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Original research

Quantification of tackling demands in professional Australian football using integrated wearable athlete tracking technology

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ABSTRACT

Objectives: To describe and quantify the frequency, velocity and acceleration at impact during tackling in Australian football using a combination of video and athlete tracking technology.
Design: Quasi-experimental.
Methods: Data was collected from twenty professional Australian Football League players during four in-season matches. All tackles made by the player and those against the player were video-coded and time stamped at the point of contact and then subjectively categorised into low, medium and high intensity impact groups. Peak GPS and acceleration data were identified at the point of contact. Two-way analysis of variance was used to assess differences ($p < 0.05$) between tackle type (made and against) and tackle intensity.
Results: A total of 173 tackles made and 179 tackles against were recorded. Significant differences were found between all tackle intensity groups. Peak velocity was significantly greater in high (19.5 ± 6.1 km h^{-1}) compared to medium (13.4 ± 5.8 km h^{-1}) and low intensity (11.3 ± 5.0 km h^{-1}) tackles. Peak Player Load™, a modified vector magnitude of tri-axial acceleration, was significantly greater in high (7.5 ± 1.7 a.u.) compared to medium (4.9 ± 1.5 a.u.) and low intensity (4.0 ± 1.3 a.u.) tackles.
Conclusions: High intensity tackles, although less frequent, are significantly greater in speed of movement immediately prior to contact and in the resultant impact acceleration compared to tackles of lower intensity. Differences in accelerometer data between tackles observed to be progressively greater in intensity suggest a level of ecological validity and provide preliminary support for the use of accelerometers to assess impact forces in contact invasion sports.

1. Introduction

Integrated wearable athlete tracking technology that includes global positioning system (GPS), accelerometer and gyroscope sensors has recently been used to describe movement and physical demands in the football codes[1–3] and other invasion sports such as hockey[4] and basketball.[5] In Australian football, GPS data has helped describe the changing speed of the game[3] and assess differences between regular season and finals' intensities[6], while in soccer match running performance changes associated with fatigue and level of opposition have been assessed.[2]

Studies describing accelerometer data in basketball[5] and Australian football[7,8] have also reported on 'player load', a variable that describes the instantaneous and accumulated rate of change of acceleration in three planes of movement.[7] As acceleration is proportional to force, accelerometer-derived player load has been presented as a potential useful measure of 'whole body dynamics' (physical demand),[5] 'gross fatiguing movements'[7] and 'total load'[8] in contact invasion sports. Automated tackle and collision detection has also been described in rugby league based on criteria-defined algorithms that incorporate spikes in accelerometer data and a change in device orientation.[9] Validity and reliability data is not readily available for the use of the accelerometer as it has been used in these field studies although preliminary data suggest encouraging findings.[7,9]

The ability to tackle and tolerate repeated physical collisions is paramount to success in rugby league.[10] Previous studies have documented collisions and quantified the frequency and nature of tackle events in the sport, including links with muscle damage and injury.[11,12] Significant skeletal muscle damage appears highly dependent on the number of heavy collisions in rugby league while the highest incidence of injury is also known to occur during tackling.[13] The high incidence of injury during tackling has also been described in rugby union.[14,15] Given these observations, understanding the nature and frequency of tackles and collisions in contact invasion sports is crucial.

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The evolution of Australian football, a sport whose objectives and game structure are similar to soccer, has led to rapid changes in the physical demands on elite players.[3,16] Athlete tracking technology is now widely adopted within the professional Australian Football League (AFL) to monitor player physical loads and guide tactical management strategies.[3] The technology has described player demands using GPS-derived distance covered, the number of repeated high intensity efforts and the increasing speed and intensity within the game.[3,16,17] Australian football, like rugby and other contact invasion sports, allows considerable physical contact between players and tackling is considered an important performance indicator in the sport. The average number of tackles made per match per team was 69 in 2011, an increase of 176% since 1999.[18] The AFL Medical Officers Association have raised concern about the rising trends of collision, shoulder and soft tissue injuries[19] and it has been suggested that the increased number and rising ferocity of tackles has contributed to increased injury risk.[20]

The physical demands of rugby league[9,11,21] and rugby union,[14,15] including tackles and collisions and their association with injury and muscle damage have been well described. In contrast, little is known about the nature and impact forces associated with tackling in Australian football, despite documented increases in the speed of the game[3] and the suggested link between the frequency of collisions and injury.[19,20] The objective of this study therefore was to describe and quantify the frequency, velocity and impact acceleration during tackling in Australian football using a combination of video and athlete tracking technology. A secondary objective was to assess the ecological validity of accelerometer impact data against the criterion measure of observed and categorised tackles from video footage.

2. Methods

Twenty professional male Australian football players (4 defenders, 5 forwards, 11 midfielders) from the one AFL team (mean ± SD; age: 24.1 ± 3.7 y; body mass: 85.0 ± 9.6 kg; height: 185.7 ± 8.4 cm; playing experience: 88.0 ± 85.8 matches) participated in this study. Data relating to tackle events during four professional matches from the 2011 AFL season were analysed. The study protocol was approved by Deakin University Human Ethics Advisory Group, all procedures followed ethical guidelines for human research and participants provided written informed consent prior to participating.

Television broadcasting video from the AFL match was used to determine tackle events. The footage was taken from a side-on view of the field that captured the play near the ball. The participating AFL team played in all matches with a different opposition each time (opponent data was not analysed). Tackles made by a player or when an opponent tackled the player (against) were identified and coded using commercially available software (Sportstec, Sportscode Version 8.4.0).

Each tackle identified was time-coded at the point of contact and its perceived intensity determined. Tackles were categorised into low, medium or high intensity based on criteria that considered the observed speed and force of impact (Supplementary Table). To assess inter-rater reliability for tackle detection and categorisation, a complete match consisting of 50 tackles made and 60 tackles against was re-coded by a secondary match analyst (Cohen's Kappa $K = 0.813$). Test–retest reliability was established by re-coding the first match after a wash-out period of six weeks ($K = 0.934$).

Athlete tracking technology (MinimaxX S4, Catapult Innovations, Melbourne, Australia) was used to assess player movement velocity and acceleration. The MinimaxX unit was worn in a small pocket located in the playing jersey, on the upper back between the shoulder blades. The GPS sensor sampled at 10 Hz and was used to establish peak velocity immediately prior to the point of contact. These units are accurate for measuring short distances run at high speed and have high intra- and inter-device reliability.[22] The tri-axial accelerometer sampled at 100 Hz and measured impact acceleration in three planes of movement (x, y, z). With the player standing upright, these planes describe sideway (medio-lateral), forward–back (anterior–posterior) and vertical acceleration and deceleration. The manufacturer also reports instantaneous Player Load^{TM}, described as a modified vector magnitude of the instantaneous rate of change in acceleration in the three planes.[5,7] Accumulated Player Load^{TM}, which is divided by a scaling factor of 100 and reported in arbitrary units (a.u.), is summed over time and has been used to describe overall physical load in training and competition.[5,8] Within and between device reliability, expressed as a coefficient of variation (%CV), has been reported as 0.9–1.05% and 1.02–1.10%, respectively, in controlled laboratory test conditions and 1.9% between devices in field testing.[7]

To assess the ecological validity of athlete tracking technology, tackles observed and categorised into low, medium and high intensity groups were compared based on GPS and accelerometer data. Video footage, collected at 50 Hz, was imported into the manufacturer's software (LoganPlus Version 4.7.1, Catapult Innovations, Melbourne, Australia) and synchronised with GPS and accelerometer data. For all categorised tackles, peak velocity and accelerometer data were identified within a 3 s tackle zone (from 1 s before to 2 s after the point of impact). The 3 s tackle zone was decided after determining that the majority of tackle events occurred within this time frame and the peak velocity of the player prior to contact and the peak impact acceleration associated with a sustained tackle were both captured.

Data are presented as mean ± standard deviation (SD). A two-way between-groups analysis of variance was used to determine differences between tackle type (made and against) and tackle intensity (low, medium and high). Gabriel's post hoc tests were used to further assess differences between multiple groups, with the level of significance set at $p < 0.05$. IBM SPSS Statistics Version 20.0 was used for all statistical analyses.

3. Results

A total of 352 tackles were recorded during the four matches, comprising 173 tackles made (68 low, 100 medium, 5 high intensity) and 179 tackles against (47 low, 118 medium, 14 high intensity), with an average of 3.9 ± 2.3 (mean ± SD) tackles made and 4.0 ± 1.9 tackles against per player per match. The majority of tackles were classified as medium intensity (61%) while only 6% were classified as high intensity.

Most tackles occurred at velocities between 7 and 20 km h^{-1} although 12.5% were at velocities greater than 20 km h^{-1} (Fig. 1A); the highest recorded velocity during a tackle was 31.4 km h^{-1}. Impact acceleration in any plane of movement during a tackle ranged from 0.5 to 7.5 g, with average values ranging from 3.2 to 5.6 g (Table 1). Instantaneous Player Load^{TM} was typically very light (62%), with only 9% of tackles resulting in a Player Load^{TM} above 7 a.u. (Fig. 1B); the highest recorded Player Load^{TM} was 11.4 a.u.

Comparisons between tackle type found no significant differences in accelerometer or velocity data (Table 1, Fig. 2), although trends of faster velocity for tackles made ($p = 0.06$) and greater medio-lateral acceleration for tackles against ($p = 0.06$) were evident.

Significant differences ($p < 0.01$) were found between the three tackle intensity groups for peak velocity and all accelerometer variables (Table 1). Player Load^{TM} was significantly greater in high compared to medium and low intensity tackles (Fig. 2B).