TECHNICAL REPORT

Quantifying the Physical Demands of Collision Sports: Does Microsensor Technology Measure What It Claims to Measure?

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Abstract

Gabbett, TJ. Quantifying the physical demands of collision sports: does microsensor technology measure what it claims to measure? *J Strength Cond Res* 27(8): 2319–2322, 2013—The physical demands of rugby league, rugby union, and American football are significantly increased through the large number of collisions players are required to perform during match play. Because of the labor-intensive nature of coding collisions from video recordings, manufacturers of wearable microsensor (e.g., global positioning system [GPS]) units have refined the technology to automatically detect collisions, with several sport scientists attempting to use these microsensors to quantify the physical demands of collision sports. However, a question remains over the validity of these microtechnology units to quantify the contact demands of collision sports. Indeed, recent evidence has shown significant differences in the number of "impacts" recorded by microtechnology units (GPSports) and the actual number of collisions coded from video. However, a separate study investigated the validity of a different microtechnology unit (minimaxX; Catapult Sports) that included GPS and triaxial accelerometers, and also a gyroscope and magnetometer, to quantify collisions. Collisions detected by the minimaxX unit were compared with video-based coding of the actual events. No significant differences were detected in the number of mild, moderate, and heavy collisions detected via the minimaxX units and those coded from video recordings of the actual event. Furthermore, a strong correlation ($r = 0.96$, $p < 0.01$) was observed between collisions recorded via the minimaxX units and those coded from video recordings of the event. These findings demonstrate that only one commercially available and wearable microtechnology unit (minimaxX) can be considered capable of offering a valid method of quantifying the contact loads that typically occur in collision sports. Until such validation research is completed, sport scientists should be circumspect of the ability of other units to perform similar functions.

Key Words contact sport, impact, rugby, microtechnology, validity

The Importance of Quantifying Contact Load in Collision Sport Athletes

Although collisions are responsible for the majority of rugby league, rugby union, and American football injuries, success in these sports are also heavily dependent on tackling ability, the ability to tolerate physical collisions, and the ability to "win" the tackle contest. Consequently, tackling is one of the most practiced skills in rugby league, rugby union, and American football, as the ability (or inability) to effectively perform tackles may prove critical to the outcome of the game. From a physical conditioning perspective, exposing players to a high number of collisions in training is analogous to high-volume running for endurance-based sports (e.g., Australian football); high numbers of physical collisions are thought to be imperative to adequately prepare players for the demands of the game (3). Despite the importance of tackling in collision sports, clearly a balance exists between the minimum number of collisions required to improve skill and physical conditioning and the maximum number of collisions tolerable before eliciting fatigue and sustaining marked increases in injury rates. Furthermore, it has recently been shown that exposure to repetitive collisions, including those that are subconcussive in nature, may increase the risk of traumatic brain injury (1). Repeated concussions have also been linked to early-onset Alzheimer's disease, depression, dementia, and chronic traumatic encephalopathy (1).

Do Microtechnology Units Measure What They Claim to Measure?

The physical demands of rugby league, rugby union, and American football are significantly increased through the large number of collisions players are required to perform during training and match play. Although collisions can be readily quantified by coding events from video recordings, this

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Figure 1. Examples of a 1-on-1 (A, B), 2-on-1 (C), and 3-on-1 (D) tackle performed in rugby league.

methodology is extremely time consuming and labor-intensive, making analysis of large data sets problematic. Consequently, manufacturers of wearable microsensor (e.g., global positioning system [GPS]) units have refined the technology to automatically detect these collisions, with several sport scientists attempting to use these microsensors to quantify the physical demands of collision sports. However, a question remains over the validity of these microtechnology units to quantify the contact demands of collision sports.

To date, few studies have attempted to quantify the demands of collision sports (2,4,7), with much of the early research conducted on American football players (5,6,8,9). Researchers have investigated the accelerations that occur from head impacts sustained in American football (5,6,9). Using 6 accelerometers mounted inside a football helmet, the commercially available Head Impact Telemetry (HIT) system reports data on the time of impact, location of impact, and linear acceleration resultant of the head center of gravity (6). Data acquisition is triggered when any accelerometer exceeds impact forces of 10 G (8). The acceleration of the helmet was shown to be 16.6% greater than the peak head acceleration, demonstrating that the accelerometers measure head acceleration and not simply the acceleration of the helmet in response to impact. Importantly, the mean error in measuring peak linear acceleration was as low as 0.01%.

Although these studies have provided important insight into the impacts associated with American football, and the validity of the HIT system, a major difference between American football and the rugby codes (i.e., league and union), is that 'rugby' players do not wear helmets and use minimal protective padding (Figure 1). Hence, the microsensors must be worn on the body (not the head). Second, the microsensors that are employed in rugby league and rugby union are significantly different from those employed in American football as they also use GPS technology to

TABLE 1. Zones used to study "impacts" in rugby union and rugby league.*

Zone	Gravitational force	Description of impact
1	<5.0–6.0	Very light impact, hard acceleration/deceleration/change of direction while running
2	6.1–6.5	Light to moderate impact, minor collision with opposition player, contact with the ground
3	6.5–7.0	Moderate to heavy impact, making tackle or being tackled at moderate velocity
4	7.1–8.0	Heavy impact, high-intensity collision with opposition player/s, making direct front on tackle on opponent traveling at moderate velocity, being tackled by multiple opposition players when running at submaximum velocity
5	8.1–10.0	Very heavy impact, high-intensity collision with opposition player/s, making direct front on tackle on opponent traveling at high velocity, being tackled by multiple opposition players when running at near maximum velocity
6	>10.1	Severe impact, high-intensity collision with opposition player/s, making direct front on tackle on opponent traveling at high velocity, being tackled by multiple opposition players when running at maximum velocity

*Redrawn from Cunniffe et al. (2) and McLellan et al. (7).

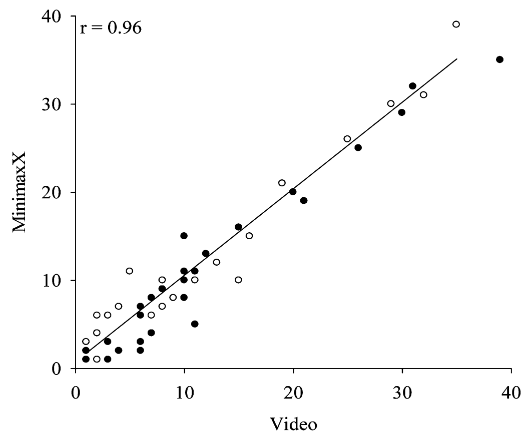

Figure 2. Comparison of minimaxX and video methods for recording collisions. Reproduced from Gabbett et al. (3).

quantify the running demands of these sports. Some units (e.g., minimaxX; Catapult Sports, Melbourne, Australia) also incorporate gyroscopes to enhance the detection of collisions and magnetometers (essentially an electronic compass) to allow the sport scientist to report the direction of travel (e.g., forward, backward, or lateral movement).

McLellan et al. (7) used a GPS unit sampling at 5 Hz and triaxial accelerometers (GPSports, Canberra, Australia) to measure displacement, velocity, and acceleration and quantify the "impact" demands of professional rugby league. Impacts were divided into 6 separate zones based on "manufacturer recommendations" (Table 1).

Collisions (hit-ups and tackles) were also quantified from video analysis. Several of the author's findings question the validity of this particular microsensor unit to accurately measure collisions. First, no attempt was made to externally validate the units to determine its accuracy in quantifying the physical demands of a collision sport. Second, the average number of impacts performed per player (830 $\pm$ 135) was significantly greater than the actual number of tackles (14.9 $\pm$ 10.5) and hit-ups (10.2 $\pm$ 3.8) coded from video. Even when changes of direction while running and minor collisions with the ground and opposing players were excluded from their data, an average of 464 impacts involving moderate to severe collisions with players were recorded per player. Finally, it has been reported that approximately 600 tackles (300 by each team) occur in a professional rugby league match (4), although these values may vary depending on the quality of the game and time that the ball is in play. The fact that the average number of impacts performed by individual players was considerably greater than the total number of collisions typically performed by both teams during an entire match (i.e., 26 players on a field at one time) suggests that these data should be interpreted with a degree of caution.

In the only other study to quantify the collision demands of rugby league match play (3), a different scientific approach was taken. First, a microtechnology unit (minimaxX; Catapult Sports) that included GPS and triaxial accelerometers, and also a gyroscope and magnetometer, was used to quantify collisions. Importantly, the ability to accurately quantify collisions was first determined by comparing the microtechnology unit with video-based coding of the actual collisions (3). No significant differences were detected in the number of collisions detected via the minimaxX units and those coded from video recordings of the actual event. A strong correlation ($r = 0.96$, $p < 0.01$) was observed between collisions recorded via the minimaxX units and those coded from video recordings of the event (Figure 2).

These findings demonstrate that the minimaxX microtechnology units offer a valid method of quantifying the contact load of collision sport athletes, specifically the high-intensity collisions that occur in the rugby (league and union) codes. The capacity to automatically monitor the contact load of collision sport athletes clearly demonstrates the practical utility of this unit. The inclusion of the gyroscope and magnetometer to automatically detect collisions seems to be a critical feature that differentiates the minimaxX unit from other commercially available wearable microtechnology units (Table 2).

Table 2. Technology embedded in commercially available microtechnology units.*

Sensors	MinimaxX	GPSports	HIT system
Positioned	On upper back	On upper back	Inside football helmet
GPS	Sampling at 10 Hz	Sampling at 5 Hz	Not present
Accelerometers	Sampling at 100 Hz	Sampling at 100 Hz	Sampling at 1,000 Hz
Gyroscopes	Sampling at 100 Hz	Not present	Not present
Magnetometers	Sampling at 100 Hz	Not present	Not present

*GPS, global positioning system; HIT, Head Impact Telemetry.

The Importance of Scientific Controls

Although scientific controls exist (and are mandatory) in other scientific disciplines (e.g., genetics, agriculture, and aeronautics), it is questionable whether the same level of scientific rigor has been applied when quantifying the contact loads of collision sport athletes. Indeed, at best, the failure to provide evidence of the validity of some of these units to measure contact loads reflects poorly on those that promote and use the technology for scientific measurement. At worst, these units offer an inadequate method of monitoring athletes who deserve and expect world-class sport science support. The HIT System (mounted inside football helmets) has been shown to offer a valid measurement of the head accelerations that typically occur in American football. To date, only one wearable microtechnology unit (minimaxX) can be considered capable of offering a valid method of quantifying the contact loads that typically occur in collision sports. Until such validation research is completed, sport scientists should be circumspect of the ability of other units to perform similar functions.

Summary

Although microtechnology units are reported to quantify the contact loads of collision sports, sport scientists should be cautious of the claims made by manufacturers when no independent data demonstrating the validity of the units are available. If microtechnology units have undergone "internal" validation by manufacturers, then publishing these results in a reputable peer-reviewed scientific journal would lend some support to the validity of these microsensors for quantifying the contact loads of collision sports. Helmet-mounted accelerometers (e.g., the Helmet Impact Telemetry System) offer a valid measurement of the head accelerations that occur in American football. However, to date, only one wearable microtechnology unit (minimaxX) has undergone external validation; this unit has been shown to offer a valid method of quantifying the number and intensity of collisions performed in rugby league. Until other microtechnology units have been similarly validated, the collision loads recorded by these units should be interpreted with caution.

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Update

Following acceptance of this manuscript, a group of researchers (Daniel Kelly, Garrett Coughlan, Brian Green, and Brian Caulfield) developed a method of automatically detecting collisions by using the accelerometer signal obtained from GPSports units. Although the software provided by the manufacturer does not appear to permit valid detection of collisions, the analysis of the accelerometer signal by independent researchers suggests that it may be possible to identify these events by using tackle-detection algorithms. For more information on the development of this technique, the reader is referred to: Kelly, D., Coughlan, G.F., Green, B.S., and Caulfield, B. Automatic detection of collisions in elite level rugby union using a wearable sensing device. *Sports Eng*, 15:81–92, 2012.

Although there are several other commercially available microtechnology units (e.g. the Viper Pod 10 Hz system, STATSports Technologies, UK and VX Log 4 Hz system, VXSport, New Zealand), at the time of manuscript acceptance there were no published studies using these systems to quantify collisions, and as such they were excluded from the literature review.

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