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The use of GPS and inertial devices for player monitoring in team sports: A review of current and future applications

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Abstract

Player-worn devices, combining global positioning system and inertial monitors, are being used increasingly by professional sports teams. Recent interest focusses on using the data generated to track training-load and whether this may lead to more effective training prescription with better management of injury risk. The aim of this review is to summarize the development and current use of this technology alongside proposed future applications. PubMed and Medline searches (2000-2017) identified all relevant studies involving use in team sports or comparative studies with other accepted methods. Our review determined that the latest devices are valid and reliably track activity levels. This technology is both accurate and more efficient than previous methods. Furthermore, recent research has shown that measurable changes in training-load (the acute-to-chronic load ratio) are related to injury risk. However, results remain very sport specific and generalization must be done with caution. Future uses may include injury-prevention strategies and return-to-play judgement.

Introduction

The use of player-worn monitors, to track training load, has increased over the last decade with the number of publications reflecting further innovation in this technology. In seeking a competitive advantage, professional sports teams are utilizing this technology to maximize training efficiency and limit injuries.[1] The amount of data produced by these devices is large and, thus, the interpretation requires a working knowledge of the principles involved. Increasingly multidisciplinary discussions, regarding player management and training prescription, are being made with reference to this data. The involvement of physicians, alongside dedicated sports science teams, therapists and trainers, requires an appreciation of these monitoring techniques as participants in a multidisciplinary medical team. The aim of this review is to provide a summary of the recent advances in this technology and the ways it is being used by the sports scientists to guide training and player injury management. The evolution of this technology will be discussed alongside research comparing this technology to other methods, reliability and validity assessment of the data produced, the monitoring of training load (and its relationship to injury) and potential areas where this may be used in the future.

Materials and Methods

Dedicated PubMed and Medline searches were performed. Searches were limited to publication between 2000 and 2017 (inclusive), to ensure the evolution of present devices was identified, and English language. "GPS monitors", "Inertial monitors" and "player monitoring" were searched as primary terms alongside combination with "sport", "injury", "injury-prevention", "injury risk" and "training" and "training load". The searches were then repeated with GPS pseudonyms (satellite, global, tracker, positional monitor, microsensor) and inertial monitor components (magnetometer, accelerometer, gyroscope). This initial search yielded 764 studies. Identified titles and abstracts were screened for relevance by each author. Studies were required to discuss either GPS or inertial monitors (or both), focus on team sports, and provide quantitative results relevant to the review topics. 57 studies were identified with this number reduced to 28 studies once duplicate publications were accounted for. Next, those relevant studies were read, in full, by the authors and any missed cross-references added for further consideration. 10 further studies were identified at this stage.

Results were combined into topics (evolution of devices, technology, current use, comparison to other methods, validity and reliability, training prescription, injury risk, efficiency, limitations, future applications) with a summary table for current use generated.

Results

Player monitoring and evolution of devices

Each player's response to training is dependent on variables, such as age and injury history, as well as pre-existing fitness.[2] Monitoring a player's training load can be used to assess levels of fitness and the individual response to the prescribed training. In addition, data from competitive matches can be used to model the requirements of a sport and non-game training that can be prescribed to meet these particular demands.[3] Training can become more sport specific and comparisons can be made between similar sessions to observe trends in performance.[3]

The amount of work performed by an athlete can be described by either external or internal load.[4] The external load refers to the prescribed activity, in terms of variables such as distance covered, average velocity and number of accelerations (within a given period), whereas internal load describes the athlete's physiological response.[4] Traditional ways of monitoring external load have been either time-consuming (such as time-motion video analysis) or inaccurate.[5,6] Internal load has similarly been cal-

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culated using heart rate (HR) monitors or ratings of perceived exertion (RPE) (where exertion level is multiplied by the duration of the exercise).[5,6] However, most of these techniques have required post-exercise analysis (providing little readily accessible real time information) and are subject to variation dependent on age and fitness levels.[5] The first use of global positioning system (GPS) receivers allowed tracking of players, in outdoor areas, where sufficient satellite coverage was available. However, although these monitors were able to provide basic tracking of external load (distance and velocity), their utility was limited when trying to observe rapid changes of direction or speed.[7,8] Some of these devices included a HR monitor to give some indication of internal load. The incorporation of inertial monitors (accelerometers, magnetometers and gyroscopes) has given the opportunity to account for the effect of changes in direction on the athlete, better quantify exertion and, thus, measure internal load (Figure 1).[6] Most systems are worn in a position on the upper back (slightly above the scapulae, close to the player's skin) so that movement is not restricted, injury secondary to impact with the device is limited and the inertial monitor is only recording body movements (Figure 2). Technological advancement has allowed this equipment to be packed into a smaller device (that can be worn without affecting performance) but also systems that can be used indoors. The accompanying computer software enables rapid interpretation and data comparison to produce real time feedback.[9]

GPS and positional monitors

GPS devices detect signals that are continually emitted by 27 satellites in orbit (the US-based GPS system) and at least 4 satellites are required to give an accurate reading.[8] The latest generation of devices can take advantage of additional satellites - the Russian-based GLONASS system - to further increase coverage and decrease dropout. This combined system is known as GNSS (Global Navigation Satellite System). The devices calculate the distance to each satellite with the combination interpreted as a position in terms of longitude, latitude and altitude.[8] Velocity is calculated using the Doppler shift phenomenon – with the frequency of signals received changing in response to movement of the receiver.[8] Prior to recording, devices often need to be placed in open area, to achieve a lock onto satellites but then can be used uninterrupted throughout the session.

The first devices were 1Hz (One measurement every second) or 5 Hz receivers. However, advances now mean that 10 and 15 Hz receivers are more commonly used.[8] Velocity readings are commonly grouped into bands to allow for calculation of time spent at each level. Although variably reported, the commonest bands are as follows (described for rugby): Standing/Walking (0-1.6 m/s), Jogging (1.6-2.7 m/s), Cruising (2.7-3.8 m/s), Striding (3.8-5.0 m/s), Running (5.0-6.1 m/s) and Sprinting (>6.1 m/s).[10] However, these bands may not be appropriate for other sports, both sexes and different age groups. An alternative is to calculate the maximum velocity for each player (and describe bands based on a percentage of this) but this is, obviously, more time-consuming. Stadium based systems have now been developed to allow the use of receivers for indoor sports (or where satellite coverage is deficient).[9] It is claimed that these Local Positioning Systems (LPS) can pinpoint position, within the arena, to within 10 cm.[9] At present, the expense of installation and calibration has limited their use. However, as this technology becomes more widespread, additional information will be known about how these can be used and whether similar metrics to the outdoor GPS systems, can be measured by the sports science teams.[9]

Inertial monitors

Most devices use accelerometers (and some a gyroscope or magnetometers) to measure motion (Figure 1). Triaxial accelerometers use a piezoelectric system to measure the incidence and magnitude of accelerations in 3 different vectors (vertical, horizontal, and lateral). The combination of the accelerometer readings is then combined to give a measure of displacement. The commonest method of doing so is by summing the squares of each reading and dividing the square root of this value by 100. The resultant measure (with arbitrary units) is variably called Player Load™ (PL)

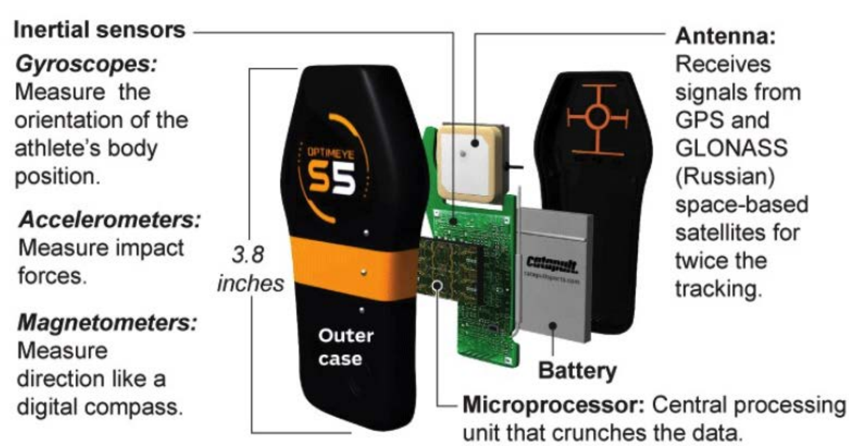

Figure 1. Schematic of Catapult OptimeyeS5 monitor (reproduced with permission).

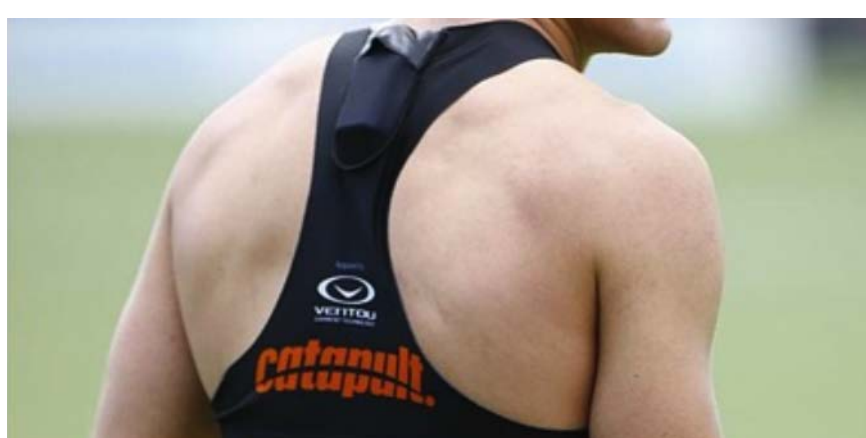

Figure 2. Photograph of Catapult monitor vest allowing the player to wear between shoulder blades (reproduced with permission).

(Catapult Sports) or Body Load™ (GPSports).[5,11-13] These devices can record at 100-120 Hz (as they are not reliant on a satellite connection) and therefore are more sensitive to rapid changes in both direction and velocity.[11] They can also be used indoors or in situations where GPS signal is not available. Computer programs, combined with this technology, can use algorithms to detect a different series of changes in inertial momentum that are a signature of some non-locomotive activities (including collisions, tackles, shots and strokes).[14,15] These can also be used to record both the frequency and magnitude of events within a session.

Summary of current use

The majority of published data is from outdoor team sports including Australian Rules football and rugby league.[4,10,16-24] The detail of how these studies were identified is given in the methods section. A summary of recorded GPS and inertial metrics are displayed in Table 1. Differences can be seen between the mean values seen in different sports. This, alongside differences seen in intensity and activity pattern, highlight the specific demands of the sport and may guide how this can be mirrored in

Table 1. Summary of Studies using GPS and Inertial Monitors.

Author, System	Sport	Parameters Total Distance (m)	Sprint Distance (m)	Average Velocity (m/min)	Maximum Velocity (m/s)	Total Force Load / Player Load™ (AU)	Average Load (AU/min)
Brewer *et al.* (2010) *GPSports SPI-10*	AFL (Per Game)	12311		128	8.09 (29.1 km/h)		
Coutts *et al.* (2010) *GPSports SPI-10*	AFL (Per Game)	12939	3885 (>14.4 km/h)	109	7.92 (28.5 km/h)		
Wisbey *et al*. (2010) *GPSports SPI-10 and SPI-Elite*	AFL (Per Game)	12198		122			
McLellan *et al.* (2011) *GPSports SPI-Pro*	Rugby League (Per Game)	5258	218 (>5.6 m/s)	65.7	8.60		
Gabbett *et al.* (2012) *Catapult MinimaxX*	Rugby League (Per Game)	5709	429 (>5 m/s)	96			
Austin *et al.* (2013) *GPSports SPI-Elite*	Rugby League (Per Game)	6702	281 (>20 km/h)				
White & MacFarlane (2013) *Catapult MinimaxX*	Field Hockey (Per Game)	5824		71.7	7.58		
Casamichana *et al.* (2013) *Catapult MinimaxX*	Soccer (Per Session – Training)	6385	210 (>18 km/h)			789	
Colby *et al.* (2014) *GPSports SPI ProX*	AFL (Per Session – Training)	9184	135			712	
Malone *et al.* (2015) *GPSports SPI Pro X*	Soccer (Per Session – Training)	5667	205 (>5.5 m/s)	81.7			
Jones *et al.* (2015) *Catapult MinimaxX*	Rugby Union (Per Game)	5446	209 (>5.6 m/s)	63.6			
Polglaze *et al.* (2015) *Catapult MinimaxX*	Field Hockey (Per Game)	6095		131		617	13.2
Polley *et al.* (2015) *Catapult MinimaxX*	Lacrosse (Per Game)	4155		88.8		401	8.59
Hendersen *et al.* (2015) *GPSports SPI Elite*	Junior AFL (Per Session – Training)	5587	1288 (>14.4 km/h)	76	7.78 (28 km/h)		
Ehrmann *et al.* (2016) *GPSports SPI Pro*	Soccer (Per Session – Training)	7104	272 (>19.7 km/h)	81.0		158	
Ritchie *et al.* (2016a) *Catapult MinimaxX*	AFL (Per Week – Training)	13457	3764	94.1		1291	
Murray *et al.* (2016) *Catapult Optimeye S5*	AFL (Per Week – Training)	15748	2373 (>18 km/h)			1526	
Windt *et al.* (2017) *GPSports SPI-HDU*	Rugby League (Per Week – Training)	9780	621				
McLaren *et al.* (2016) *Catapult MinimaxX*	Rugby Union (Per Game)	5720	300 (>19.9 km/h)	71.5		550	6.88

training. Most software systems create a dashboard of results. These can be customized to concentrate on the metrics that the sports medicine teams feel are most relevant to their sport. Comparisons can be made with previous sessions and trends viewed over a training cycle. In doing so, improvements may be monitored alongside any drops suggesting the player is struggling or is injured. A traffic light warning system may also be used to quickly highlight changes in an individual's performance and focus on specific players within the team.

Comparison to other methods

Both distance/velocity and PL measurements have been shown to correlate well with previous methods. Castellano *et al*. found acceptable results when comparing distances generated by athletes, completing measured 15m and 30m runs,[30] and Varley *et al.* found accurate instantaneous velocity measurements (versus a tripod-mounted laser).[31] In game-play, strong correlation has been shown across a number of sports with some studies showing a superiority.[8] Montgomery *et al.* found measured accelerations predict the demands in basketball better than either HR and oxygen-demand (PL 2-3 times more accurate than previous methods)[6] and Casamichana *et al.* also found a correlation between PL and both RPE and HR methods (as well as blood lactate levels) in soccer players.[5]

In addition, within studies using this equipment, the measures of external and internal load correlate strongly across multiple sports. Polglaze *et al.* found a strong correlation between PL with total distance recordings in field hockey[12] whilst Sparks *et al*., in university soccer players, found a significant correlation between measured velocity zones and HR zones (particularly at lower speeds).[13] Finally, Casamichana *et al.* found this correlation between PL, distance and HR methods to be large to very large in another study of soccer players [5]

Validity and reliability

Validity refers to the ability of an instrument to accurately measure what it is intended to measure[32] whereas reliability refers to the reproducibly of values of a test over repeated recordings.[33]

GPS devices have been shown to have acceptable validity in field-testing. A review by Scott *et al.* showed 1 and 5 Hz devices measured total distance and longer distance intervals accurately but were less accurate at recording short high-speed sprints or frequent changes in direction.[8] However, in this review, 10 Hz devices were found to be superior to the 1 and 5 Hz monitors for all distances (including these shorter sprints).[8] In further comparative testing, 10 Hz monitors appear to give optimal results with 15 Hz devices, in fact, performing slightly worse.[8,30] When the validity of readings is divided into velocity zones and compared, very high speed activity is still the least accurate, even when newer devices are used.[3,14] However, a 10% error rate, shown in most comparative papers,[33] is probably an acceptable pay off for the convenience conferred by this technology.

Similarly, inertial monitors have been shown to have good validity and reliability in both laboratory and field testing.[11] Noise produced by this recording (the co-efficient of variation) has been shown to be less than smallest worthwhile difference suggesting their use is accurate.[11] The reliability testing of these devices has shown that intra-unit is better than inter-unit reliability.[8] Therefore, it is recommended that, where possible, the same device is used by an individual player each time to allow comparison between sessions without the confounding of different devices.[8]

Training Prescription

The exact prescription of training depends on the individual sport, the frequency of competition and the athlete's fitness level.[15] In many sports, where matches are played once a week, training is low intensity, early in the week, to aid recovery before increasing in intensity (but decreasing in volume) as the week progresses and game day approaches.[15] A high training load may have positive effects (increased fitness – aerobic capacity, strength and sprint repetition) as well as negative effects (fatigue).[4]

In addition, low intensity training may be used to improve technical or tactical skill levels but may result in injury during maximum intensity seen during games. Benefit has been found in attempting to match the demands of the game played (in terms of duration of activity, time in different velocity zones, length of rest periods) to encourage advantageous physiological adaptation.[3] In monitoring this, PL (alongside RPE) has been shown to be more stable (both within and between players) than using total distance, low speed velocity, or high speed velocity time.[3] In group sessions, PL is also found to be more uniform within the group than other measures.[3]

Injury Risk

As described by Banister's model, both the positive (fitness) and negative (fatigue) effects of training have an effect on injury risk.[24] However, these modifiable injury risk factors (including those metrics measured by GPS and inertial monitors) should be viewed in context of non-modifiable factors (including age and injury history).[2]

The importance of fitness, as protection from injury, is highlighted by work by Windt *et al.* looking at pre-season training in rugby league players.[4] In this study, the completion of 10 additional preseason sessions was associated with a 17% reduction in risk of injury and fewer number of games missed during the season.[4] Once fitness is established, high weekly distance (and accumulative distance) has been shown to be protective against injury[4] whereas low chronic workload (fitness) has been shown to be associated with increased risk of injury.[34] Fatigue may be induced by increases in overall training load (most commonly measured as total distance) or increases in intensity (measured in distance per minute or time spent in high-speed zone during session). In a study of Australian Rules football players, Colby *et al*. showed that increases in 3-week accumulative distance (total distance 73-86 km compared with <73 km) led to an increase in injury risk by 5.5 times and rises in 3-week force-load (a cumulative measure of both foot strides and collisions - >5.397 AU compared to <4.561 AU) led to an increase in risk of injury by 2.5 times.[21] Therefore, both the total load and the manner in which this load is applied (running, jumping, collisions) is likely important. Increasing intensity (with a higher percentage of distance performed at high speed) has been shown to lead to increased injury rates in rugby league players.[4] Additionally, in professional soccer, non-contact soft-tissue injuries have been shown to be associated with increased intensity (Measured in m/min) in the preceding weeks.[29] Ehrmann *et al.* found that increases in both the 1-week and 4-week averages of high speed running led to injury despite total distance remaining constant.[29]

The combination of low fitness with high fatigue is a particularly hazardous combination. Hulin *et al*. showed that, in rugby league, non-contact injury risk significantly increased when acute high-speed distance (fatigue) was combined with low chronic high-speed distance (fitness).[34] Therefore, there appears to be a zone of fitness that should not be exceeded (in terms of over-training) for injury prevention but also a need to prescribe sufficient load to adequately prepare players for games.

Gabbett describes this as the training-injury prevention paradox - rapid increases in load increase the risk of injury whereas chronic exposure to higher load strengthens physical capabilities and resilience to injury.[24,35]

Recent research suggests that it is the relationship between acute load (calculated over 1 week) and chronic load (calculated as a rolling total over 4 weeks – averaged to

1 week) that is an important predictor of injury.[2,24,34-37] Sudden increases (spikes) in load are particularly detrimental.[37] In a study of Australian Rules football players, increases greater than 10% in total distance above 12 km/h explained 40% of injury in next 7 days.[37] A similar finding was found in a study of rugby league, by Hulin *et al.,* associated with very high spikes in total distance.[34]

A ratio can be calculated by dividing acute by chronic load in this way, the A:C ratio.[2,34,35,38] In a study of cricket fast-bowlers, doubling the A:C ratio led to three-fold increase in injury risk.[38] Similarly, in rugby league players, contact injury risk increased when A:C ratios, for total distance and acceleration, were high.[2] In general terms, slow increases in acute load relative to chronic load, are preferable and protective against injury. Gabbett describes a "sweet-spot" (A:C ratio 0.8-1.3), where injury risk is lowest, with increases in risk either side of this zone (Figure 3).[35]

The weeks immediately after a spike are most vulnerable (whilst the athlete is in this fatigued state).[24,35] Murray *et al.* showed, whilst studying non-contact injuries in Australian Rules football, an A:C ratio greater than 2.0 (for total distance) led to 8 times risk in the current week (5 times in subsequent week) and an A:C ratio above 2.0 (for high speed distance) led to an 11 times risk of injury in the current week (5 times for subsequent week).[24] Hulin *et al.* found similar results in rugby league.[34] This group found that an overall A:C ratio over 2.11 increased injury by 16.7%, in the current week, and by 11.8% in the subsequent week.[34] In this study, the greatest risk of injury was associated with a very high 2-week A:C ratio (≥1.54).[34] However, it is not just the A:C ratio per se that is important as the chronic load seems to affect the A:C ratio tolerated. In their study of rugby league players, Hulin *et al.* compared A:C ratio to chronic load.[34] A very high A:C ratio was bad in all groups and high chronic load combined with moderate A:C ratio (1.02-1.18) gave a smaller risk of injury than the low chronic load group.[34] However, in high chronic load groups, increases in A:C ratio above 1.5 lead to increased injury risk whilst the threshold in low chronic load groups was a ratio of 2.0.[34] Therefore, although high chronic load is seen to be protective, relative increases in load are less well tolerated. Much of the with personal monitors is based on external load but correlations suggest that the same may be true of internal load (PL). This has been shown using previous internal load measurements such as RPE and HR.[35] It is, therefore, likely that a combination of internal and external load measures is useful in injury prevention.[23] Finally, Gabbett contests that, if training load is important, it should be accurately measured (up to twice daily) and over weeks / months (a season) to give an accurate assessment of trends and quantify injury risk appropriately.[35]

Efficiency

The relationship of external and internal load can be used to give some indication of mechanical efficiency. Increases in efficiency may be represented by a decrease in internal load in association with maintained external load (performance) – it becomes easier for athlete to perform task. Similarly, a decrease in external load or increase in internal load may be suggestive of increased effort. This may indicate low-level injury or fatigue requiring a modification of training.

Limitations of this technology

Current limitations to this technology include a lack of monitoring during competitive games, the relative inability to monitor static exertion, the transfer of current results between sports, and the potential conflict with other coaching methods. At present, many professional sports do not allow in-game monitoring - limiting use to practice sessions. Despite careful design of practice sessions, competitive play has been shown to differ considerably from training.[22] Henderson *et al*. showed, in a study of junior Australian Rules footballers, that many measurements (distance, mean HR, time above 80% HR and RPE) were lower in training.[22] In-game sprints were also found to be shorter in duration and distance.[22] Furthermore, it has been shown that most injuries occur within competitive games when the athletes may be exceeding training levels.[22] Thus, it would seem desirable to include competitive matches within the monitoring of a player's load. The main reasons for preventing monitoring in games appears to be players' skepticism about how the data will be used and contractual issues between teams. Where competitive monitoring is used, full game analysis has been shown to differ from time-on-pitch analysis.[12,22] In sports with multiple interchanges or substitutions, the total distance and peak velocity may be the same but the percentage time spent at low speed increases (and all other zones decreases) if time off the field of play is not accurately accounted for.[12,25] This should be considered when analyzing this data and prescribing training in these sports.

GPS systems have been developed (and are currently mostly used) in field sports with low levels of contact. The devices are good to monitor running but less accurate for other activities. In a study of field hockey, Polglaze *et al.* showed good correlation with distances covered but less correlation with low stance and evasive movements observed throughout the game.[12] This may be an area where inertial monitors are superior. Sports with high levels of static exertion (scrum in rugby, competing on the boards in ice hockey, batting sports) are not as well detected by either monitoring system, despite these events causing player fatigue. Quantifying these efforts remains a challenge. Furthermore, other locomotive methods seen in sports (including gliding in ice hockey or cycling) involve a much smaller vertical vector. Therefore, the PL,

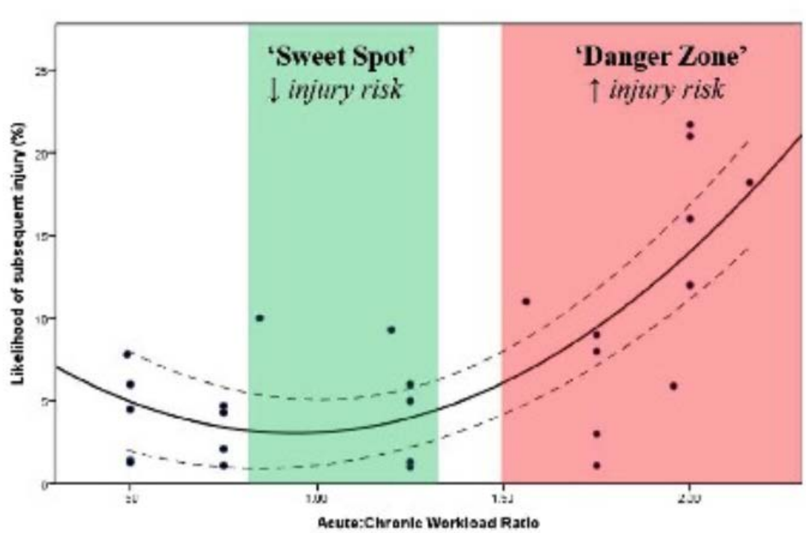

Figure 3. Graph showing the relationship between injury risk and acute:chronic (A:C) training load (Reproduced from Gabbett *et al.*, 2016).[35]

measured by the triaxial accelerometers, is considerably less. This limits comparative data, to other sports, although it remains to be shown whether relationships (including those to injury risk) are similar. The transfer of data, from outdoor team sports (using external load measures), to different sports may not be straightforward. Table 1 shows large differences, between sports played in similar environments, in the metrics measured and it may be that different parameters prove most valuable to each sport. The sport-specific application of this technology requires appreciation of the demands of each sport and limits generalizability.

The greatest problem is the transition of this theoretical research into daily practice. A study by Akenhead *et al.* showed that a lack of buy-in, from both coaches and management, was the biggest barrier to using this equipment.[1] In this study, only 37% of head coaches rated this technology as effective (on a numerical scale) and, thus, were keen to use this system.[1] Therefore, use must be carefully planned in such a way as to support coaching decisions (rather than impose restrictions on players) wherever possible. Effective communication is needed to help the whole team understand the data generated and look for the most acceptable ways to use this. It should be noted that the same study found that the actual effectiveness of training load monitoring was lower than expected for injury prevention, individual player performance enhancement and team performance enhancement.[1] Therefore, any proposed implementation should be performed in a judicious way with monitoring of the effects of its use and modification as further information becomes available.

Future areas of interest

The use of these monitors may include injury prevention and judging return to play following injury. It would be beneficial to identify fatigued players, prior to injury occurring, and potentially prevent injury (or limit severity). Measuring and limiting training load may play a role, but there may also be scope in developing algorithms that identify when a players' performance (or efficiency) begins to drop below normal levels or there is a change in the way players are working. Data from a study by Ehrmann *et al.* showed a decrease in the recorded PL in the weeks preceding injury.[29] The authors suggest this may be due to an inability to reach the same level of performance or cruising through the session.[29] Other methods to detect these changes may include efficiency calculations (including external and internal load measurements) or side-to-side comparisons demonstrating a change in limb preference. At present many protocols may be in place to guide a player's return following a given injury. However, much of this is time-based and prescribed in an arbitrary way without any way to judge relative fitness. Using these monitors, to measure internal and external training load, would allow the trainers to compare performance to pre-injury levels and judge the return to the same training load and efficiency. Blanch and Gabbett have already suggested that the A:C ratio could be used for such decisions[36] but also caution that the data used to assess this would need to be injury and sport specific. It may not be necessary to return to 100% of pre-injury levels but achieving a particular percentage of this may be protective against re-injury. In addition, it is likely that other factors – such as strength and previous injury – will interact with A:C ratio measurements in terms of injury risk. Therefore, it is likely that, rather than relying solely on this data, combination with existing injury prevention programs (such as FIFA 11+ in football) and other return-to-sport functional assessments will be most successful. Further research is required to define these limits and goals however.

Conclusions

GPS and inertial monitor technology provide an effective and efficient method to measure both internal and external training load. These devices have been shown to be both valid and reliable and compare favorably to previous methods.

The A:C ratio of training load has been shown to be associated with the risk of injury. Therefore, monitoring load (using this ratio) may be a successful way to prevent both contact and non-contact injuries. Ideally this monitoring would include load accumulated in both training and competitive matches although current restrictions prevent this in some sports.

This technology also potentially provides a way of identifying fatigued players and adapting training to prevent injury. Return to play, following injury, may also be guided by the data generated by these devices and comparison to previous performance. Further development is likely to make this technology more accessible and the metrics more sport-specific. However, the information that this provides must be interpreted in the context of non-modifiable variables such as age and previous injury history. Rather than replacing the coach's control of player management, it is likely that this technology will form part of a multifactorial decision-making process. An awareness of how this technology is currently being used is key to the medical team and coaches so they can partake in discussions around the data produced. Increasingly, decisions may be based on this data and understanding the strengths, limitations and potential further uses is vital to ensure this is adopted in an appropriate way. Further research will guide the way to more sport-specific understanding and may broaden its use to amateur groups and other healthcare opportunities.

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