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Authors: Billy T. Hulin, Tim J. Gabbett, Rich D. Johnston, David G. Jenkins

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Wearable microtechnology can accurately identify collision events during professional rugby league match-play

Billy T Hulin[a], Tim J Gabbett[b], Rich D Johnston[c], David G Jenkins[d]

[a]Mr **Billy T Hulin** and Dr **David G Jenkins**, School of Human Movement and Nutrition Sciences, Level 5, Human Movement Studies Building (26B), Blair Drive, University of Queensland, St Lucia QLD 4072.
E-mail: d.jenkins@uq.edu.au
[b]Dr **Tim J Gabbett**, Gabbett Performance Solutions, Brisbane, Queensland, Australia
E-mail: tim_gabbett@yahoo.com.au
[c]Dr **Rich D Johnston**, School of Exercise Science, Australian Catholic University, 1100 Nudgee Road, Banyo QLD 4014
E-mail: Richard.Johnston@acu.edu.au

Corresponding author: Mr Billy T Hulin
Telephone: +614 13 224 667
E-mail: billyhulin@hotmail.com

Abstract

Objectives: Collision frequency during rugby league matches is associated with team success, greater and longer lasting fatigue and increased injury risk. This study researched the sensitivity and specificity of microtechnology to count collision events during rugby league matches.

Design: Diagnostic accuracy study

Methods: While wearing a microtechnology device (Catapult, Optimeye S5), eight professional rugby league players were subjected to a total of 380 collision events during matches. Video footage of each match was synchronised with microtechnology data. The occurrence of each collision event was coded in comparison with whether that event was or was not detected by microtechnology.

Results: Microtechnology detected 371 true-positive collision events (sensitivity = 97.6 ± 1.5%). When low-intensity (<1 PlayerLoad AU), short duration (<1 second) events were excluded from the analysis, specificity was 91.7 ± 2.5%, accuracy was 92.7 ± 1.3%, positive likelihood ratio was 11.4 ×/÷ 1.4 and the typical error of estimate was 7.8% ×/÷ 1.9 (*d* = 0.29 ×/÷ 1.9, *small*). Microtechnology collisions

were strongly and positively correlated with video coded collision events (r = 0.96). The ability of microtechnology to detect collision events improved as the intensity and duration of the collision increased.

Conclusions: Microtechnology can identify 97.6% of collision events during rugby league match-play. The typical error associated with measuring contact events can be reduced to 7.8%, with accuracy (92.7%) and specificity (91.7%) improving, when low-intensity (<1 PlayerLoad AU) and short duration (<1 second) collision reports are excluded. This provides practitioners with a measurement of contact workload during professional rugby league matches.

Keywords: Workload; Training load; Validity; Sensitivity; Specificity.

Introduction

Field-based team sports involve brief periods of high-intensity running and acceleration efforts interspersed with longer periods of low-intensity activity.[1,2] The ability to measure running demands with global positioning systems (GPS) and microtechnology (accelerometers, gyroscopes and magnetometers) has provided useful information on the physical demands of match-play,[3] differences between successful and less successful teams,[4] and the risk of athletes sustaining an injury.[5,6] Additional to running demands, rugby league players can be involved in up to 55 collision events during match-play.[7] A higher collision frequency during matches has been associated with greater team success in elite[8] and semi-elite[4] rugby league. Furthermore, including physical contact in game-based activities produces more upper body neuromuscular fatigue, a greater and longer lasting increase in plasma creatine kinase activity, and an increased perception of effort compared with game-based activities involving no contact.[9] Not surprisingly, tackles and physical collisions are the mechanism for the majority of rugby league injuries during matches.[10,11] However, even though the incidence of collision injuries during training sessions has been considered relatively low (6.4 per 10,000 collisions),[12] the capability to accurately quantify contact events that are related with the occurrence of injury, on-field

success and increased physiological and psychological load is an important component of contemporary training monitoring in professional rugby league.

Gabbett *et al.*[12] investigated the ability of wearable microtechnology to detect 237 collision events during 21 training sessions and 1 trial match of a professional rugby league team. Collisions were defined as contact made with the player, which resulted in an alteration to the player's momentum.[12] Microtechnology measured collisions using a custom designed algorithm that detected a spike in instantaneous 'PlayerLoad' shortly before a change in orientation of the microtechnology device (Catapult MinimaxX). PlayerLoad was calculated as the square root of the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (X, Y and Z axis).[13] The authors found that the detection of collision events via wearable microtechnology had a strong positive correlation ($r = 0.96$) with video coded collision events during rugby league training sessions. However, the physical demands of training sessions can differ from match-play demands in professional rugby league.[3] Moreover, the microtechnology devices used by Gabbett *et al.*, were worn in a customised harness, which differs from the contemporary method of storing this equipment within the player's jersey. Indeed, research is yet to investigate a number of factors in regards to the accuracy of microtechnology for detecting collision events. Specifically, (1) the accuracy of these devices when they are housed within the playing garment, (2) the sensitivity of the equipment (i.e. true-positive to false-negative ratio), (3) the ability of the equipment to *not* report collision events, when collision events *do not* occur (specificity – true-negative to false-positive ratio) and (4) the accuracy of these devices to identify collision events during competitive rugby league matches.

Others have investigated the impact forces (i.e. *g*-forces) associated with collision events during rugby league match-play.[14] Using video analysis, tackles and hit ups were time-coded and subsequently compared with information provided via wearable microtechnology (GPSports). Although this study provided useful information on the tackle and hit-up profile of rugby league players, the accuracy of

this equipment to detect collision events without the use of video coding was not investigated.[14] Using the same equipment as Cummins and Orr,[14] McLellan *et al.*[15] reported that individual rugby league players can be subjected to 464 'impacts' per match, which is substantially greater than the number of collisions reported by others.[3,7,14] Importantly, accelerometer-derived 'impacts' do not take into account a change in orientation of the microtechnology device that can occur during collision or tackle events.[16] Unsurprisingly, spikes in accelerometer data can occur during a high-intensity acceleration or change of direction and may indeed be recorded by this equipment as an 'impact',[17] which can be incorrectly interpreted by practitioners as a collision or contact event with an opponent.[16] Although wearable microtechnology has demonstrated validity when measuring collision and impact forces during walking, running, and team sport movements,[17,18] research is yet to investigate the accuracy of a microtechnology device to distinguish between collision events and other spikes in accelerometer data during professional rugby league match-play.

Given that the frequency of contact events is associated with team success,[4,8] greater physiological load and neuromuscular fatigue,[9] and the incidence of injury in rugby league match-play,[10,11] the purpose of this study was to investigate the sensitivity and specificity of microtechnology devices to accurately count the number of contact events that occur during rugby league matches.

Methods

Eight elite rugby league players, (mean ± SD age 25.4 ± 2.6 y, height 185.4 ± 5.6 cm, and body mass 98.3 ± 11.6 kg) comprising 2 adjustables, 2 outside backs, 2 wide-running forwards and 2 hit-up forwards were subjected to a total of 380 collisions events (47.5 ± 10.5 per player) during eight individual appearances in the Australian National Rugby League competition. The study was approved by an ethics committee at the University of Queensland. All participants were informed of the risks and benefits prior to providing consent.

Before the commencement of the season, each participant was fitted with a jersey, which contained a small pouch on the upper back, between the scapulae. Jerseys were tailored to fit tightly, with the intention of minimising movement of the microtechnology unit within the jersey's pouch. Housed within the microtechnology unit (Catapult, Optimeye S5, firmware version 7.27, Melbourne, Australia) were tri-axial accelerometers, gyroscopes and magnetometers, which sample at 100 Hz and were used to detect collision events.

Each match was recorded by video from an elevated position that was in line with the halfway mark on the field. One researcher used software (Openfield, version 1.12.0, Catapult, Melbourne, Australia) to synchronize video footage of each match with each player's microtechnology data. As such, the same researcher was able to simultaneously view and code the occurrence of each collision event (n = 380) in comparison with whether that event was or was not detected by the microtechnology device. Collisions that were identified by video were defined as the player making contact with either another player or the ground, which resulted in an alteration to the player's momentum or the player's direction of travel (Gabbett et al., 2010). The definitions described in Table 1 were then used to determine the sensitivity and specificity of the equipment to detect collision events. Previous research has demonstrated intra-rater reliability to be <5% (typical error of estimate) for coding contact related events during rugby league match-play.[7]

Laboratory testing has demonstrated that the technology used in this study has acceptable within- (CV 0.91 to 1.05%) and between-device (1.02 to 1.90%) reliability for measuring acceleration forces that are used to calculate 'PlayerLoad', the calculation of which has been described in detail by others.[13] In order for a collision to be detected by the microtechnology device, a spike in instantaneous PlayerLoad ≥2 arbitrary units (AU) is required to occur along with a change in orientation of the device, which is measured using the gyroscopes axes for yaw, pitch, and roll (McNamara *et al.*, 2015). As spikes in accelerometer data can occur during locomotor movements,[17,18] a spike in PlayerLoad at the threshold

of ≥2 AU was also used to identify the occurrence of true-negative events (i.e. events where collisions *do not* occur, but spikes in PlayerLoad ≥2 AU are reported). True-negative and false-positive events were then used to calculate the ability of the microtechnology to *not* report collision events when collision events *do not* occur (i.e. specificity) (Tatsioni *et al* 2005).

Insert Table 1 About Here

The intensity and duration of each collision event were also quantified. Firstly PlayerLoad, and secondly the time accumulated between the initial spike in accelerometer data caused by a detected collision event and the return of the device to an upright (i.e. vertical) position was recorded. As such, the intensity (i.e. accumulated PlayerLoad) and duration of each contact event was obtained. The positive predictive value (i.e. true-positive / (true-positive + false-positive)) was subsequently calculated for collision events of varying intensity and duration.

Microtechnology and video-based data were log-transformed and compared using the typical error of estimate expressed as a co-efficient of variation (CV). The magnitude of the CV was interpreted using the following thresholds of Cohen's effect size statistic (*d*): <0.1, trivial; 0.1-0.3, small; 0.3-0.6, moderate; >0.6, large.[19] Additionally, an independent *t*-test was used to identify any differences, with significance set at $p < 0.05$. The relationship between the microtechnology data and video-based measures of collisions was determined using Pearson's product moment correlation coefficient. The number of true-positive and false-negative results were used to calculate sensitivity, while specificity was determined by comparing the number of true-negative and false-positive findings. Other metrics of test performance such as accuracy, and positive and negative likelihood ratios were determined using the calculations described by Tatsioni *et al.*[20] and reported with 95% confidence intervals.

Results

Of the 380 collision events observed, microtechnology units were able to detect 371 true-positives (sensitivity = 97.6 ± 1.5%; Figure 1A). Overall, a total of 60 false-positives were identified (specificity

= 87.6 ± 2.9%; Figure1A). More than 50% of detected collision events were false-positive when only considering collisions reports that were <1 PlayerLoad AU (positive predictive value = 0.0 ± 0.0%), and <1 second (positive predictive value = 42.4 ± 16.9%) (Supplementary Tables 1 & 2). When reported events <1 PlayerLoad AU and <1 second were excluded from the analysis, specificity increased to 91.7 ± 2.5%, sensitivity decreased to 93.9 ± 2.4%, accuracy was 92.7 ± 1.3%, and the positive likelihood ratio was 11.4 ×/÷ 1.4 (Figure 1). Overall, changes in direction resulted in the greatest number of false-positives (*n* = 19; 31.7%) (Supplementary Table 3).

Insert Figure 1 About Here

The positive predictive value ranged from 84.5 ± 5.5% to 100.0 ± 0.0% when collision intensities ≥2 AU were classified into 1 AU increments (Supplementary Table 1). The positive predictive value ranged from 97.2 ± 3.1% to 100.0 ± 0.0% when collision ≥2 seconds were classified into 1 second increments (Supplementary Table 2).

Insert Figure 2 About Here

When collision reports <1 PlayerLoad AU and <1 second were excluded from the analysis, collisions identified by microtechnology devices demonstrated a strong positive correlation with video coded collision events (*r* = 0.96, 95% CI, 0.79-0.99) (Figure 2), the typical error of estimate was 7.8% ×/÷ 1.9 (*d* = 0.29 ×/÷ 1.9, *small*; Figure 1B) and there was no difference between the number of collisions identified by microtechnology and video coding (p = 0.72).

Discussion

This is the first study to demonstrate the sensitivity and specificity of wearable microtechnology to detect collision events in professional rugby league matches. These findings demonstrate that the microtechnology used is sensitive to detect 97.6% of collisions that occur during match-play. The specificity of microtechnology (i.e. the ability to *not* report collision events when collision events did *not* occur) was 91.7% when short duration (i.e. <1 second) and low-intensity (i.e. <1 PlayerLoad AU) events were excluded. The rationale for this exclusion of short duration and low-intensity events was

that this resulted in the highest accuracy (92.7%) and positive likelihood ratio (11.4) and the lowest typical error of estimate (7.8%). Furthermore, the positive predictive value was less than 50% for detecting low-intensity collisions that were less than 1 second in duration. However, the ability of these devices to report collision events improved as the intensity and duration of the collision increased.

Reported collision events that were longer than 2 seconds in duration demonstrated a positive predictive value of ≥97.2%. That is, of the 245 true- and false-positive collision events ≥2 seconds, 98.4% (n = 241) were true-positive outcomes and 1.6% (n = 4) were false-positive. McNamara *et al.* recently demonstrated that microtechnology: (1) was sensitive to detect bowling counts in cricket fast bowlers,[21] (2) provided a reproducible measure of external workload,[22] and (3) could be used to identify spikes in high-intensity acute:chronic workload ratios.[23] Although the risk of team sport athletes sustaining a contact injury has been associated with poor high-intensity running ability,[24] changes in locomotor distance and acceleration workloads (i.e. acute:chronic workload ratios >1.7),[5] and session-RPE workloads,[25] to date no study has investigated the influence of acute and chronic contact workloads on contact injury risk in professional team sport. Given that the acute:chronic workload ratio derived from distance covered is associated with injury in rugby league players.[6] The present findings and the above-mentioned studies provide evidence that researching contact-only workloads may be possible over acute and chronic periods, which could provide greater insight into collision injury risk.

This study demonstrated that during professional rugby league match-play, collision events identified by microtechnology devices have a strong positive correlation with video coded collision events (r = 0.96), with no difference between the number of collisions identified by microtechnology and video coding. These findings are supported by others who established that microtechnology can accurately detect collisions events during professional rugby league training sessions. In the same study, Gabbett *et al.*,[12] demonstrated that the incidence of collision injury was 2-fold greater during pre-season training than during the competitive phase of the season. Interestingly, the higher incidence of collision injuries

reported during pre-season training occurred despite fewer collision events during the pre-season than the in-season. Indeed an off-season break may decrease a player's ability to withstand workloads when returning to pre-season training.[26] Additionally, chronic workloads can protect against injury in cricket fast bowlers,[27] and during congested fixture periods in rugby league players.[28] Collectively these studies suggest that the accumulation of higher chronic contact workloads may protect against contact injury. This study and others[12] demonstrate that contact workloads obtained during training and match-play can be recorded with accuracy and ease through the use of wearable microtechnology.

The greatest number of true-positive events and no false-positive events occurred while players were making a tackle (252 true-positives) or carrying the ball into a tackle (85 true-positives). These findings also have potential implications for injury risk and match performance. Specifically, the majority of rugby league injuries occur during tackles and physical collisions.[10,11] Successful rugby league teams concede fewer missed tackles, break more tackles, and are involved in more collisions than less successful teams.[8,29] Including physical contact in game-based activities is associated with greater physiological load and neuromuscular fatigue than game-based activities involving no contact.[9] These factors highlight that for rugby league teams to be successful, players must subject themselves to collision events that will heighten injury risk and perceptual and neuromuscular fatigue. The findings of the present study provide practitioners with a method to accurately quantify these events, in order to monitor and manipulate training workloads, potentially reducing injury risk and improving performance.

The greatest number of false-positive collision events occurred during a change in direction (n = 19; 32%) and the second greatest number of false-positives (n = 14; 23%) were the result of an error where the microtechnology device reported the same collision data twice. However, the exclusion of 22 low-intensity, short duration false-positive events resulted in an improvement in accuracy and positive likelihood ratio. These findings demonstrate that the accuracy issues related to low-intensity, short

duration collision events are related to the ability of the equipment to *not* report collision events when collision events *do not* occur (i.e. specificity). These findings are supported by another study demonstrating that during rugby league training sessions, mild low-intensity collision events have a poorer correlation with video coded collisions than high-intensity collision events (r = 0.89 *vs.* r = 0.99).[12] Furthermore, it should be noted that the ability to exclude these events can be achieved easily with the software used in this study (Openfield, Catapult, Melbourne, Australia). Although these findings are favourable for measuring contact events during rugby league match-play, the microsensor algorithm employed in this study may not be suitable to measure collisions in other team sports. For example, Gastin and colleagues[30] demonstrated that the collision detection algorithm developed for rugby league, which was used in this study is not suitable for tackle detection in Australian Football. Considering that activity profiles may differ among, rugby league, soccer and Australian football, further investigation is warranted before the findings of this study may be applied to a sport other than rugby league.

Conclusions

This research demonstrated that the microtechnology used in this study is sensitive to detect 97.6% of collisions that occur during rugby league match-play. The specificity of microtechnology can be improved to 91.7% with the exclusion of low-intensity, short duration collisions, which resulted in the highest accuracy (92.7%) and positive likelihood ratio (11.4), and the lowest typical error of estimate (7.8%). It should be noted that the findings are specific to the microtechnology used in this study and may not apply to other commercially available devices. Importantly, the current findings provide evidence that contact-only workloads can be accurately recorded and modelled over acute and chronic periods, which may provide more information on the manipulation of training workload to reduce injury risk and improve performance.

Practical implications

- Wearable microtechnology is sensitive to identify 97.6% of all collision events during professional rugby league match-play
- The error associated with measuring contact events is related to the ability of microtechnology to *not* report collision events when collision events *do not* occur
    - This error can be reduced to 7.8%, with accuracy (92.7%) and specificity (91.7%) improving when low-intensity (<1 PlayerLoad AU) and short duration (<1 second) collision reports are excluded
- The accuracy of microtechnology devices to detect collision events improved as the intensity and duration of the collision increased
- Recording contact-only workloads can be achieved during training sessions and matches, which may provide more information on the manipulation of training workload

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Figure legends

Figure 1. Sensitivity, specificity and accuracy (A), and positive likelihood ratio and typical error of estimate as a coefficient of variation (CV) (B) for microtechnology devices detecting collision events during professional rugby league match-play.

Insert Figure 1 here

Ex <1 AU = excluding reported collisions less than 1 PlayerLoad AU; Ex <1 s = excluding reported collisions less than 1 second; Ex <1 AU & <1 s = excluding reported collision less than 1 PlayerLoad AU and less than 1 second. Sensitivity calculated using the number of true-positives; 371 (overall), 371 (Ex <1 AU), 357 (Ex <1 s), 357 (Ex <1 AU & <1 s) and the number of false-negatives; 9 (overall), 9 (Ex <1 AU), 23 (Ex <1 s), 23 (Ex <1 AU & <1 s). Specificity calculated using the number of true-negatives; 422 (overall-Ex <1 AU & <1 s) and the number of false-positives; 60 (overall), 55 (Ex <1 AU), 41 (Ex <1 s), 38 (Ex <1 AU & <1 s).

Figure 1. Sensitivity, specificity and accuracy (A), and positive likelihood ratio and typical error of estimate as a coefficient of variation (CV) (B) for microtechnology devices detecting collision events during professional rugby league match-play.

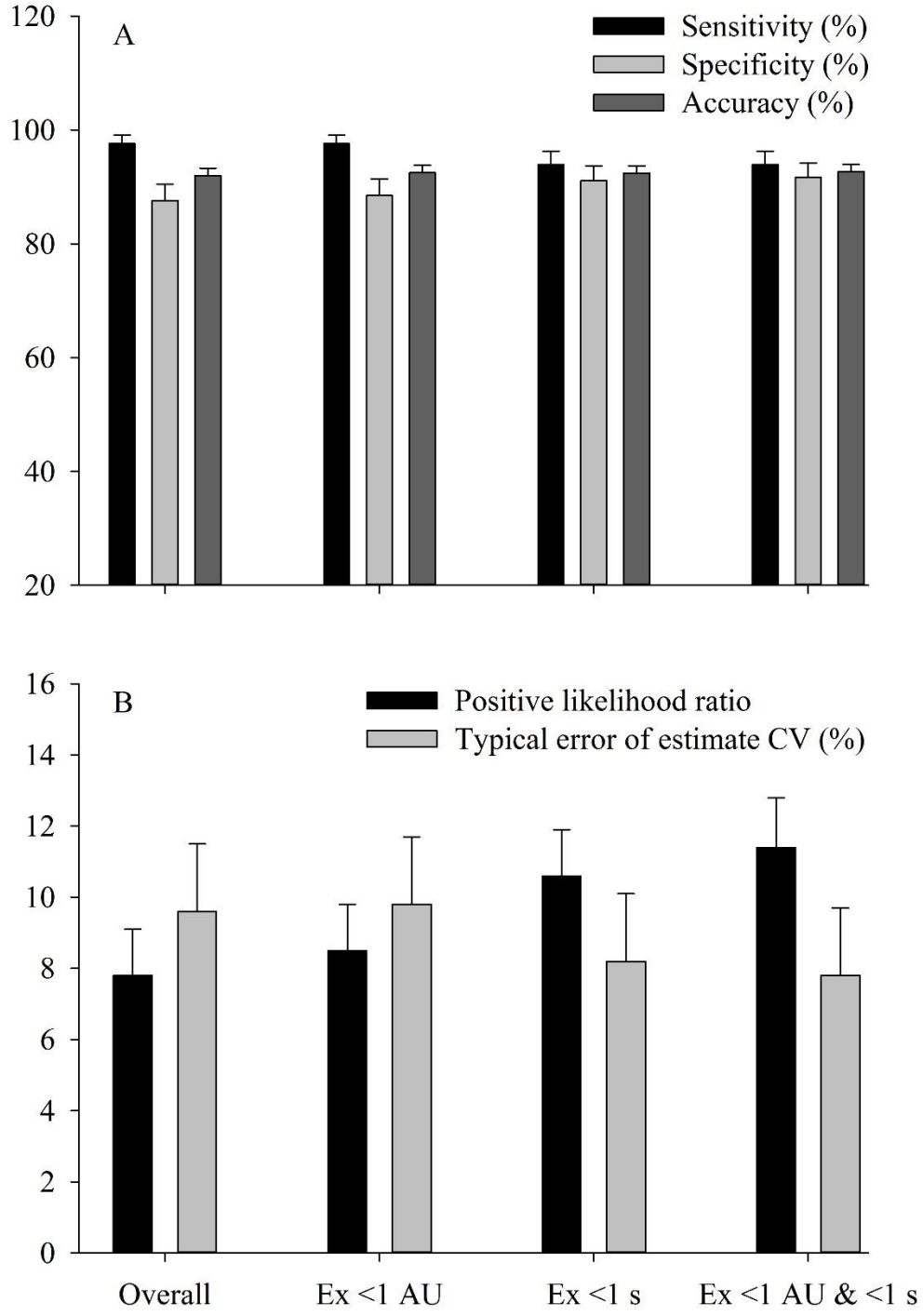

Figure 2. Relationship between the number of collisions detected by microtechnology and manual video coding in professional rugby league matches.

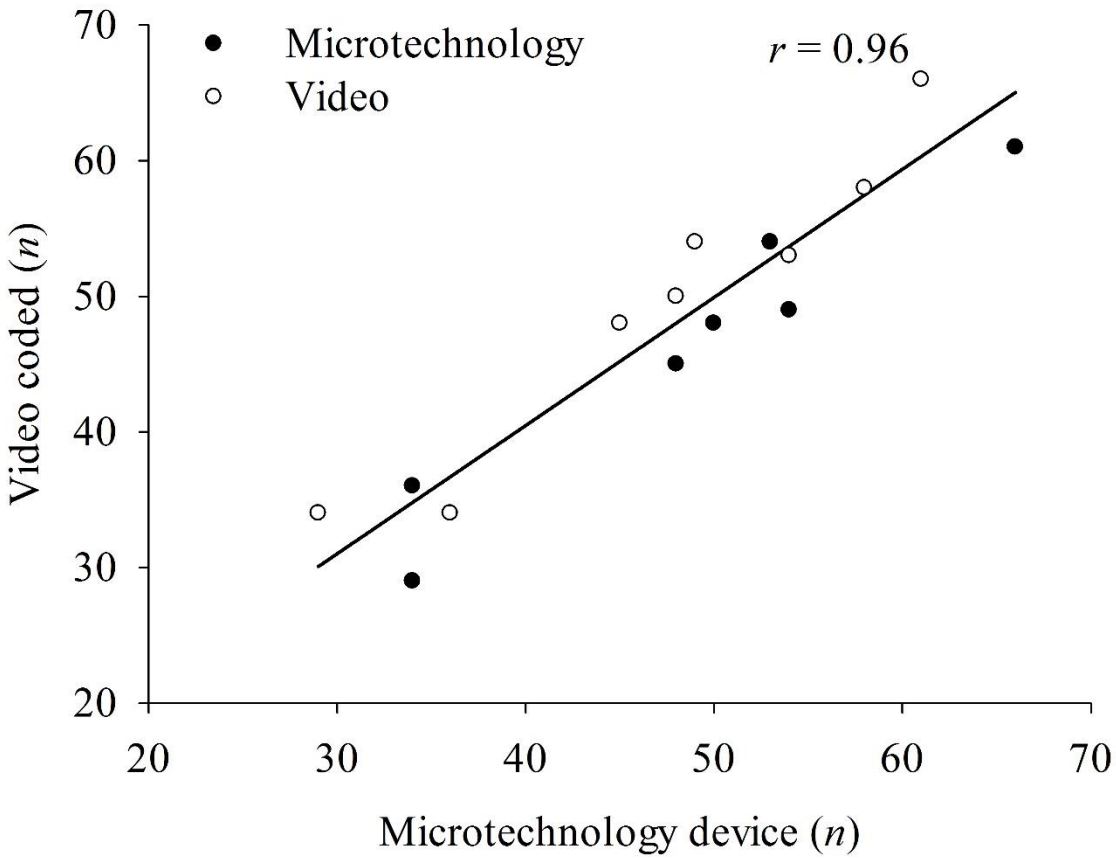

Table 1. Definition of events used to calculate the sensitivity and specificity of microtechnology devices to automatically report collision events in professional rugby league match-play.

Sensitivity (collision did occur)		Specificity (collision *did not* occur)	
True-positive	False-negative	True-negative	False-positive
The player was involved in a collision and the microtechnology unit reported a collision.	The player was involved in a collision and the microtechnology unit *did not* report a collision.	The following conditions were met: 1) the microtechnology device recorded a spike in instantaneous PlayerLoad of ≥2 AU, 2) the player was *not* involved in a collision and 3) the microtechnology device *did not* record a collision.	The player was *not* involved in a collision and the microtechnology unit reported a collision.