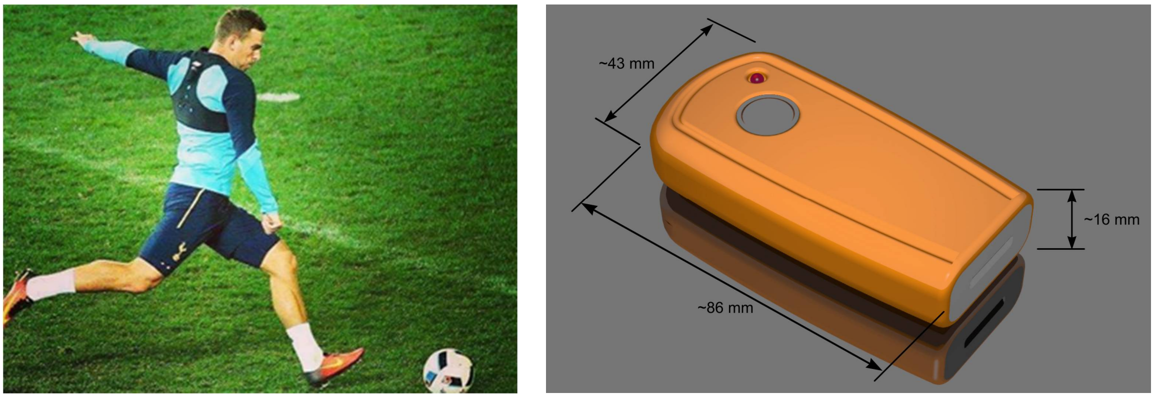
Abstract: In competitive association football, wearing electronic performance and tracking system (EPTS) devices was approved in 2015. Safety concerns regarding their use have been raised; however, research and understanding is limited. Recently, FIFA has taken steps to assess possible injury mechanisms associated with wearing EPTS devices. This study identifies potential injury scenarios in football and associated impact energies. EPTS device use was first surveyed by questionnaire and semi-structured interviews. Unexpected, backward falls were highlighted as potential injury scenarios. An anthropomorphic test device (ATD), wearing a mock-EPTS device, was dropped onto 3G turf. Impact energy was 142.4 ± 42.1 and 5.8 ± 4.0 J whilst wearing and not wearing mock-EPTS devices respectively. Results indicate that wearing EPTS devices markedly increased impact energy experienced at the upper-back during falls. Further investigation into possible injury mechanisms (e.g., EPTS device shape and/or contact-area) of skin laceration and/or contusion risk, is warranted.

Keywords: football; wearable; tracking; device; impact; energy

1. Introduction

In competitive association football, the use of wearable electronic performance and tracking system (EPTS) devices during match-play (e.g., Figure 1) was approved in 2015 [1]. Wearable EPTS devices, which include measurement technologies such as a Global (GPS) or Local (LPS) Positioning System, accelerometer, gyroscope and magnetometer, had become prevalent in football training to control and improve performance [1,2]. Subsequently, requests were made to allow players to wear EPTS devices to track match-play performance [1]. The International Football Association Board (IFAB) approved an amendment to Law 4—The Players' Equipment [1], which allowed players to wear EPTS devices in principle; however, approval was subject to further research assessing the safety of EPTS device use, as well as restrictions on in-match transmission of EPTS device data [1].

Safety concerns regarding players wearing EPTS devices during match-play have been raised; however, limited empirical evidence supports this assertion [2]. Medina and colleagues [2] assessed reported player injuries at FC Barcelona (first team, second team, under 19, under 18 and first team female) between 2011 and 2016. Over five years, 190 EPTS devices were used daily for training (total of 56,414.5 h) and match-play (total of 8970.0 h), during which no serious injury or event, which caused the loss of one or more training days, were reported [2]. However, six minor thoracic contusions (3.17 injuries per 1000 playing hours) for female players wearing a specific EPTS device, where the chest strap holds the device over the sternum, were reported. Medina and colleagues [2] highlighted that players reporting these injuries were all goalkeepers with injuries reflecting the nature of the playing position (e.g., catching or collecting ball). Further, the positioning of this particular device was an exception; all other EPTS devices reported within the study were worn on the upper-back [2]. When considering EPTS devices worn on the upper-back, only minor skin abrasion injuries were reported by the under 18 and 19 teams, corresponding to 0.21 and 0.39 injuries per 1000 playing hours respectively [2]. However, skin abrasion injuries were associated with excessive tightness of the chest vests used to wear devices (e.g., Figure 1a), rather than EPTS devices themselves. In summary, whilst outfield players did not report traumatic injuries when wearing EPTS devices, goalkeepers did report minor contusion injuries associated with impacts to the EPTS device and subsequently the chest [2]. Therefore, whilst the incidence of reported contusion injury was low, players wearing EPTS devices were exposed to a different risk to their safety, when compared to players not wearing EPTS devices. In response to safety concerns, The Fédération Internationale de Football Association (FIFA) has recently taken steps to assess possible injury mechanisms associated with wearing EPTS devices. The aim of this two-phase study was to identify (a) potential injury scenarios in football and (b) associated impact energies.



(**a**) (**b**)

Figure 1. (**a**) Example of an upper-back mounted EPTS device worn during match-play; (**b**) illustration of mock-EPTS device (dimensions representative of current EPTS devices).

2. Materials and Methods

Prior to participation, all procedures were approved by the Research Ethics Committee of the Faculty of Health and Wellbeing, Sheffield Hallam University.

2.1. Injury Scenarios

To identify potential injury scenarios, a questionnaire, canvassing EPTS device use, was distributed online to Football Medical Association members. However, despite high questionnaire circulation (≈7000 views), questionnaire responses were limited. In addition, semi-structured interviews with industry experts, including professional football team doctors and performance heads, national football centre lead sport scientists, EPTS device consultants and EPTS device industry representatives, were conducted, transcribed and analysed. When considering EPTS devices worn on the upper-back, industry experts consistently highlighted unexpected, backward falls onto ETPS devices (e.g., players competing in air for a ball) as a potential injury scenario during match-play. Therefore, based on semi-structured interviews, the primary injury scenario was identified as an unexpected backward fall.

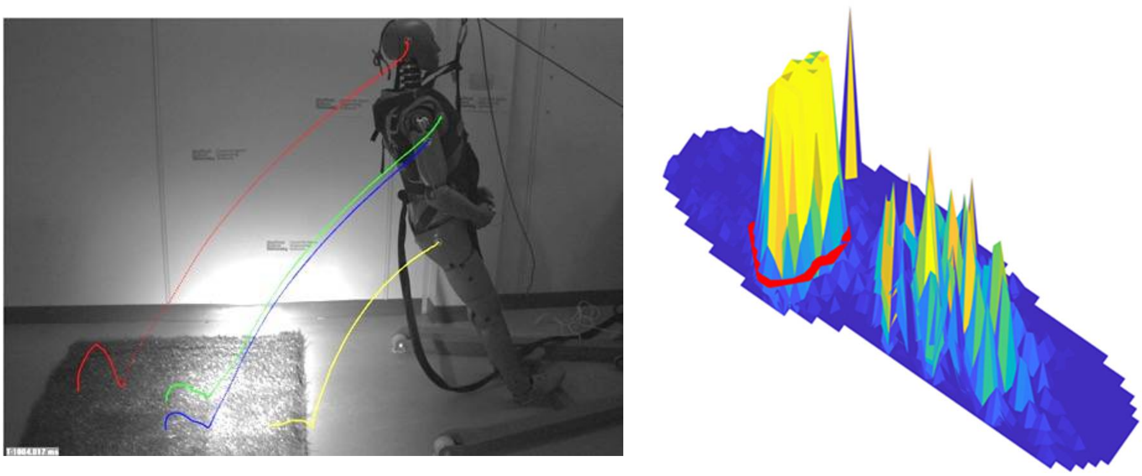
2.2. Associated Impact Energies

Based on the identified injury scenario, an anthropomorphic test device (ATD; Hybrid III 50th Male, Humanetics, Farmington Hills, MI, USA), was dropped (1.65 m; n = 25) onto 3G turf (e.g., Figure 2a) whilst wearing and not wearing a mock-EPTS device. The mock-EPTS device was based on representative device dimensions, obtained from seven currently available EPTS devices. The mock-EPTS device dimensions were 43 × 86 × 16 mm (width × length × depth) whilst edge radius was 2 mm and footprint area (i.e., surface facing player when worn) was 3698 mm^2.

(**a**) (**b**)

Figure 2. (**a**) ATD in full-body harness supported by hoist with quick release mechanism; (**b**) ATD wearing mock-EPTS device in standard padded vest with pressure sensor between the vest and ATD.

The mock-EPTS device was mounted in a standard, padded vest with a pressure sensor sampling at 500 Hz (Tekscan F-scan 3000E, 'Sport', South Boston, MA, USA) placed between the ATD and vest (e.g., Figure 2b). Markers, placed on the ipsilateral head, chest, upper-arm and hip of the ATD (e.g., Figure 3a), were filmed from a sagittal perspective at 500 Hz and resolution of 1280 × 800 pixels (Miro, Vision Research, Wayne, NJ, USA). The high-speed camera was calibrated using the planar checkerboard calibration method and simultaneously triggered with the pressure sensor, allowing kinetic and kinematic data to be synchronised. Subsequently, marker trajectories were tracked [3] and smoothed using a discretised smoothing spline, based on generalised cross-validation [4]. Planar marker position data were reconstructed [5] and instantaneous velocity [6], in global horizontal, global vertical and resultant directions, were calculated.



(**a**) (**b**)

Figure 3. (**a**) Illustration of ATD fall (e.g., marker trajectory) onto 3G turf; (**b**) automatic, regional pressure sensor analysis (red ring highlighting mock-EPTS device region) used to quantify impacts.

Pressure data were first baseline adjusted (initial ten samples) prior to a bespoke, regional pressure analysis (e.g., Figure 3b), allowing pressures associated with the mock-ETPS device impacts to be quantified. For trials where no mock-EPTS device was present, a spatial mask (based on mock-EPTS data) was applied. For each pressure sensing element, the product of pressure and area (element resolution: 25 mm^2) yields force; impulse was calculated using trapezoidal integration. Subsequently, effective mass for all impacts was calculated using the following [5]:

$$m_e = \frac{\int_{t_1}^{t_2} F dt}{\Delta v} \quad (1)$$

where m_e is effective mass, *Fdt* is force as a function of time with *dt* representing an infinitesimal time increment, t_1 is the time of first contact, t_2 the instant where motion is momentarily zero and Δv is the change in velocity over this time period. Impact energy (E_{Kin}) was calculated by the following:

$$E_{Kin} = \frac{1}{2} m_e \Delta v^2 \quad (2)$$

Trials were included in analyses if inclusion criteria (e.g., pressure associated with EPTS impact clearly identifiable) were met. All kinetic and kinematic data were processed using Matlab (R2017a, MathWorks, Natick, MA, USA). To aid interpretation, Cohen's d effect sizes were calculated to explore mock-EPTS device and no device condition differences. Effect sizes were calculated as $ES_B = \bar{x}_1 - \bar{x}_2 / S_c$ [7]. Effect sizes of 0.2, 0.5 and >0.8 were considered small, medium and large effects respectively [7].

3. Results

Semi-structured interviews with industry experts identified that an unexpected backward fall was a primary injury scenario. The likely incidence of such events was considered to be low; however, it was highlighted that a backward fall would expose players to a different injury risk, depending on whether EPTS devices are worn. For backward falls, kinematic analysis indicate that pre-impact velocities were similar for mock-EPTS and no device falls (5.8 ± 0.4 and 5.9 ± 0.3 $m \cdot s^{-1}$ respectively; ESB = −0.1). Kinetic analyses indicate that impact impulse (48.9 ± 13.9 and 2.0 ± 1.3 Ns respectively; ESB = 3.4), effective mass (8.4 ± 2.5 and 0.3 ± 0.2 kg respectively; ESB = 3.3) and impact energy (142.4 ± 42.1 and 5.8 ± 4.0 J respectively; ESB = 3.2) was markedly greater for mock-EPTS falls when compared to no device falls (Table 1).

Table 1. Kinetic and kinematic parameters associated with the upper-back during unexpected, backward falls.

	Pre-Impact Velocity ($m \cdot s^{-1}$)	Impact Impulse (Ns)	Effective Mass (kg)	Energy (J)
Mock-EPTS device (*n* = 9)	5.8 ± 0.4	48.9 ± 13.9	8.4 ± 2.5	142.4 ± 42.1
No device (*n* = 4)	5.9 ± 0.3	2.0 ± 1.3	0.3 ± 0.2	5.8 ± 4.0
ES_B	−0.1	3.4 *	3.3 *	3.2 *

* Large effect size (e.g., $|ES_B| > 0.8$).

4. Discussion

Concerns regarding the safety of players wearing EPTS devices in football have been raised; however, research and understanding is limited. The purpose of this study was to provide preliminary information regarding potential injury scenarios and impact energies associated with wearing an upper-back mounted EPTS device. Despite the high circulation (≈7000 views) of an online questionnaire to a relevant audience (e.g., Football Medical Association members), responses were very limited. This might reflect opinions that EPTS devices are not perceived as an injury risk. For example, preliminary injury incidence data [2] has reported only eleven minor injuries (e.g., contusion or abrasion) in 65,384.5 h of football training and match-play, with lost training of match-play days associated with these injuries. However, during semi-structured interviews, industry experts were asked to consider potential injury scenarios associated with wearing EPTS devices, mounted on the upper-back. Experts consistently highlighted an unexpected, backward fall onto an ETPS devices (e.g., players competing for a ball in the air) as a potential injury scenario during match-play. Further, one expert reported their observation of contusion injury related to goalkeepers wearing upper-back mounted EPTS devices in professional English football:

"I perceive a greater risk to goalkeepers wearing devices compared to outfield players. In the few instances that a player has complained about some kind of soft tissue injury related to wearing a GPS device, more often than not it will be the goalkeeper through his direct contact from landing on the backs during a dive or during a cross and like they get clattered by an attacker and end up awkwardly landing on the device that way."

"…more of a contusion really, more of an impact from the device itself."

Whilst the likely incidence of such an event was considered to be low, the risk of injury to a player wearing an EPTS devices was therefore different to that of a player not wearing an EPTS device.

Due to clear safety and ethical considerations, an ATD was dropped onto 3G turf whilst wearing and not wearing a mock-EPTS device (e.g., Figure 3a). Analysis of falls highlight that whilst impact velocities for mock-EPTS device and no device falls were similar, impact impulse, effective mass and impact energy were markedly greater ($ES_B \geq 3.2$) when a mock-EPTS device was worn. Findings indicate that, in the event of an unexpected backward fall, wearing EPTS devices markedly increase impact energies experienced at the upper-back. Whilst the use of an ATD provides a repeatable method to assess impact energies associated with backward falls, the nature of impacts cannot be mitigated. For example, when assessing the biomechanical loading of the hip during sideways dives performed by goalkeepers, Schmitt and colleagues [8] reported that different goalkeepers adopted different landing strategies, to help reduce loading to the hip during dives. In match-play, it is unlikely that a player—if knocked off balance when competing for a ball in the air—would fall to the pitch without adopting a fall strategy to mitigate the impact of landing. As the use of EPTS devices becomes more prevalent and the physical characteristics (e.g., size, shape and edge radii) of devices become more diverse, it is important to understand how wearing EPTS devices can affect player injury risk. Current findings highlight that during an unexpected, backward fall scenario, loads experienced at the upper-back are markedly greater when wearing an EPTS device. Therefore, in order for EPTS devices to comply with international standards regarding the safety of player equipment [1], EPTS devices must demonstrate that, in conditions representative of an unexpected backward fall, they do not present an unacceptable risk of injury to players. Based on current findings, further investigation into potential skin contusion and laceration injury mechanisms, as a function of EPTS device shape and size is therefore warranted, and is currently being conducted at the request of FIFA.

5. Conclusions

Wearing EPTS devices markedly increased impact energy experienced at the upper-back during a relevant, football injury scenario. Current findings inform subsequent research into skin laceration and contusion injury mechanisms of EPTS device use and future EPTS device test standards.

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Conflicts of Interest: The authors declare no conflict of interest.

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