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Research article

Tackle Technique and Changes in Playerload™ During a Simulated Tackle: An Exploratory Study

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Abstract

In collision sports, the tackle has the highest injury incidence, and is key to a successful performance. Although the contact load of players has been measured using microtechnology, this has not been related to tackle technique. The aim of this study was to explore how *PlayerLoad™* changes between different levels of tackling technique during a simulated tackle. Nineteen rugby union players performed twelve tackles on a tackle contact simulator (n = 228 tackles). Each tackle was recorded with a video-camera and each player wore a Catapult OptimEyeS5. Tackles were analysed using tackler proficiency criteria and split into three categories: Low scoring(≤5 Arbitrary units (AU), medium scoring(6 and 7AU) and high scoring tackles(≥8AU). High scoring tackles recorded a higher *PlayerLoad™* at tackle completion. The *PlayerLoad™* trace was also less variable in the high scoring tackles. The variability in the *PlayerLoad™* trace may be a consequence of players not shortening their steps before contact. This reduced their ability to control their movement during the contact and post-contact phase of the tackle and increased the variability. Using the *PlayerLoad™* trace in conjunction with subjective technique assessments offers coaches and practitioners insight into the physical-technical relationship of each tackle to optimise tackle skill training and match preparation.

Key words: Rugby, microtechnology, collisions, training, injury prevention.

Introduction

The tackle is a highly physical and technical contest where opposing players compete for territory and ball possession (Davidow et al., 2020; Burger et al., 2020; Hendricks et al., 2016; Hendricks and Lambert, 2010). It is a common event in all major tackle-based collision sports, such as American football, rugby union, rugby sevens and rugby league (Hendricks and Lambert, 2010). Within each of these collision sports, it is also the most frequently occurring contact event. In rugby union for example, an average of 221 tackles occur during a match (Fuller et al., 2007; Paul et al., 2022), with each player involved in approximately 10-15 tackles per match (Burger et al., 2020). In all tackle-based collisions sports, team success is associated with the ability of the ball-carrier or tackler to repeatedly win the tackle contest (Gabbett, 2016; Ortega et al., 2009). This is also a key performance indicator for individual players (Hendricks et al., 2014). However, the tackle has the highest injury incidence compared to other events in the game, may cause the greatest number of days lost (severity), and carries a high injury burden (injury incidence rate × mean days absent per injury) (Brooks et al., 2005; Schwellnus et al., 2014; Roberts et al., 2014; Fuller, 2018). For example, in under nineteen rugby sevens, the tackle event causes an average of 37.2 (24.3 - 50.0) days absent, with tackling injury incidence of 40.1 injuries per 1000 playing hours (21.6-58.6) (Lopez et al., 2020).

In 2014, based on the available research at the time, Hendricks and Lambert modelled the relationship between tackle load (acute and chronic), tackle injury risk and tackle performance (Hendricks and Lambert, 2014). The model suggests that well-conditioned players with high technical ability can tolerate the high physical load of repeated tackle contact, without negatively impacting their tackle injury risk and performance (Hendricks and Lambert, 2014). Since then, studies in rugby union and rugby league have emerged to support this model (Gabbett et al., 2011; Davidow et al., 2020; Tierney et al., 2018). In rugby league for instance, players involved in the most tackle contests have the lowest contact injury incidence (Gabbett et al., 2011). Several studies have also highlighted the important role of proper contact technique in reducing the risk of injury and optimising performance (Burger et al., 2016; Hendricks and Lambert, 2010; Hendricks et al., 2014).

Monitoring players for variables associated with injury risk and optimal performance is important for player wellbeing (Quarrie et al., 2016; Soligard et al., 2016). Many of these variables can be measured using micro-electrical mechanical systems (MEMs). Catapult Sports, OptimEye S5 (Catapult Innovations, Melbourne, Australia) is an example of a wearable MEMs unit designed for monitoring in sport (Cummins *et al.*, 2013). MEMs provide scientists and practitioners with accelerometer-derived load measures such as *PlayerLoad*™ (Catapult Sports)(Malone et al., 2017). *PlayerLoad™* is calculated as a modified vector magnitude, expressed 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 - and divided by 100 (Boyd et al., 2011; Bredt et al., 2020; Hulin et al., 2017; Nicolella et al., 2018). Although several studies

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recommend *PlayerLoad^{TM}*, or similar load variables, as a potential tool to monitor collision load in training and matches (MacLeod et al., 2018; Roe et al., 2016; Tierney et al., 2020), *PlayerLoad^{TM}* is still largely used to describe non-contact demands (Whitehead et al. 2018). Also, for collision monitoring, *PlayerLoad^{TM}* is summarised into distinct categories (for example >2 arbitrary units) to detect collision counts (Hulin et al., 2017, Gastin et al., 2014). While this method has shown a strong correlation to observed collision counts using video, collision events (tackle, scrum, ruck, maul) have been grouped together. In other words, the load of the tackle specifically cannot be differentiated. Because collision events have been grouped together, and analysed for counts only, how *PlayerLoad^{TM}* changes in relation tackle specific factors such as technique, tackle type and shoulder dominance are not understood. In 2020, Burger et al. highlighted the importance of studying the tackle in controlled-lab based settings to gain a deeper insight into the demands and movement patterns of the tackle (Burger et al. 2020). The authors note that for experimental and explorative research, the benefits of studying the tackle in controlled-laboratory- based settings may outweigh its limitations, provided the setting is representative and the findings can be translated into training and matches (Burger et al. 2020). With this mind, Burger et al., (2019) developed and validated a tackle contact simulator where a ≈38kg 'tackle dummy' is propelled at match comparable speeds towards a player. This tackle contact simulation resembles the physical and technical demands of one-on-one tackling without the added risk of injury experienced during live bodily tackles (Burger et al., 2019), making it useful for explorative tackle research.

Quantifying the demands of the tackle using *PlayerLoad^{TM}* has the potential to provide information for researchers and coaches to determine whether players are 'collision fit' (Paul et al., 2022). This will have application for training and indirectly potentially contribute to enhancing performance and reducing the risk of injury. Since this variable is commonly used amongst coaching staff, investigating how *PlayerLoad^{TM}* changes between different levels of tackling technique will help coaches monitor tackle contact load. Therefore, the aim of this study was to explore how *PlayerLoad^{TM}* changes between different levels of tackling technique during a simulated tackle.

Methods

Nineteen (n = 19) male amateur rugby union players participated in this study (age: 21.4 ± 2.6 years, body mass: 83.3 ± 9.5kg, height: 1.73 ± 0.06 m, experience 12.5 ± 5.6 years). All players were senior community club level rugby players from the top competitive amateur league within the region. Each participant performed twelve tackles on the tackle contact simulator over two testing sessions (six tackles per session). This amounted to total of 228 tackles. Each player performed three tackles on their dominant shoulder and three tackles on their non-dominant shoulder per a session. Each participant provided informed consent before testing. All tackle data on the tackle contact simulator is stored in a registered database (HREC REF R027/2019). Ethical approval for this specific study was granted by the University of Cape Town Human Research Ethics Committee (HREC REF 803/2019).

Tackle contact simulator

Each participant performed a tackle on the tackle contact simulator (Burger et al., 2019). A previous study using the tackle contact simulator showed that the simulator is comparable to real-life one-on-one tackle drills and tackle contact (Burger et al., 2019). In brief, the tackle contact simulator comprises of two A-frames spanned by three horizontal beams attached to a pneumatic system to drive a detachable 'tackle dummy'. The 'tackle dummy' has a mass of 37.8 kg and comprises of three separate metal shells (upper body, torso and lower limb) enclosed by three layers of foam and rubber. The design allows for flexion and extension. A lever is secured to the central horizontal beam via a movable trolley (trolley 'A'). This trolley is situated adjacent to a second 'floating' trolley (trolley 'B') that has a hook for the attachment of a detachable 'tackle dummy'. Trolley 'B' and the dummy are propelled forward by the lever arm and trolley 'B' of the pneumatic system along the central horizontal beam. The desired velocity is determined via the force of pressure exerted by the compressor that drives the pneumatic system. For testing, the 'tackle dummy' moves at approximately 2.12 ± 0.09 metres per second towards the tackler before a tackle is performed, which is comparable to speed in real matches (Hendricks et al., 2012).

Tackle proficiency criteria

Each tackle was recorded with a video camera (EOS 200D, Canon, South Africa) positioned three meters away and parallel to the midpoint of the tackle contact simulator. The tackle proficiency was assessed by one researcher using the standardized tackling technique criteria that were adapted from Burger et al., (2019). The assessor was an experienced movement therapist with 7 years of experience in using the standardised technical criteria to score the tackle. The technique criteria consists of a list of observable actions that represents the model form of movement and are used to coach techniques for tackling into contact (Davidow et al., 2020). The player is either awarded one point if the action is performed correctly or zero points for an incorrect action. The scoring of player technical proficiency was tested for intra-rater and inter-rater reliability. To test reliability, 30 tackles were randomly selected using an online random number generator (http://www.random.org/) and scored on two separate occasions (intra) separated by at least 1 week, and by two separate assessors (inter). The two-way random-effects interclass correlation coefficient (ICC) and the typical error of measurement (TEM) were used to determine intra-rater reliability. For intra-rater reliability, ICC = 0.93 and TEM = 0.53 and for inter-rater reliability, ICC = 0.85 and TEM = 0.71. A total score is calculated for the complete tackle and for each of the three tackle phases - (1) pre-contact phase, (2) contact phase, and (3) post-contact phase (Hendricks et al., 2010; 2014; 2020). The maximum technical proficiency score on the contact simulator is 11 arbitrary units (AU) (Davidow et al., 2020). The total technical proficiency score and percentage are provided for each category. Total percentage is the sum of the tackling proficiency criteria divided by the total criteria number (11 AU) multiplied by 100.

Microtechnology

The *PlayerLoad*^{TM} for each tackle was captured using the Catapult OptimEye S5 (Firmware version: 7.42.) (OptimEye S5, Catapult Innovations, Melbourne, Australia). Participants wore the device as they would in a match i.e., on their upper back, between the scapulae and secured by a vest. Catapult OptimEye S5, is a 10 Hz GPS unit and includes an inbuilt accelerometer, gyroscope and magnetometer of 100 Hz. The *PlayerLoad*^{TM} data were retrieved from OpenField software 1.22.0 (OpenField Cloud – Catapult Wearables, 2019).

Data analysis

Following the download of the Comma separated value (CSV) files for each player from OpenField, each tackle was individually analysed. The *PlayerLoad*^{TM} data were analysed alongside the video to determine *PlayerLoad*^{TM} trace for each phase of the tackle: (1) pre-contact, (2) contact, (3) post contact and (4) tackle completion (Figure 1) (Hendricks et al., 2010; 2014; 2020). This helped reduce the error rate of the analysis. Using a similar tackle ability grouping approach to Speranza et al. (Speranza ***et al.***, 2015; 2016; 2017a; 2017b), the player's technical proficiency scores were divided into tertiles: Low scoring tackles (≤ 5 AU, n = 26), medium scoring tackles (6 and 7 AU, n = 93) and high scoring tackles (≥8 AU, n = 109). Tackles were also divided into dominant and non-dominant shoulder tackles.

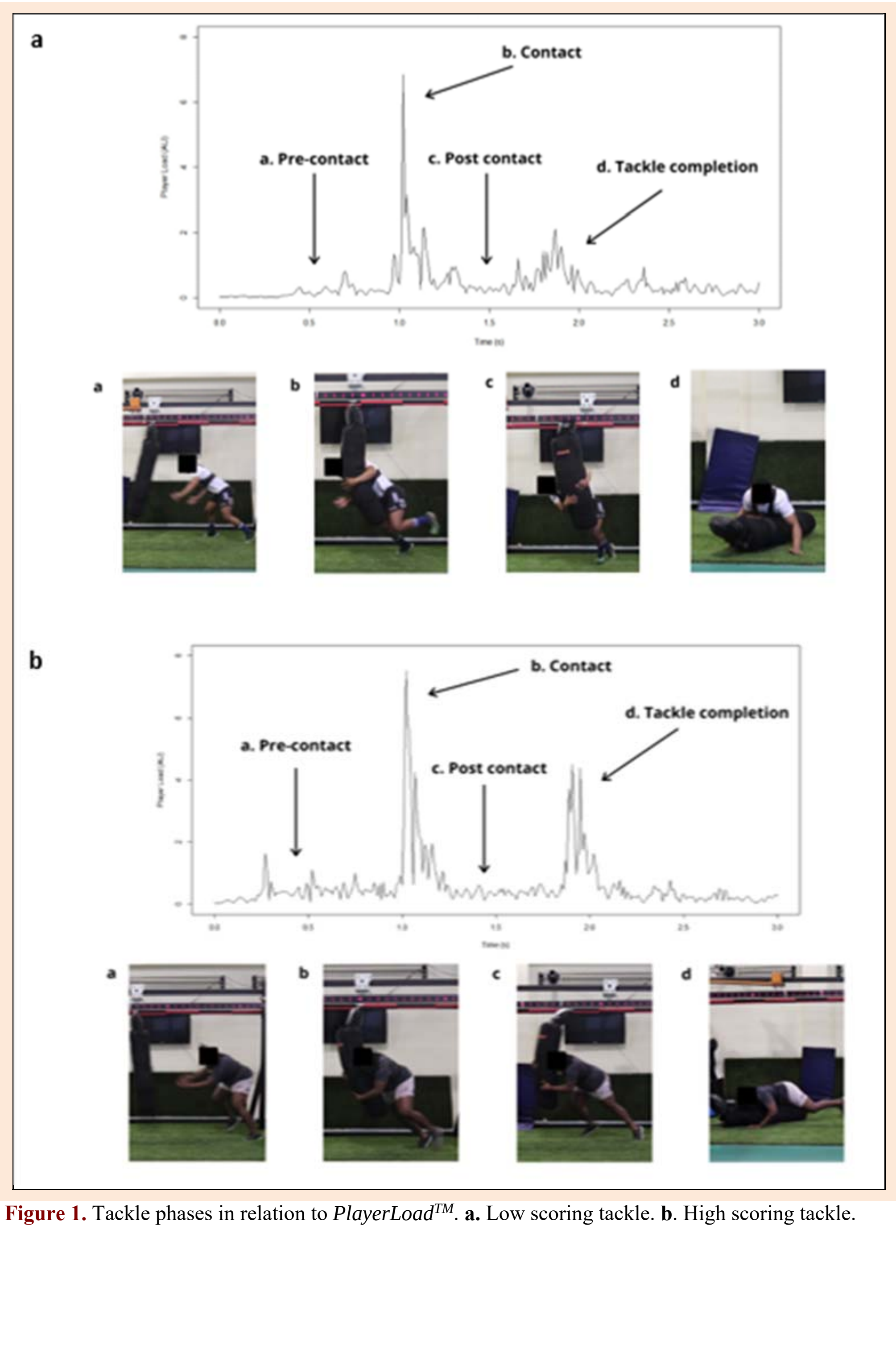

Figure 1. Tackle phases in relation to *PlayerLoad*^{TM}. **a.** Low scoring tackle. **b**. High scoring tackle.

For the tackle proficiency scores, mean, 95% confidence intervals (95%Cl) and standard deviation (SD) were reported for each technique by technical scoring category. For *PlayerLoad™*, mean, 95%Cl and SD are reported for the highest peak of the trace, the second highest peak of the trace and the time difference between the two peaks by shoulder dominance and for each technical scoring category. Differences between shoulder dominance and technical scoring categories were considered meaningful if there was no overlapping of 95%CI (Schenker and Gentleman, 2001; Sainani, 2011). We accept the limitations of this method of examining 95%Cl overlap (i.e., rejects the null hypothesis less often than the standard method when the null hypothesis is true, and fails to reject the null hypothesis more frequently than does the standard method when the null hypothesis is false), but are satisfied with level of accuracy for this study. Coefficient of variation (CV) was also calculated for of the pre-contact period (0.50 - 0.99s), contact period (1.00 - 1.24s), post contact period (1.25 - 1.74s) and tackle completion period (1.75 - 2.25s). All statistics and graphs were produced in R statistical program (R Core Team, 2013).

Results

Technical Score Categories

There were no differences in *PlayerLoad™* between the technical scoring categories at point of contact and the time difference between the two peaks (Table 1). The *PlayerLoad™* for high scoring tackles' at tackle completion was significantly higher than low and medium scoring tackles (Table 1). Supplementary Table 1 shows the total technical proficiency scores for each technique and the overall score for each technical scoring category. Graphically, the *PlayerLoad™* trace for the high scoring tackles was more consistent than the low scoring tackles (Figure 2). This was supported by high scoring tackles demonstrating a lower CV% for the pre-contact phase (lower scoring: 33.3% vs higher scoring tackles: 14.2%) and complete tackle (lower scoring: 130.8% vs high scoring tackles: 107.7%) than lower scoring tackles (Table 2).

Shoulder dominance

There was no significant difference in *PlayerLoad™* between the dominant and non-dominant shoulder tackles at point of contact and the time difference between the two peaks (Table 1). Also, there were no differences in *PlayerLoad™* in the dominant and non-dominant shoulder tackles between categories (Supplementary Table 2). The dominant shoulder tackle trace was more consistent in comparison to the non-dominant shoulder tackle trace (Supplementary Figure 1), (Table 2). Non-dominant shoulder tackles have a significantly lower score than the dominant shoulder tackles (7.1 (95%Cl 6.8 - 7.3; 1.4) AU and 7.9 (95%Cl 7.4 - 8.0; 1.4) AU, respectively). Supplementary Figure 2 shows the dominant and non-dominant shoulder tackles for each category.

Table 1. Mean PlayerLoad™, 95% confidence intervals (95%Cl) and standard deviation (SD) at point of contact, time difference between peaks and point of tackle completion by shoulder dominance and technical scoring category. Data reported at Arbitrary Units.

	Point of contact (AU)			Time difference between peaks (s)			Point of tackle completion (AU)		
	Mean	95%Cl	SD	Mean	95%Cl	SD	Mean	95%Cl	SD
				Categories					
Low scoring tackles (n = 26)	5.4	4.3 - 6.5	±2.8	0.9	0.8 - 0.9	±0.2	2.9	2.0 - 3.9	±2.2
Medium scoring tackles (n = 93)	5.9	5.5 - 6.3	±1.9	0.9	0.8 - 0.9	±0.1	4.2	3.7 - 4.7	±2.4
High scoring tackles (n = 109)	5.9	5.5 - 6.2	±1.8	0.9	0.8 - 0.9	±0.1	5.6 *	5.1 - 6.1	±2.6
				Dominant and non-dominant shoulder tackles					
Dominant shoulder tackles (n = 114)	6.2	5.8 - 6.5	±1.8	0.9	0.8 - 0.9	±0.2	5.1	4.6 - 5.6	±2.6
Non-dominant shoulder tackles (n = 114)	5.5	5.1 – 5.9	±2.0	0.9	0.8 - 0.9	±0.2	4.4	3.8 – 4.9	±2.6

*Significantly higher than low and medium scoring tackles.

Table 2. Coefficient of variation (CV%) for the pre-contact, contact, post contact and tackle completion phases of the tackle by shoulder dominance and for each technical scoring category.

	Pre-contact phase (%)	Contact (%)	Post contact phase (%)	Tackle completion (%)	Total (%)
		Categories			
Low scoring tackles	33.3	69.6	22.1	27.1	130.8
Medium scoring tackles	22.7	69.2	14.7	38.6	117.1
High scoring tackles	14.2	66.6	23.2	38.1	107.7
		Dominant and non-dominant shoulder tackles			
Dominant shoulder tackles	15.3	69.7	22.6	34.3	116.7
Non-dominant shoulder tackles	21.4	66.2	16.5	32.2	108.5
		Dominant and non-dominant shoulder tackles for each category			
		Low scoring tackles			
Dominant shoulder tackles	43.8	81.4	28.4	48.00	163.1
Non-dominant shoulder tackles	31.1	66.3	24.4	30.1	117.8
		Medium scoring tackles			
Dominant shoulder tackles	21.7	72.6	21.1	52.2	126.8
Non-dominant shoulder tackles	25.5	67.6	15.4	34.2	112.1
		High scoring tackles			
Dominant shoulder tackles	13.6	67.8	25.9	40.9	110.8
Non-dominant shoulder tackles	20.2	66.1	22.4	38.0	104.7

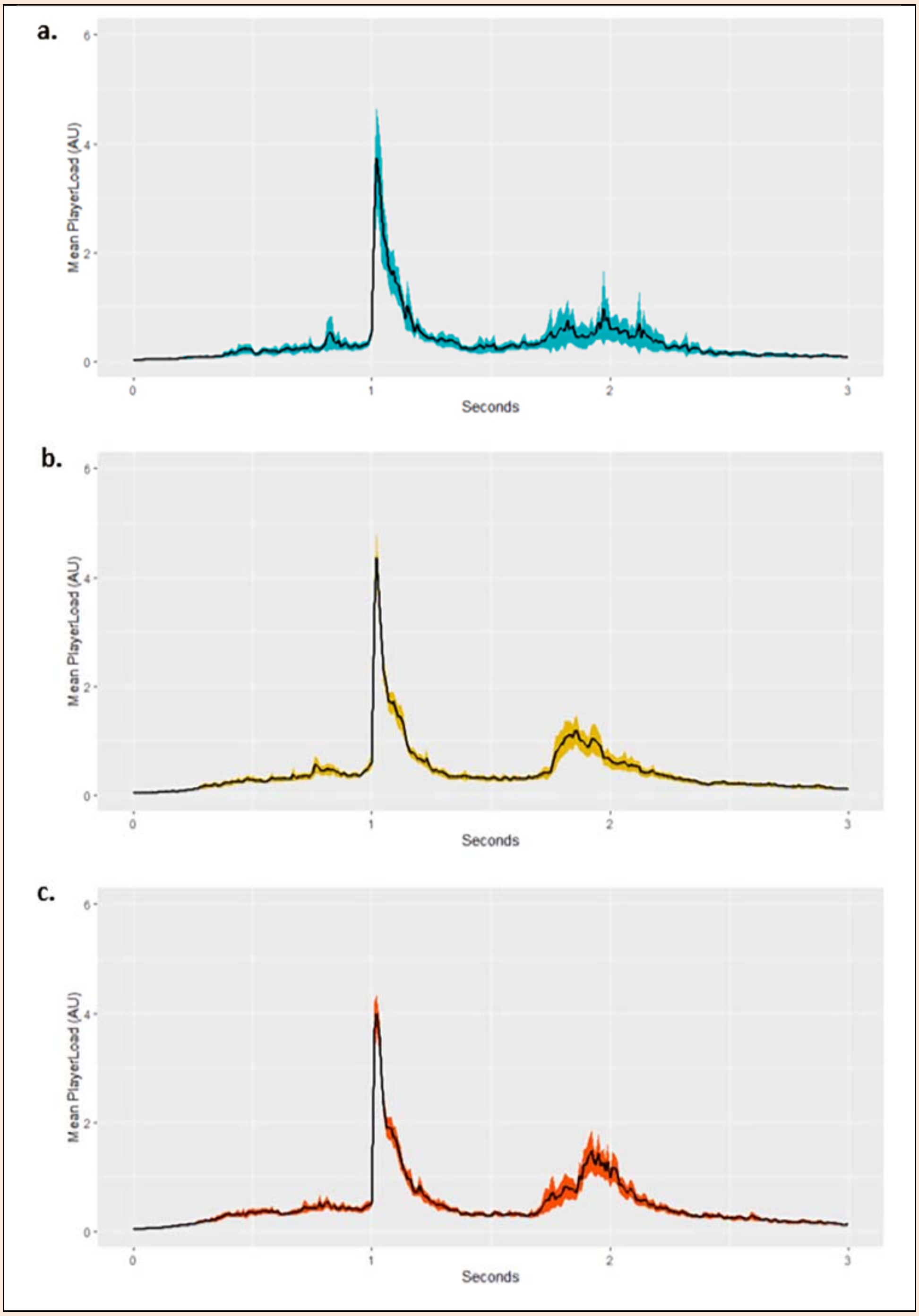

Figure 2. Mean PlayerLoad^{TM} and 95% confidence intervals of the 3 categories of tackles. a. Low scoring tackles (tackles scoring ≤ 5). b. Medium scoring tackles (tackles scoring 6 and 7). c. High scoring tackles (tackles scoring ≥8).

Discussion

This is the first study to explore the *PlayerLoad^{TM}* trace during a simulated tackle and how it changes between different levels of tackling technique. *PlayerLoad^{TM}* did not significantly differ between technical score categories at the point of contact. However, during the tackle completion phase, tackles within the high technical scoring category recorded a higher *PlayerLoad^{TM}* than low and medium technical scoring tackles. The *PlayerLoad*^{TM} trace of tackles within the high technical scoring category were also more consistent throughout the tackle. There were no differences between non-dominant and dominant shoulder tackles, both within and between technical scoring categories. To date, six studies have investigated *PlayerLoad^{TM}*, or similar load variables, as a summary of tackles or collision demands, both during training (Hulin et al., 2018) and matches (Gastin et al., 2014; MacLeod et al., 2018; Hulin et al., 2017; Roe et al., 2016; Tierney et al., 2020). Four of these studies have shown a near perfect correlation between collision load (MacLeod et al., 2018; Tierney et al., 2020) or PlayerLoad (Roe et al., 2016; Hulin et al., 2017) and the observed tackle count. Based on this near perfect correlation, the use of microtechnology load metrics such as *PlayerLoad^{TM}* has been recommended for the monitoring of training and match tackle demands (MacLeod et al., 2018; Roe et al., 2016; Tierney et al., 2020). Tackling however, is a movement skill, and while knowing the tackle count is useful, the present study provides the necessary next step by relating the physical demands of tackling to its technique. Arguably, knowing the physical-technical relationship of each tackle will allow coaches and practitioners in all tackle-collision based sports to optimise their tackle skill training and match preparation.

The consistency of the *PlayerLoad^{TM}* trace throughout the tackle seems to be an indicator of the player's technical proficiency. The *PlayerLoad^{TM}* trace of tackles within the low technical scoring category were highly variable compared to the high scoring tackles. The difference in *PlayerLoad^{TM}* variability between tackling technique categories suggests that *PlayerLoad^{TM}* variability may be an indicator for the construct validity of the metric when analysing tackling technique. This variability was most prominent in the preparation phase of the low technical scoring tackles, where players did not perform the techniques to adequately prepare for the ensuing contact. Specifically, players were not shortening their steps before contact. This pre-contact technique allows players to reduce their speed, which allows them to control their actions in the subsequent contact and post contact phases (Hendricks and Lambert, 2010; Burger et al., 2016; Tierney et al., 2018). Also, studies that have analysed tackling technique in matches have shown that players who shorten their steps before contact have a reduced risk of injury (Burger et al., 2016; Davidow et al., 2018; Hendricks et al., 2015; Tierney et al., 2018; 2016) and a higher likelihood to win the tackle (Tierney et al., 2016). Plausibly, the consistency of the *PlayerLoad^{TM}* trace within the high technical scoring category may also be an indicator of the player's movement efficiency. That is, players with good tackling technique maintain a low variability in the physical load of each tackle, which helps conserve energy to manage the physical demand of repeated tackling during a match (Burger et al. 2020). Further work in matches is however required to support or refute this hypothesis.

Previous studies have shown that tackling technique and tackling impact forces differ between the dominant and non-dominant shoulder (Davidow et al., 2020; Usman et al., 2011; Seminati et al., 2017; Morgan and Herrington, 2013). During non-dominant shoulder tackles, players are more susceptible to technique decrements due to fatigue (Davidow et al., 2020; Seminati et al., 2017), produce less impact force (Seminati et al., 2017), have poorer shoulder positional sense (Morgan and Herrington, 2013), adopt a more passive biomechanical strategy (Seminati et al., 2017) and have less control of their head movements (Seminati et al., 2017). In the current study however, there were no notable differences in *PlayerLoad^{TM}* between the dominant and non-dominant shoulder. The similarity in *PlayerLoad^{TM}* between the dominant and non-dominant shoulder may be explained by the positioning of the device on the player's back between the scapulae. While this position is commonly used in matches and training, and has shown encouraging validity in terms of measuring the external global tackle contact intensity (Nedergaard et al., 2017; Wundersitz et al., 2015), its placement does not seem to allow it to differentiate between dominant and non-dominant shoulders. Practitioners should be cognisant of this when monitoring tackle contact load during training and matches.

The importance of proper tackling technique for reducing injury risk and optimising performance is well recognised (Burger et al., 2016; Hendricks and Lambert, 2010; Hendricks et al., 2014; 2018). Building a player's physical-technical capacity to resist technical fatigue and maintain proper technique throughout a match and season has also been highlighted before (Davidow et al., 2020; Hendricks et al., 2018; Hendricks and Lambert, 2014). With these tackle training objectives as the foundation, Hendricks et al. (2018) described a tackle contact skill framework and training plan based on skill acquisition and skill development literature (Hendricks et al., 2018). For the tackle skill framework, Hendricks et al. (2018) also provided internal and external load measurements that can be used to monitor and progress the tackle training plan to ensure optimum learning and transfer to matches. The external load measuremments however, were only focused on the frequency of tackle contacts and the duration of sesssion. This demonstrates that the *PlayerLoad^{TM}* trace (or a similar contact load metric) can also potentially be used as an additional external load measurement to monitor technical-skill progress as part of a tackle training plan or return to contact programme.

For this study, all tackles were performed on a tackle contact simulator which replicates the physical and technical demands of a one-one tackle in a controlled setting (Burger *et al.*, 2019). The controlled setting satisfied the exploratory nature of the present study and to characterise the *PlayerLoad^{TM}* trace. The next step is to determine whether the *PlayerLoad^{TM}* measurement is associated with tackling technique during live tackling in training and matches. How the *PlayerLoad^{TM}* measurement may change according to other factors such as contextual factors (e.g., match scenario), playing position, playing level, and type of tackle also requires investigation. The present study only analysed one external physical load metric. Future research on understanding the physical-technical relationship of tackling should include subjective load measurements (e.g., rating of perceived exertion and rating of perceived challenge), biomechanical measurements (e.g., speed of tackler before contact), and the amount of impact force produced from each tackle. New technologies such as instrumented mouthguards (coupled to the upper dentition of the player) (Tierney et al. 2021; Jones et al., 2022) and automated tackle detection from video (Martin et al., 2021) have recently emerged to assist in analysing the demands of the tackle. Foreseeably, these technologies will be used in conjunction with *PlayerLoad^{TM}* and video analysis of technique to gain a superior understanding of the physical-technical demands of tackling.

Conclusion

This is the first study to explore the *PlayerLoad^{TM}* trace during a simulated tackle and how *PlayerLoad^{TM}* changes between different levels of tackling technique. *PlayerLoad^{TM}* did not differ between low, medium and high technical scoring tackles at the point of contact. High technical scoring tackles did however show a higher *PlayerLoad^{TM}* than low and medium scoring tackles during the tackle completion phase. Also, the *PlayerLoad^{TM}* trace of tackles within the high technical scoring tackles show less variability throughout the tackle. The variability in the *PlayerLoad^{TM}* trace may be the consequence of players not shortening their steps before contact, reducing their ability to control their movement during the contact and post-contact phase of the tackle. Using the *PlayerLoad^{TM}* trace in conjunction with technique assesssments offers coaches and practitioners insight into the physical-technical relationship of each tackle to optimise tackle skill training, monitoring and match preparation.

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Key points

- In this study, *PlayerLoad™* did not differ between low, medium and high technical scoring tackles at the point of contact.
- High technical scoring tackles did however show a higher *PlayerLoad™* than low and medium scoring tackles during the tackle completion phase.
- The *PlayerLoad™* trace of tackles within the high technical scoring tackles show less variability throughout the tackle which may be consequence of players not shortening their steps before contact, reducing their ability to control their movement during the contact and post-contact phase of the tackle.

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Supplementary Material

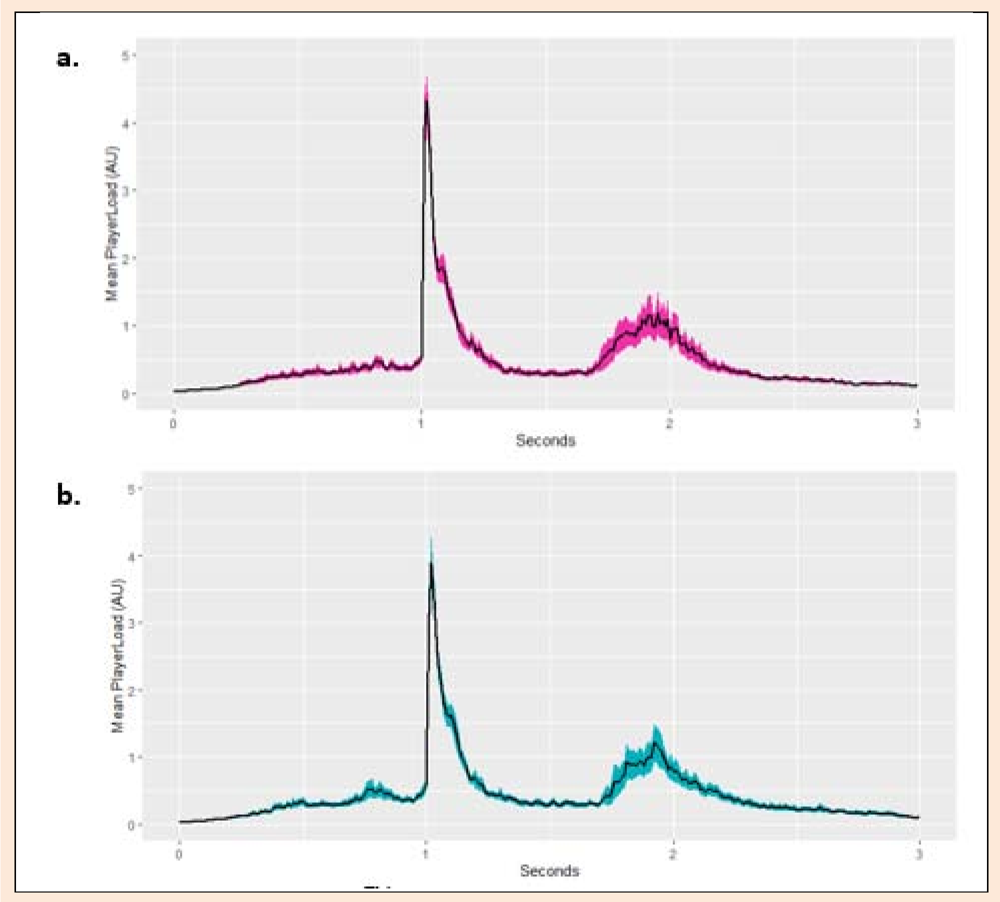
Supplementary Table 1. Mean, 95% confidence intervals (95%Cl) and standard deviation (SD) of tackle proficiency scores for each category. Data reported at Arbitrary Units.

Tackle Proficiency Criteria	Low scoring tackles			Medium scoring tackles			High scoring tackles		
	Mean	95%Cl	SD	Mean	95%Cl	SD	Mean	95%Cl	SD
Low body position (dipping i.e., upright-to-low)	0.7	0.6 – 0.9	0.5	0.8	0.7 – 0.8	0.4	0.9	0.9 -1.0*	0.2
Straight back, centre of gravity ahead of base of support	0.9	0.7 – 1.0	0.4	0.9	0.9 – 1.0	0.2	0.9	0.9 – 1.0	0.2
'Boxer stance' (elbows bent, hands forward and open)	0.04	0 – 0.1	0.2	0.4	0.3 – 0.5*	0.5	0.7	0.6 – 0.8*	0.5
Head up and forward with eyes open	1.0	0	0	1.0	0	0	1.0		0
Shortening steps	0	0	0	0.1	0.07 – 0.2*	0.3	0.4	0.3 - 0.4*	0.5
Pre-contact total	2.6	2.4 – 2.8	0.5	3.2	3.1 – 3.4*	0.7	3.9	3.8 – 4.1*	0.7
Explode with leading leg into contact	0.2	0.03 – 0.4	0.4	0.5	0.4 – 0.6	0.5	0.8	0.8 – 0.9*	0.4
Contact target with shoulder within region below shoulders and above hips	0.8	0.6 – 0.9	0.4	0.9	0.9 – 1	0.2	1.0*	0	0.1
Place head on correct side of ball-carrier	1.0	0	0	1.0	0	0	1.0	0	0
Contact total	2	1.8 – 2.2	0.5	2.5	2.4 – 2.6*	0.5	2.8	2.7 – 2.9*	0.4
Drive through contact with legs and shoulder	0.04	0 – 0.1	0.2	0.2	0.1 – 0.3	0.4	0.6	0.5 – 0.7*	0.5
Arm usage (wrap i.e., hit-and-stick)	0.04	0 – 0.1	0.2	0.3	0.2 – 0.4*	0.4	0.4	0.4 – 0.5*	0.5
Jackle	0.1	0 – 0.3	0.3	0.6	0.5 – 0.7*	0.5	0.8	0.7 – 0.9*	0.4
Post contact total	0.2	0.03 – 0.4	0.4	1.04	0.9 – 1.2	0.8	1.7	1.7 – 2.0*	0.7
Total Score	4.8	4.6 – 4.9*	0.4	6.7	6.6 – 6.8*	0.5	8.6	8.4 – 8.7*	0.8
Percentage	44 %			61 %			78 %		

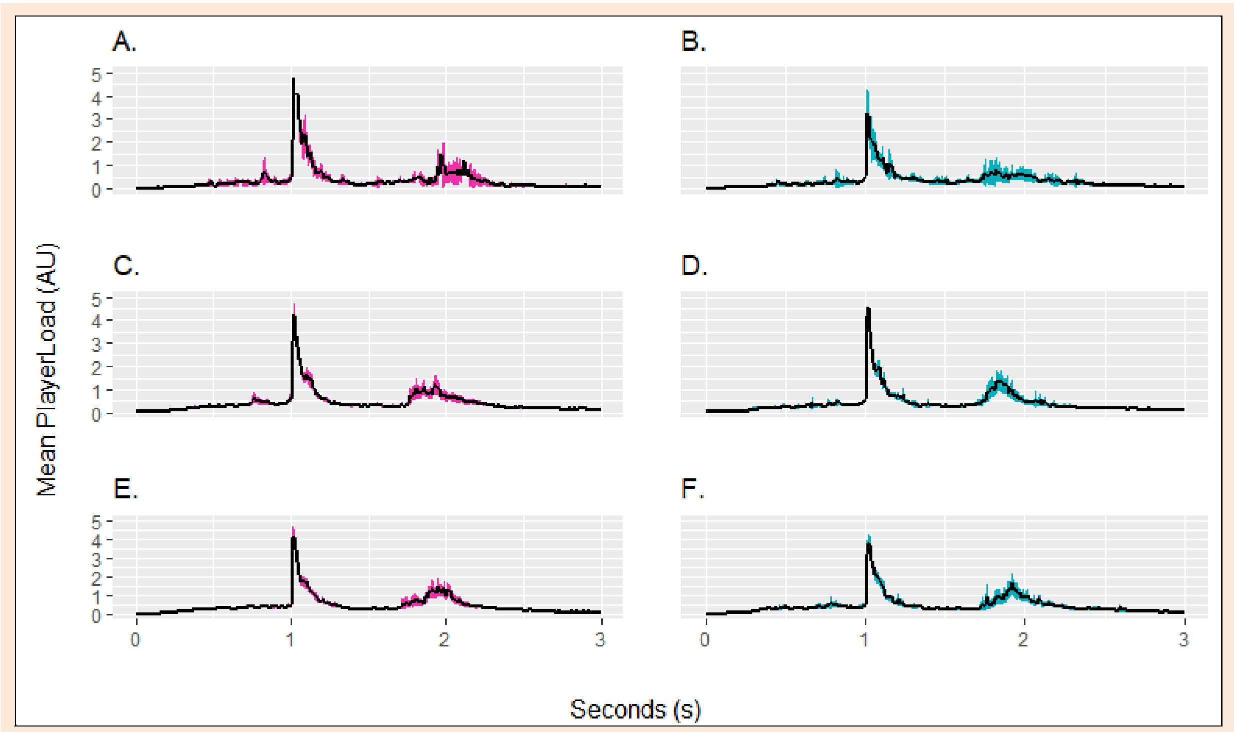
*Significantly higher than low or middle scoring tackles

Supplementary Table 2. Mean PlayerLoad™, 95% confidence intervals (95%Cl) and standard deviations (SD) at point of contact, time difference between peaks and point of tackle completion by shoulder dominance between technical scoring categories. Data reported at Arbitrary Units.

	Point of contact (AU)			Time difference between peaks (s)			Point of tackle completion (AU)		
Low scoring tackles									
	Mean	95%Cl	SD	Mean	95%Cl	SD	Mean	95%Cl	SD
Dominant shoulder tackles	7.0	4.8 - 9.2	2.9	0.8	0.6 - 1.0	0	3.5	1.3 - 5.8	2.9
Non-dominant shoulder tackles	4.6	3.3 - 5.8	2.4	0.9	0.7 - 1.0	0	2.6	1.7 – 3.4	1.5
Medium scoring tackles									
Dominant shoulder tackles	6.2	5.7 - 6.8	0.5	0.9	0.8 - 0.9	9.0	4.3	3.6 - 5.0	2.1
Non-dominant shoulder tackles	5.6	5.1 - 6.2	2.0	0.9	0.8 - 0.9	12.4	4.1	3.3 - 4.9	2.7
High scoring tackles									
Dominant shoulder tackles	6.0	5.6 - 6.5	1.7	0.9	0.8 - 0.9	16.4	5.7	5.1 - 6.4	2.7
Non-dominant shoulder tackles	5.7	5.1 - 6.2	1.8	0.9	0.8 - 0.9	13.1	5.3	4.5 - 6.1	2.5



Supplementary Figure 1. **Mean PlayerLoad™ and 95% confidence intervals of dominant and non-dominant shoulder tackles. a. Dominant shoulder tackles. b. Non-dominant shoulder tackles.**



Supplementary Figure 2. **Mean PlayerLoad™ and 95% confidence intervals of dominant and non-dominant shoulder tackles for low scoring tackles: A. Dominant shoulder tackles. B. Non-dominant shoulder tackles, medium scoring tackles: C. Dominant shoulder tackles. D. Non-dominant shoulder tackles and high scoring tackles: E. Dominant shoulder tackles. F. Non-dominant shoulder tackles.**