

Technical Note

Running Title: Microtechnology and Collision Sports

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

Tim J. Gabbett

*School of Exercise Science, Australian Catholic University, Brisbane, Australia*

*School of Human Movement Studies, The University of Queensland, Brisbane, Australia*

Address correspondence to:

Dr. Tim J. Gabbett

School of Exercise Science,

Australian Catholic University,

Brisbane, AUSTRALIA 4014

Email: [tim\\_gabbett@yahoo.com.au](mailto:tim_gabbett@yahoo.com.au)

## **ABSTRACT**

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. Due to the labour-intensive nature of coding collisions from video recordings, manufacturers of wearable microsensor (e.g. global position 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, Canberra, Australia) and the actual number of collisions coded from video. However, a separate study investigated the validity of a different microtechnology unit (minimaxX, Catapult Sports, Melbourne, Australia) that included GPS and tri-axial 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 sub-concussive 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. While collisions can be readily quantified by coding events from video recordings, this methodology is extremely time-consuming and labour-intensive, making analysis of large datasets problematic. Consequently, manufacturers of wearable

## Technical Note

microsensor (e.g. global position 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 six 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 centre of gravity (5). 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%.

While 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). Secondly, the microsensors that are employed in rugby league and rugby union are significantly different from those employed in American football

as they also use global positioning system technology to 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).

*Insert Figure 1 About Here.*

McClellan et al (7) used a GPS unit sampling at 5Hz and tri-axial 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).

*Insert Table 1 About Here.*

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. Firstly, no attempt was made to externally validate the units in order to determine its accuracy in quantifying the physical demands of a collision sport. Secondly, 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 this 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. Firstly, a microtechnology unit (minimaxX, Catapult Sports, Melbourne, Australia) that included GPS and tri-axial 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).

*Insert Figure 2 About Here.*

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 appears to be a critical feature that differentiates the minimaxX unit from other commercially available wearable microtechnology units (Table 2).

*Insert Table 2 About Here.*

## **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 rigour 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 Helmet Impact Telemetry (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**

While 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 is 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

## Technical Note

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.

## Acknowledgements

The author has no conflicts of interest related to this study.

## Postscript

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 using the accelerometer signal obtained from GPSports units. While the software provided by the manufacturer does not permit valid detection of collisions, the analysis of the accelerometer signal by independent researchers suggests that it may be possible to identify these events 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.

## References

1. Breedlove, E.L., Robinson, M., Talavage, T.M., Morigaki, K.E., Yoruk, U., O'Keefe, K., King, J., Leverenz, L.J., Gilger, J.W., and Nauman, E.A. Biomechanical correlates of symptomatic and asymptomatic neurophysiological impairment in high school football. *J Biomech*, 45:1265-1272, 2012.
2. Cunniffe, B., Proctor, W., Baker, J.S., and Davies, B. An evaluation of the physiological demands of elite rugby union using global positioning system tracking software. *J Strength Cond Res*, 23:1195-1203, 2009.
3. Gabbett, T., Jenkins, D., and Abernethy, B. Physical collisions and injury during professional rugby league skills training. *J Sci Med Sport*, 13:578-583, 2010.
4. Gabbett, T.J., Jenkins, D.G., and Abernethy, B. Physical collisions and injury in professional rugby league match-play. *J Sci Med Sport*, 14:210-215, 2011.
5. Manoogian, S.J. Analysis of linear head accelerations from collegiate football impacts. *Unpublished Master of Science in Mechanical Engineering Thesis*, Virginia Polytechnic Institute and State University, April 2005.
6. Manoogian, S., McNeely, D., Duma, S., Brolinson, G., and Greenwald, R. Head acceleration is less than 10 percent of helmet acceleration in football impacts. *Biomed Sci Instrument*, 42:383-388, 2006.
7. McLellan, C.P., Lovell, D.I., and Gass, G.C. Biochemical and endocrine responses to impact and collision during elite rugby league match play. *J Strength Cond Res*, 25:1553-1562, 2011.

## Technical Note

8. Rowson, S., Beckwith, J.G., Chu, J.J., Leonard, D.S., Greenwald, R.M., and Duma, S.M. A six degree of freedom head acceleration measurement device for use in football. *J Appl Biomech*, 27:8-14, 2011.

9. Rowson, S., Brolinson, G., Goforth, M., Dietter, D., and Duma, S. Linear and angular head acceleration measurements in collegiate football. *J Biomech Eng*, 131:0610161-0610167, 2009.

**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 travelling 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 travelling 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 travelling 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).*

**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 1000 Hz
Gyroscopes	Sampling at 100 Hz	Not present	Not present
Magnetometers	Sampling at 100 Hz	Not present	Not present

GPS; Global Positioning System. HIT System; Head Impact Telemetry System.

Technical Note

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

A



B



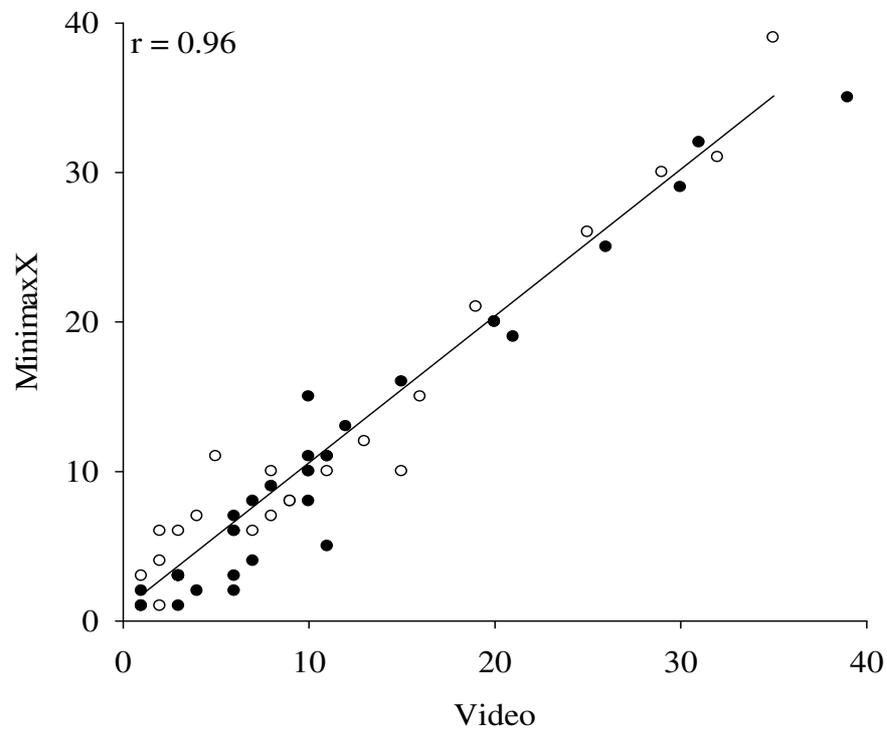
C



D



**Figure 2.** Comparison of MinimaxX and video methods for recording collisions.



*Reproduced from Gabbett et al. (3).*