Title: The effects of physical contact type on the internal and external demands during a rugby league match simulation protocol.

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Abstract

This study investigated how the type of contact influences physiological, perceptual and locomotive demands during a simulated rugby league match. Eleven male university rugby league players performed two trials of the rugby league movement simulation protocol for forwards (RLMSP-i) with a traditional soft tackle bag (BAG) and a weighted tackle sled (SLED) to replicate contact demands. Locomotive rate, sprint speed, tackle intensity, heart rate, rating of perceived exertion and blood lactate concentration were analysed in four periods during the first and second bout of both trials. Countermovement jump (CMJ) was measured before and immediately after each trial. More time was spent in heart rate zone between 90 – 100% HR_{peak} during the first (effect size ± 95% confidence interval: 0.44 ± 0.49) and second bout (0.44 ± 0.43), and larger (0.6 ± 0.69) decrements in CMJ performance were observed during SLED (5.9, s = 4.9%) compared to BAG (2.6, s = 5.4%). Sprint into contact speed was faster during BAG compared to SLED in the first (1.10 ± 0.92) and second bout (0.90 ± 0.90), which impaired high intensity running ability but did not increase physiological strain. Changing the type of contact during the match simulation subtly altered both the internal and external load on participants. These findings indicate that tackle training apparatus should be considered regarding the outcome of a training session.

Introduction

The external and internal match demands of rugby league have been examined extensively (Austin & Kelly, 2013; Coutts, Reaburn & Abt, 2003; McLellan, Lovell & Gass, 2011; Waldron, Twist, Highton, Worsfold & Daniels, 2011). Average distance covered can range between 3000–7500 m depending on playing position, with backs covering greater distances and more high-intensity running than forwards (Gabbett, Jenkins & Abernethy, 2012). Despite playing times for forwards (~50 min) being shorter than backs (~70 min), classifying running into locomotive rates shows that both positions cover similar relative distances of ~89-95 $m \cdot min^{-1}$ during a match (Waldron et al., 2011; Austin & Kelly, 2013; 2014). Alongside running requirements, the number and intensity of physical collisions also contributes greatly to player load during a rugby league match (Gabbett, Jenkins & Abernethy, 2012). Forwards perform more tackles and ball carries than backs during a match, with collision rates of ~1.0 per min and ~0.3 per min for these positions, respectively (Gabbett, Jenkins & Abernethy, 2011; 2012; Twist, Waldron, Highton, Burt & Daniels, 2011). Despite differences in running and tackling requirements, average heart rate (HR) during a match is similar (~80% maximum) for both positional groups (McLellan, Lovell & Gass, 2011).

Large inter-match variability in movement demands has been identified in time motion analyses of soccer (Rampinini, Coutts, Castagna, Sassi & Impelizzeri, 2007) and rugby league (Kempton, Sirotic, & Coutts, 2013). Indeed, between-match variation in elite rugby league has been reported as 14.6% and 37.9% for high-speed running and very high-speed running, respectively (Kempton et al., 2013). Large variation, in these and other match characteristics such as relative distance and number of maximal accelerations, can be explained to some extent by the quality of opposition and whether the team is winning or losing (Gabbett, 2013). Accordingly, match simulation protocols provide a tool to replicate sport performance reliably, enable measurements deemed too invasive for competitive sport and perform analyses of intervention strategies. In rugby league, match simulations for both whole match players (RLMSP; Sykes, Nicholas, Lamb & Twist, 2012) and interchange players (RLMSP-i; Waldron, Highton & Twist, 2012) have been developed. Results from these studies have shown that simulations elicit similar internal demands to those seen during competition but have limitations when replicating external load. For example, heart rate responses (~87 and ~88% HR_{peak}), peak running velocities (26.7 and 26.9 $km \cdot h^{-1}$) and relative low speed distance (~80 and ~78 $m \cdot min^{-1}$) are comparable between the RLMSP-i and Super League match data, respectively. However, relative high speed (~27 and ~17 $m \cdot min^{-1}$) and total distance (~107 and ~95 $m \cdot min^{-1}$) was greater than that reported in matches (Waldron et al., 2012). A potential cause of the greater running volume in the simulation protocol might be reduced intensity of the simulated contact relative to elite rugby league matches (Waldron et al., 2012). Therefore, further examination of the collision replication is warranted to improve the validity of the simulation protocol.

Physical contact is a key mechanism responsible for reducing physical output in rugby league. Indeed, repeat sprint performance is impaired with the addition of a collision into a soft tackle cylinder at the end of each effort (Johnston & Gabbett, 2011). When comparing contact to non-contact trials, this study also reported greater average heart rate, peak heart rate, total time to complete the test and rating of perceived exertion (RPE). Similarly, non-contact small-sided games result in greater running distance when compared to contact games (Johnston, Gabbett, Seibold & Jenkins, 2013). Thus, contact increases the internal demand on players, which appears to reduce running ability and increase the physiological demands during repeat sprint performance and training games. However, these findings are reported in short-duration, very high intensity training sessions that do not replicate the more prolonged and varied running demands associated with match play. When simulated rugby league match play was compared with and without contact, internal and external demands were higher in the contact trial compared to both the non-contact trial and match play (Mullen, Highton & Twist, 2015). The authors speculated that the overall increase in running speed was the result of the type of contact used in the simulation (i.e. 23 kg soft tackle bag) that encouraged a faster running speed into impact compared to running into a human body. However, the study did not examine the running kinematics into contact, which might provide further insight to the role of collision on fatigue and running performance during intermittent activity.

Physical collisions reduce lower body neuromuscular performance immediately after rugby league competition (McLellan & Lovell, 2012; McLellan, Lovell & Gass, 2011). Impaired neuromuscular function has been attributed to greater muscle damage resulting from eccentric muscle actions associated with wrestling and contact (Singh, Guelfi, Landers, Dawson & Bishop, 2011; Johnston et al., 2013). Acute decrements in lower body muscle function have also been attributed to excitation-contraction coupling failure as a result of metabolic disturbance and low frequency fatigue (McLellan & Lovell, 2012; West et al., 2013; MacLaren, Gibson, Parry-Billings, & Edwards, 1989). Accordingly, physical contact influences the internal and external load imposed on rugby players and contributes to fatigue during prolonged intermittent activity (Gabbett, Jenkins & Abernethy, 2011). However, assessing the effect of simulated contact type on physiological load, running performance and neuromuscular function during team sport activity still requires further investigation. Therefore, the aim of this study was to examine how the type of physical contact influences the internal and external demands during and after a simulated rugby league match.

Methods

Participants and design

The study was a randomized, repeated measures crossover design, in which eleven male university rugby league players (mean ± s body mass = 86.4 ± 6.9 kg; stature = 186.5 ± 7.4 cm; age = 21.8 ± 1.3 years; predicted $\dot{V}O_2max$ = 47.9 ± 2.1 $ml \cdot kg^{-1} \cdot min^{-1}$) were required to complete two trials of the rugby league match simulation protocol for interchange players (RLMSP-i; Waldron et al., 2012) on an outdoor synthetic grass pitch (3G all-weather surface) with 7 – 10 days between each trial. Before the first trial, participants signed a written consent form and completed a health screening questionnaire to ensure suitability to participate in the study. The Faculty of Life Sciences Research Ethics Committee granted ethical approval for the study.

Before the first trial, participants were required to complete a 20 m multi-stage fitness test (MSFT) to estimate maximal oxygen uptake ($\dot{V}O_2max$). To be included in the study, participants had to achieve level 9 (~45 $ml \cdot kg^{-1} \cdot min^{-1}$) to replicate the characteristics of elite rugby league players (Gabbett, Jenkins & Abernethy, 2011). One familiarisation session of the protocol was completed where participants performed six cycles of the match simulation, including three cycles of both conditions. Participants were asked to refrain from any strenuous exercise in the 36 hours before the first trial, as well as to avoid ergogenic supplementation and maintain normal dietary habits.

In one trial contact was replicated using a soft tackle cylinder (BAG; Gilbert Rugby, East Sussex, England; mass = 23 kg), while the other trial used a modified weighted tackle sled (SLED; mass = ~70 kg). On each visit, participants body mass was recorded after which they performed three counter movement jumps (CMJ) before completing the RLMSP-i with the nominated contact condition. During the simulation, movement demands, heart rate, blood lactate concentration and RPE were measured. Immediately after completing the simulation, body mass was recorded again and CMJ measurements repeated. Trials were conducted at similar times of the day (± 1 h) for each participant. A schematic of the RLMSP-i can be found in Figure 1.

****Figure 1 near here****

Multi-stage fitness test

After a standardised warm up, participants completed the multi-stage fitness test (MSFT) on an indoor wooden surface (Ramsbottom et al., 1988). The test consisted of shuttle running between two markers placed 20 m apart at increasing running speeds (0.14 $m \cdot s^{-1}$) until exhaustion (Leger & Gadoury, 1989). Maximal heart rate was recorded immediately after the test via a heart rate monitor (Polar Electro, Oy, Finland). Maximal oxygen uptake (VO_{2max}) was estimated from the level and stage reached using the table of Ramsbottom et al. (1988).

The RLMSP-i

Participants were required to move between a linear series of cones, with movement speeded controlled by an audio signal. Two bouts of 12 cycles were interspersed with a 20-minute passive recovery period to replicate the average match demands of elite interchanged rugby league players (Waldron, Highton, Daniels & Twist, 2013). The simulation was designed to reproduce total relative running demands of ~95 $m \cdot min^{-1}$, 0.7 contacts per minute and heart rate peak (HR_{peak}) of 85-90%. During SLED, the contact was modified from the previous protocol (Waldron et al., 2012) to involve a collision with a weighted tackle sled. The sled incorporated a cushioned tackle arm onto a metal frame weighing ~70 kg. Participants were instructed to sprint into the collision and make contact with the sled at hip height. At contact, the participant was instructed to flex the hips, knees and ankles whilst making contact with their preferred shoulder and wrapping both arms around the padded tackle arm. Immediately after contact, participants performed a "flapjack" exercise that involved dropping into a prone position on the ground before rolling laterally 360° to the left and then rolling back to the original prone position. This exercise was included to meet criteria for tackle detection that requires the GPS unit to change orientation and to simulate tackling an opponent to the ground. Once complete, participants returned to standing and awaited the next audible instruction. Specific instructions and demonstrations were given to the participants on how to perform a contact event with the tackle sled, which was performed once per cycle. The second contact event in each cycle required the participant to perform the flapjack exercise without colliding with the tackle sled. During BAG trial, the sled was replaced with the soft tackle cylinder (23 kg) with tackles performed as described by Waldron et al. (2012). The frequency of contact was identical between trials.

Movements were recorded using a 10 Hz GPS device (Optimeye S5, Catapult Innovations, Melbourne, Australia) fitted into a vest that was securely positioned between the participant's scapulae. Total distance run was recorded and then categorised into low (<14.0 km·h^{-1}) and high speed (>14.1 km·h^{-1}) distance covered to correspond with previous research on rugby league demands (Waldron, Twist, Highton, Worsfold & Daniels, 2011). Typical error of measurement for distance and velocity is 0.8% at slow speeds and up to 13.7% during very high speed running (Johnston, Watsford, Kelly, Pine & Spurrs, 2014). Peak velocity (km·h^{-1}) of sprint A (first 20.5 m sprint), sprint to contact (8 m sprint into contact with sled or bag) and sprint B (second 20.5 m sprint) were measured during every cycle of the simulation. The device also included a 100 Hz tri-axial accelerometer, gyroscope and magnetometer to provide data on contact events. Tackle load (AU), measured as the accumulated Player Load™ during the contact event with a scaling factor, was determined from every contact with both the sled and bag in addition to total tackle count. Previous research data has found the tackle detection functionality of the devices to be valid and reliable (CV% = 1.9%) for identifying rugby specific actions (Gabbett, Jenkins & Abernethy, 2010; Boyd, Ball & Aughey, 2010).

A HR monitor (Polar Electro Oy, Kempele, Finland) was wirelessly paired to the GPS device and fitted around the chest of the participant. Both movement and HR data were downloaded to a laptop and analysed (Sprint, Version 5.1, Catapult Sports, VIC, Australia). Heart rate data were analysed as a percentage of the participant's peak heart rate determined from final heart rate during MSFT (%HR_{peak}). Time spent in five heart rate zones was calculated and used to determine summated heart rate using the methods of Edwards (1993). Zones were determined from HR_{peak} and classified as 51-60%, 61-70%, 71-80%, 81-90% and 91-100%. Internal and external demands were analysed in total (24 cycles), by bout (12 cycles) and by period (three cycles). RPE (Borg, Ljunggren & Ceci, 1985) was measured at the conclusion of each bout using the 6-20 Borg scale along with blood lactate concentration from a finger prick capillary blood sample measured using a portable analyser (Lactate Pro; Arkay KDK Corp., Kyoto, Japan).

Lower-body power assessment

Jump height was estimated from flight time during a counter-movement jump (CMJ). Participants warmed up with five minutes of light cycling, 10 bodyweight squats and five submaximal CMJs. Participants then performed three maximal effort CMJ repetitions. Depth of counter-movement and foot position were self-selected and participants were instructed to jump as high as possible with each attempt while maintaining hands firmly placed on hips throughout. A 90 s rest period was allowed between maximal attempts. Jump height was measured using an infra-red timing system (Optojumo, Microgate S.r.l., Boozano, Italy) connected to a laptop. Jump height was estimated from flight time as (9.81 x flight time^2) / 8 (Bosco, 1983). This method of estimating jump performance has been previously found to be both valid and reliable (CV = 2.7%; Glatthorn et al., 2011). The mean of the two closest jump heights were taken for analysis (Jennings, 2005).

Statistical Analyses

Differences in muscle function, blood lactate concentration, RPE, peak sprint speed, relative distance measures and tackle intensity between the two trials were assessed using separate two-way (trial x time) repeated measures analysis of variance (ANOVA). Any significant main effects were analysed with *post hoc* paired samples *t* –tests to locate the differences. Validity of the GPS unit for tackle detection was analysed using coefficient of variation (CV%) calculated as; (*s* diff/√2) / (grand mean) x 100 (Hopkins, 2000). Correlations between the external and internal demands were analysed using the Pearson correlation coefficient. The following criteria were adopted to interpret the magnitude of the correlation (r) between test measures: <0.1 trivial, 0.1-0.3 small, 0.3-0.5 moderate, 0.5-0.7 large, 0.7-0.9 very large, and 0.9-1.0 almost perfect (Hopkins, Marshall, Batterham & Hanin, 2009). All analyses were calculated using the Statistical Package for Social Sciences SPSS 20 (SPSS Inc, Chicago, USA). The significance level was set at $p \leq 0.05$, and all data reported as mean ± *s*. To further describe the data, effect sizes with accompanying 90% confidence intervals (Effect size ± 90% CI) were calculated for selected variables (Batterham & Hopkins, 2006). Effect sizes were calculated as the difference between trial means divided by the pooled standard deviation and supplemented with qualitative descriptors of the mechanistic effect. Threshold probabilities for a mechanistic effect based on the 90% confidence limits were: <0.5% most unlikely, 0.5–5% very unlikely, 5–25% unlikely, 25–75% possibly, 75-95% likely, 95-99% very likely and >99.5% most likely. Effects with confidence limits across a likely small positive or negative change were classified as unclear. All calculations were completed using a predesigned spreadsheet (Hopkins, 2006).

Results

Running demands

High intensity running distance was lower during BAG over the total simulation (Effect size = -0.23 ± 0.35; *possible* ↓). Sprint to contact speed was faster during BAG in total (Effect size = 1.03 ± 0.92; *likely* ↑). Sprint B speed was slower during BAG in total (Effect size = -0.33 ± 0.44; *possible* ↓). No differences were found in total distance, low intensity distance or sprint A speed between trials. Relative running demands are shown in Table 1 and sprint speeds are presented in Figure 2.

Perceptual and internal responses

RPE immediately after the second half was lower during BAG (Effect size = -0.34 ± 0.26; *likely* ↓) but there was no difference immediately after the first half (Effect size = 0.25 ± 0.47). No differences were observed in blood lactate concentration after either the first (Effect size = 0.24 ± 0.53) or second half (Effect size = -0.10 ± 0.34). Time with heart rate between 90 – 100% HR_{peak} was longer for SLED compared to BAG (12:58 ± 13:21 cf. 6:44 ± 8:06 min; ES ± 90% CI: -0.41 ± 0.48). Despite greater time spent at 90 – 100% HR_{peak} during SLED, there were no differences in summated heart rate between trials (Effect size = -0.01 ± 0.81; unclear). Perceptual and internal demands are presented in Table 2.

****Table 1 near here****

Countermovement jump performance

Jump height decreased significantly (P = 0.007) from 38.1 ± 5.2 to 35.8 ± 5.0 cm after the SLED trial but did not significantly change (P = 0.10) after BAG (36.8 ± 5.4 to 35.7 ± 5.0 cm). Relative change in jump height decreased to a greater degree (Effect size = 0.60 ± 0.69; *likely* ↑) after SLED (5.9 ± 4.9%) compared to BAG (2.6 ± 5.4%).

Contact demands

Summated tackle load over the total simulation was greater during BAG compared to SLED (Effect size = 0.14 ± 0.28; *possible* ↑). Overall, tackle detection resulted in poor validity with CV% of 11.9 and 7.0% respectively for SLED and BAG when compared with the actual tackle frequency.

****Table II near here****

Correlations

There was a *large* negative correlation (r ± 90% CI = -0.672 ± 0.114, $P < 0.001$) between high intensity running and summated heart rate during the BAG trial, which was *trivial* for the SLED trial (r ± 90% CI = -0.020 ± 0.206, $P = 0.930$). Correlations can be found in Figures 3 and 4.

****Figure 3 & 4 near here****

Discussion

The aim of this study was to investigate the influence of physical contact type on internal and external demands during a rugby league match simulation. The findings illustrate subtle differences in these demands when contact during intermittent running is replicated using either a traditional tackle bag or a weighted tackle sled. More specifically, the use of a weighted tackle sled seemingly elevated the internal load and altered the pacing strategies associated with simulated rugby league performance. The weighted tackle sled increased time spent in higher heart rate zones, suggesting a greater physiological load is associated with a heavier contact object. Larger decrements in countermovement jump performance after SLED indicated that post-trial neuromuscular responses are also influenced by the nature of contact.

Previous studies have reported lower external load during running with contact compared to non-contact (Johnston & Gabbett, 2011; Johnston et al., 2013). Our data suggest a small, *possible* decrease in high intensity running during the lighter BAG (28 ± 3 $m \cdot min^{-1}$) compared to the heavier SLED trial (29 ± 3 $m \cdot min^{-1}$). These small differences in high intensity running are in part explained by changes in sprint activity between conditions, which was the only true self-paced element of the simulation. While sprint to contact was ~9% faster in the BAG, the same condition's Sprint B speed, i.e. after contact, was actually slower (22.8 ± 0.8 $km \cdot h^{-1}$) compared to SLED (23.2 ± 1.0 $km \cdot h^{-1}$). A faster sprint to contact during BAG is likely to have resulted in greater metabolic disturbance immediately after the sprint compared to SLED, despite forceful muscular contractions associated with the higher intensity collision (Morel, Rouffet, Bishop, Rota & Hautier, 2015). Therefore, we propose that the greater sprint speed into contact during BAG lead to participants employing a pacing strategy that reduced high intensity running throughout the rest of the cycle to maintain performance. This is supported by correlational analysis indicating a *large* negative association between summated heart rate and high intensity running during BAG. This is to say, participants who maintained a lower heart rate were able to perform more high intensity running. The *trivial* association observed between high intensity running and summated HR in SLED indicates that the observed higher physiological strain was not associated with running load and instead must be a consequence of contact with a heavier tackle object. While no difference in blood lactate concentration between trails might contradict these assertions, it is likely that subtle differences between trials were not observed due to large inter-individual differences.

To the authors' knowledge, this is the first study to analyze individual sprint performances using GPS technology during a simulated rugby match and has lead to an important observation in the replication of contact in simulated match activity or training. It seems participants in this study altered their sprint kinematics depending on the type of contact. Contact with the SLED is likely to have required greater technical proficiency compared to BAG and provided more resistance due to the size and weight of the tackle arm and steel frame. Consequently, the participants reduced sprint to contact speed to ensure successful execution of skill performance and to reduce any discomfort associated with the physical collision. During the protocol, the participant is permanently a "tackler" and so greater velocity into contact as a tackler could also partly explain why total running distance and high intensity running distance are greater in the simulation than previously observed during match play (Hendricks, Karpul & Lambert, 2014). In match-play, tacklers tend to have greater velocity than ball carriers until close to the point of contact which could inflate high-intensity running during the protocol.

The *likely* greater decrements in CMJ performance (~5.9%) after SLED indicate greater neuromuscular fatigue associated with this form of contact compared to BAG (~2.6%). These findings reaffirm those of Mullen et al. (2015) who reported no change in CMJ flight time after a simulated rugby league match using the same contact bag as described here. More importantly, using the SLED appears to better replicate the lower limb fatigue observed in rugby players immediately after matches when measured using jump procedures (Twist et al., 2012; McLellan & Lovell, 2012; West et al., 2013). Acute reductions in jump performance after rugby match play has been attributed to low-frequency fatigue that impairs excitation-contraction coupling (McLellan & Lovell, 2012). This fatigue seems to be greater when intermittent running is combined with contact and driving of a heavy object and highlights the importance of the type of collision when replicating match play in simulations and training. Indeed, despite greater acute fatigue caused by faster sprint speeds, the heavier contact in SLED resulted in larger detriments to jump performance suggesting that sprinting and high-intensity running do not contribute as greatly to post-match fatigue. Further research is warranted on the relative contribution of running and tackling to acute and prolonged fatigue after rugby league performance.

Physical contact performed in conjunction with high intensity running increases the physiological strain compared to running alone (Johnston & Gabbett, 2011; Mullen et al., 2015). The results from this study go further and demonstrate that the method of physical contact influences internal load during a match simulation. The *likely* lower RPE and less time spent in high HR zones in BAG compared to SLED suggest that the use of soft tackle cylinders results in lower physiological strain. Indeed, contact during SLED appears to be more intense compared to BAG due to time spent in high heart rate zones that was not associated with greater high intensity running load, as mentioned previously. Although not directly measured in this study, it is likely that greater effort was required to collide with and drive the SLED compared to BAG. The additional weight of the SLED might have required greater force application and as such, resulted in increased muscular recruitment and an elevated physiological response.

Contact intensity was measured in this study using tackle load as calculated by the GPS device. The results were in contrast to the hypothesis that the SLED would increase the tackle intensity and found that tackle load was *possibly* greater during BAG (53.4 ± 10.3 AU) compared to SLED (51.4 ± 13.9 AU) over the whole simulation. Tackle detection requires three conditions to be met; the orientation of the device must become non-vertical, accelerometer load must be above a threshold before the change of orientation and there must be a sudden increase in accelerometer load before the change of orientation. Despite participants completing the same number of simulated tackles between conditions, the GPS tackle detection feature also reported fewer tackles in the BAG compared to SLED as well as underestimating the actual number completed in both. Accordingly, our findings challenge previous research that has reported a strong correlation (r = 0.96, $P < 0.01$) with video detection when using GPS mictrotechnology to measure contact frequency and intensity (Gabbett, Jenkins & Abernethy, 2010). Tackle load is calculated as the accumulated accelerometer load during the contact event which is determined as the time from the sudden increase in accelerometer load until the device returns to vertical. Faster sprint to contact speed during BAG could influence the accelerometer load before the contact and artificially inflate the tackle load. Additionally, the time in contact is an important factor in calculating tackle load, which would therefore attribute greater tackle load to “longer” tackles as opposed to larger impact forces. Less time is spent non-vertical in contact during the SLED because the participant remains upright during the collision, unlike the contact during BAG where the participants immediately go to ground. These findings suggest that the tackle load algorithm should therefore be used with caution to quantify the tackle intensity in contact sports.

Previously, the rugby league simulation has been found to produce comparable heart rate responses, peak running speeds and low intensity running to Super

League match performances but larger total and high intensity running metres (Waldron, Highton & Twist, 2013). The authors proposed that reduced intensity of collision with a tackle bag relative to match collisions could contribute to the observed greater running demands. This study has again found similar heart rate responses during the SLED simulation (82-89% HR_{peak}) to values reported for competitive matches (81-85% HR_{peak}; Waldron et al., 2011), but has failed to replicate running demands (105 $m \cdot min^{-1}$ vs 101 $m \cdot min^{-1}$). The disparity in distance covered could still be attributed to limited contact intensity, as only small differences were observed between contact type in this study. It is also likely that pacing strategies play a key role in the differences between competitive and simulated matches. Competitive matches vary greatly and periods of high intensity can occur at any moment which can lead to conservative pacing strategy to maintain high intensity performance (Gabbett, 2013; Sampson, Gabbett & Fullagar, 2015; Waldron et al., 2013). Contrastingly, during the simulation, participants have detailed knowledge of the task and the fixed end point which allows an even distribution of effort and might enable the participants to work at a higher intensity during the sprints which are the only true self-paced aspect. Finally, the linear nature of the simulation does not include rapid, unexpected changes of direction that would challenge participant's ability to decelerate and accelerate. Such movement patterns require major eccentric contractions which are both mechanically and metabolically challenging and would likely increase physiological demands over matched distances. The lack of such movements might enable participants to perform at higher intensities during the simulation compared to competitive match play.

Conclusion

Modifying the type of contact in a rugby league match simulation subtly alters the internal and external demands on participants by caused principally by a modification of high intensity running. Participants also appear to modify their sprint behavior into contact when a heavier object is employed. Despite incorporating collisions with a heavier object, the external demands during a forward specific rugby league simulation protocol remain greater than those observed in elite matches. These findings therefore reaffirm the challenges of replicating the collision scenario for contact sports. From a practical perspective, conditioning coaches should be aware of the influence the type of contact has on running performance, internal load and neuromuscular fatigue when planning the purpose of a training session. Finally, the ability of GPS devices to accurately quantify collision events in contact sports remains an area of contention.

Conflicts of interest

The authors declare no conflict of interest.

References

Austin, D.J. & Kelly, S.J., (2013). Positional differences in professional rugby league match play through the use of global positioning systems. *The Journal of Strength and Conditioning Research, 27,*14–9.

Batterham, A. M., & Hopkins, W. G. (2006). Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance, 1(1),* 50-57.

Borg, G., Ljunggren, G., & Ceci, R. (1985). The increase of perceived exertion, aches and pain in the legs, heart rate and blood lactate during exercise on a bicycle ergometer. *European Journal of Applied Physiology and Occupational Physiology*, *54*(4), 343-349.

Boyd, L. J., Ball, K., & Aughey, R. J. (2011). The reliability of MinimaxX accelerometers for measuring physical activity in Australian football. *International Journal of Sports Physiology and Performance*, *6*(3), 311-321.

Coutts, A., Reaburn, P. & Abt, G., (2003). Heart rate, blood lactate concentration and estimated energy expenditure in a semi-professional rugby league team during a match: a case study. *Journal of Sports Sciences, 21*, 97–103.

Edwards, S., (1993). *The heart rate monitor book*. Sacramento, CA: Feet Fleet Press.

Gabbett, T.J., Jenkins, D.G. & Abernethy, B. (2012). Physical demands of professional rugby league training and competition using microtechnology. *Journal of Science and Medicine in Sport, 15,* 80–6.

Gabbett, T.J., (2013). Influence of the opposing team on the physical demands of elite rugby league match play. *The Journal of Strength and Conditioning Research, 27*, 1629–35.17.

Gabbett, T.J., Jenkins, D.G., & Abernethy, B. (2010). Physical collisions and injury during professional rugby league skills training. *Journal of Science and Medicine in Sport*, *13*(6), 578-583.

Gabbett, T.J., Jenkins, D.G., & Abernethy, B. (2011). Physical collisions and injury in professional rugby league match-play. *Journal of Science and Medicine in Sport*, *14*, 210–5.

Gabbett, T.J., Jenkins, D.G., & Abernethy, B. (2011) Relationships between physiological, anthropometric, and skill qualities and playing performance in professional rugby league players. *Journal of Sports Sciences, 29,* 1655–64.

Girard, O., Mendez-Villanueva, A., & Bishop, D. (2011). Repeated-Sprint Ability—Part I. *Sports Medicine*, *41*(8), 673-694.

Glatthorn, J. F., Gouge, S., Nussbaumer, S., Stauffacher, S., Impellizzeri, F. M., & Maffiuletti, N. A. (2011). Validity and reliability of Optojump photoelectric cells for estimating vertical jump height. *The Journal of Strength and Conditioning Research*, *25*(2), 556-560.

Hendricks, S., Karpul, D., & Lambert, M. (2014). Momentum and kinetic energy before the tackle in rugby union. *Journal of Sports Science and Medicine*, *13*(3), 557.

Hopkins, W.G. A New View of Statistics. [Web page] 2000 [cited March 2015]; Available from: http://www.sportsci.org/resource/stats/procmixed.html/#indif.

Hopkins, W. G. (2006). Spreadsheets for analysis of controlled trials, with adjustment for a subject characteristic. *Sportscience, 10*,46-50.

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3.

Jennings, C.L., Viljoen, W., Durandt, J., & Lambert, M. I. (2005). The reliability of the FitroDyne as a measure of muscle power. *The Journal of Strength and Conditioning Research*, *19*(4), 859-863.

Johnston, R.D. & Gabbett, T.J. (2011). Repeated-sprint and effort ability in rugby league players. *The Journal of Strength and Conditioning Research*, *25*, 2789–95.

Johnston, R.D., Watsford, M.L., Kelly, S.J., Pine, M.J. & Spurrs, R.W., (2014). Validity and interunit reliability of 10 HZ and 15 Hz GPS units for assessing athlete movement demands. *The Journal of Strength and Conditioning Research, 28(6).*1649-55.

Johnston, R. D., Gabbett, T. J., Seibold, A. J., & Jenkins, D. G. (2014). Influence of physical contact on neuromuscular fatigue and markers of muscle damage following small-sided games. *Journal of Science and Medicine in Sport*, *17*(5), 535-540.

Kempton, T., Sirotic, A. C., & Coutts, A. J. (2014). Between match variation in professional rugby league competition. *Journal of Science and Medicine in Sport*, *17*(4), 404-407.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjær, M., & Bangsbo, J. (2006). Muscle and blood metabolites during a soccer game: implications for sprint performance. *Medicine and Science in Sports and Exercise*, *38*(6), 1165-1174.

Leger, L., & Gadoury, C. (1989). Validity of the 20 m shuttle run test with 1 min stages to predict VO2max in adults. *Journal Canadien des Sciences du Sport*, *14*(1), 21-26.

Maclaren, D. P., Gibson, H., Parry-Billings, M. A. R. K., & EDWARDS, R. H. (1989). A review of metabolic and physiological factors in fatigue. *Exercise and Sport Sciences Reviews*, *17*(1), 29-66.

McLellan, C. P., & Lovell, D. I. (2012). Neuromuscular responses to impact and collision during elite rugby league match play. *The Journal of Strength and Conditioning Research*, *26*(5), 1431-1440.

McLellan, C. P., Lovell, D. I., & Gass, G. C. (2011). Performance analysis of elite rugby league match play using global positioning systems. *The Journal of Strength and Conditioning Research*, *25*(6), 1703-1710.

Morel, B., Rouffet, D.M., Bishop, D.J., Rota, S.J., & Hautier, C.A., (2015). Fatigue induced by repeated maximal efforts is specific to the rugby task performed. *International Journal of Sports Science and Coaching, 10(1),* 11-20.

Mullen, T., Highton, J., & Twist, C. (2015). The internal and external responses to a forward-specific rugby league simulation protocol performed with and without physical contact. *International Journal of Sports Physiology and Performance*, In Press.

Rampinini, E., Coutts, A. J., Castagna, C., Sassi, R., & Impellizzeri, F. M. (2007). Variation in top level soccer match performance. *International Journal of Sports Medicine*, (28), 1018-24.

Ramsbottom, R., Brewer, J., & Williams, C. (1988). A progressive shuttle run test to estimate maximal oxygen uptake. *British Journal of Sports Medicine,22*(4), 141-144.

Sampson, J. A., Gabbett, T., & Fullagar, H.H.K. (2015). Knowledge of bout duration influences pacing strategies during small-sided games. *Journal of Sports Sciences*, 33(1), 85-98.

Singh, T. K., Guelfi, K. J., Landers, G., Dawson, B., & Bishop, D. (2011). A comparison of muscle damage, soreness and performance following a simulated contact and non-contact team sport activity circuit. *Journal of Science and Medicine in Sport*, *14*(5), 441-446.

Sykes, D., Nicholas, C., Lamb, K., & Twist, C. (2013). An evaluation of the external validity and reliability of a rugby league match simulation protocol. *Journal of Sports Sciences, 31*(1), 48-57.

Takarada, Y. (2003). Evaluation of muscle damage after a rugby match with special reference to tackle plays. *British Journal of Sports Medicine, 37*(5), 416-419.

Twist, C., Waldron, M., Highton, J., Burt, D., & Daniels, M. (2012). Neuromuscular, biochemical and perceptual post-match fatigue in professional rugby league forwards and backs. *Journal of Sports Sciences*, *30*(4), 359-367.

Waldron, M., Highton, J., & Twist, C. (2013). The reliability of a rugby league movement-simulation protocol designed to replicate the performance of interchanged players. *International Journal of Sports Physiology and Performance*, *8*(5), 483-9.

Waldron, M., Highton, J., Daniels, M., & Twist, C. (2013). Preliminary evidence of transient fatigue and pacing during interchanges in rugby league. *International Journal of Sports Physiology and Performance*, *8*(2), 157-64.

Waldron, M., Twist, C., Highton, J., Worsfold, P., & Daniels, M. (2011). Movement and physiological match demands of elite rugby league using portable global positioning systems. *Journal of Sports Sciences*, *29*(11), 1223-1230.

West, D. J., Finn, C., Cunningham, D. J., Shearer, D. A., Jones, M. R., Harrington, B., Crewther, B. T., Cook, C. J. & Kilduff, L. P. (2014). Neuromuscular function, hormonal, and mood responses to a professional rugby union match. *The Journal of Strength and Conditioning Research, 28(1)*, 194-200.

Tables

Table I. Mean ± *s* relative distance, low intensity running and high intensity running for tackle sled (SLED) and bag (BAG) trials. Data in italics are effect size ±90% CI and qualitative descriptor for SLED vs. BAG comparisons.

		First half	**Second half**
Total (m·min^{-1})	SLED	105 ± 6	104 ± 5
		105 ± 5	103 ± 5
	BAG	0.07 ± 0.45	-0.07 ± 0.72
		Unclear	*Unclear*
Low (m·min^{-1})	SLED	76 ± 6	75 ± 6
	BAG	77 ± 4	76 ± 5
		0.16 ± 0.51	0.05 ± 0.59
		Unclear	*Unclear*
High (m·min^{-1})	SLED	29 ± 3	28 ± 3
	BAG	28 ± 3	27 ± 3
		-0.21 ± 0.34	-0.20 ± 0.42
		Possible ↓	*Unclear*

Low intensity running: <14 km · h^{-1}.

High intensity running: ≥14 km · h^{-1}.

Table II. Mean ± *s* %HR_{peak}, summated HR and RPE for tackle sled (SLED) and bag (BAG) trials. Data in italics are effect size ±90% CI and qualitative descriptor for SLED vs. BAG comparisons.

		First half	**Second half**
HR Peak (%)	SLED	85.9 ± 5.2	86.7 ± 5.7
	BAG	86.5 ± 5.5	86.2 ± 6.1
		0.11 ± 0.45	-0.09 ± 0.50
		Unclear	*Unclear*
Summated Heart Rate (AU)	SLED	90.4 ± 11.4	92.0 ± 9.8
	BAG	90.7 ± 15.22	91.5 ± 11.6
		0.02 ± 0.82	-0.04 ±0.75
		Unclear	*Unclear*
RPE	SLED	15.4 ± 2.0	15.5 ± 1.9
	BAG	14.9 ± 1.6	14.8 ± 1.8
		-0.25 ± 0.47	-0.34 ± 0.26
		Unclear	*Likely* ↓

Figures

Figure 1. Schematic of RLMSP-i identifying sprints and including time points for CMJ, blood lactate concentration and RPE measurement. The first sprint in each cycle is labelled “Sprint A”, the second sprint, “Sprint to contact” and the third, “Sprint B”.

Figure 2. Change in sprint to contact and sprint B speed during first and second half of simulation. Values are mean with ES; ±90 CI and qualitative descriptor between trials included.

Figure 3. Correlation between high intensity running and summated heart rate during BAG ($r=-.672$, $p < 0.001$).

Figure 4. Correlation between high intensity running and summated heart rate during SLED ($r=-.020$, $P = 0.930$).