

## THE INFLUENCE OF FATIGUE ON RUGBY LEAGUE PLAYERS: COMPARING COLLEGE AND CLUB COMPETITIONS

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### ABSTRACT

Few studies have considered the impact of varying match duration on injury rate and physiological demands in junior rugby league. Forty-two male junior rugby players from school ( $n = 24$ ; age  $M = 16.46$ ,  $SD = 0.83$  years) and club level ( $n = 18$ ; age  $M = 17.2$ ,  $SD = 0.55$  years) rugby were filmed in ten competitive matches and analysed using Sportscode Elite (V10, Hudl, USA). The school matches were 30 minutes less than club matches in duration. Data was standardised for duration for each variable. Differences between level were analysed using t-tests. Significant differences occurred in ball carries ( $p < 0.001$ ), injury frequency ( $p = 0.029$ ), passes ( $p = 0.0004$ ) and tackles ( $p = 0.006$ ), with club players experiencing relatively greater scores on each measure. The majority of injuries occurred in the second half, regardless of level (71% school, 73% club). In school rugby 43% of injuries were sustained by the tackling player; whereas in club junior rugby 46% of injuries were sustained by the tackled player. The injury rate (per 1000 hours) was greatest at the junior club level. The results show a difference in the demands on junior players determined by level.

### INTRODUCTION

Few studies have considered the physiological demands in junior rugby league and the influence of varying match duration, at junior levels, on injury rate. Previous research has indicated the physiological demands that require players to have good aerobic capacity ( $VO_2 \max$ ), speed, agility, muscular strength and power (Gabbett, 2001). Gabbett (2002) found that the  $VO_2 \max$  of junior rugby league players ranged from 32.1 to 46.1 ml/kg-l, showing a decrease in aerobic capacity when compared to professional and amateur players. However, no research has considered the influence of varying duration of match time.

Speed plays an important role in rugby league. Players are required to quickly organise themselves in attacking and defensive situations (Meir et al., 2001). Meir et al. (1993) found that rugby league players rarely sprint more than 40 metres. Junior rugby league players sprinting ten and 40 meters measured 2.58 and 6.63 seconds respectively (Gabbett, 2000, 2002). Amateur senior players were faster and measured 2.17 and 6.04 seconds across the same distances (Gabbett, 2000), and professional players were timed at 1.71 and 5.08 seconds (Meir et al., 2001; O'Connor, 1996; Twist et al., 2014). Rugby league players require agility in order to accelerate and decelerate to change direction (Twist et al., 2014). Gabbett (2002) used the Illinois agility test which found a difference between senior and junior rugby league players of 17.4 and 17.9 – 22 seconds respectively. Currently, the research supports

a difference between age group demands, but has not considered differences in demand due to varying time durations at the junior level.

In rugby league, players are required to generate rapid muscular force. This is important when tackling, pulling, lifting and pushing during games (Gabbett, 2003). Baker (2001 & 2002) showed that the professional rugby league player has greater lower body strength than high school junior rugby league players. Vertical jump is another way of measuring lower muscular strength. The results from junior rugby league players show jump heights of 50-58 cms (Gabbett, 2007). Professional rugby league players have shown a 30% increase in performance of vertical jumps when compared to junior players (Gabbett, 2000). The literature has shown various differences in attributes when comparing senior and junior rugby league players. Aerobic capacity, speed, agility, muscular strength and power are all attributes that are shown to increase when the standard of play increases (Gabbett, 2002).

### **Effect of Fatigue on Defensive Skills**

The success of rugby league games is partly attributed to tackling ability and winning tackling situations (Twist et al., 2012). Gabbett (2008) showed that fatigue produces progressive decrements in tackling technique. Interestingly, players who showed the best technique (pre-fatigue) experienced the greatest reductions in tackling technique when fatigued. If coaches are able to minimise the fatigue associated with game-specific repeat sprint efforts, fatigue during tackling would decrease, allowing for an increase in quality (Gabbett, 2008).

### **Effect of Fatigue on Attacking Skills**

Johnston, Gabbett and Jenkins (2013) suggested that junior rugby league performance decreased due to fatigue during an intensified competition. Major reductions in distance, high-speed sprints, low-speed running and repeated sprint ability were found. Gabbett (2013) showed that higher match intensity, and greater distance covered at low and high speeds, were strongly correlated to winning teams in rugby league competitions. Therefore, reductions in these variables may prove beneficial for the outcome of match play in rugby league (Johnston, Gabbett, & Jenkins, 2013).

### **Incidence of Injury**

Increase in playing standard correlated with increased playing intensity, which has shown an incremental rise in injury rates (Gabbett, 2003; King et al., 2006; Gabbett, 2001). Data was standardised as the number of injuries per 1000 hours of play. Gabbett (2000) provided evidence showing the injury rate of amateur players to be 160.6 per 1000 playing hours. Interestingly, a review of amateur rugby league players participating in a seven-player tournament showed an overall injury rate of 285.5 per 1000 hours. Gabbett (2001) showed that occurrence of injury in amateur rugby league was less than that of professional rugby league, acknowledging reduced playing intensity of amateur matches compared to professional matches as the main reason for this difference. The majority of injuries in amateur (Gabbett, 2001) and professional (Stephenson, 1996) matches occur during tackles. Results from rugby league reveal that tackled players suffer more injuries than the tackling player (Gabbett, 2003; King et al., 2006; Stephenson, 1996). However, this finding is reversed in studies of amateur players, showing the tackler sustaining more injuries than the tackled (Gabbett, 2001).

Reductions in tackling technique due to fatigue in amateur rugby league have been shown to increase injury rate (Gabbett & Domrow, 2005; Gabbett, 2008).

### **Time of Injury**

The timing of injury is important in identifying whether extended game time results in decrements in quality in junior rugby league. Insight as to when injuries occur could provide evidence for making suggestions on how to select and qualify the length of the game. Gabbett (2000) found that in amateur rugby league, more than 70% of

injuries occurred in the second half of play. This reflected the notion that reductions in skill due to fatigue contribute to the occurrence of injuries. Semiprofessional players, however, show a significantly lower rate of injuries sustained in the second half. This conflicting evidence is most likely due to increased levels of aerobic fitness resulting in reductions in fatigue-induced injuries (Gabbett, 2003).

No study has investigated the relationship between injury occurrence and timing of play in junior rugby league. Johnston et al. (2013) showed that junior rugby league players showed increases in muscular fatigue over a five-day competition. Results show that highest decrements in physical performances due to fatigue were observed on days 4 and 5. Although no studies have documented when the majority of injuries in junior rugby league occur in the game, studies have shown that the rate of fatigue induced by game play decreases as the playing standard increases (Gabbett 2000; 2002; 2003).

The few studies that have focused on junior rugby league have found that the physiological demands placed on junior rugby league players differ dramatically from those placed on senior and professional players. This has been attributed to increased fitness and the greater neural and muscular adaptations experienced in training five days a week (professional players), as opposed to two days (junior players). These adaptations to training and increased fitness levels have been shown to reduce the rate of muscular and mental fatigue, which is a causal factor in decrements in skilled performance. Tackle technique in rugby league – and some offensive skills in other sports – have been shown to diminish during fatigue-induced game situations, with the rate of injury increasing as the standard of play increases. While most studies agree that the majority of injuries occur in tackles, there is conflicting evidence whether the tackled or tackling player sustains more injuries. In amateur rugby league, the tackling player sustains the majority of injuries, more often in the second half. It is plausible that similarities in junior rugby league can be found. However, no studies exist documenting the timing of injury in junior rugby league.

There are few existing studies on the effects of match play in junior rugby league, and gaps in research are evident. The purpose of this study was to (1) investigate the impact of varied match duration on performance; and 2) identify differences in injury rate due to match duration in junior rugby.

## **METHODS**

### **Design**

The performance indicators of 42 male rugby players at two levels, school ( $n=5$ ) and club ( $n=5$ ), were analysed using Sportcode Elite (V10, Hudl, USA) during ten competitive games during their season. Both team had been respective champions of their grade for the past few seasons.

### **Participants**

The school rugby players ( $n = 24$ ; age  $M = 16.46$ ,  $SD = 0.83$  years) competed in the College Rugby League (CRL), and the club rugby players ( $n = 18$ ; age  $M = 17.2$ ,  $SD = 0.55$  years) in the ARL under-18 open competition (CLBRL). Ten games from each competition were filmed and coded. Written consent was provided by each participant.

### **Procedure**

The procedure followed a variation of the protocol devised by Nicholas et al. (2004). Live footage of each game was captured through a single video camera positioned parallel to the halfway line. Each game was coded (Sportcode Elite V10, Hudl) with reference to the pre-defined performance indicators (Table 1).

## Ethics

Institutional ethical approval was granted by Auckland University of Technology ethics committee prior to the start of the study.

## Performance Indicators

Performance measures were identified (Hughes & Barlett, 2002) using research from previous studies (Eaves & Broad, 2007; Hughes & Franks, 2004; Lago-Penas, Lago-Ballesteros, Dellal, & Gomez, 2010; Twist et al., 2014). The performance actions were then refined to form an extensive list of key indicators in rugby league (Table 1).

Performance indicator	Definition
Successful passes (as % of team passes)	A deliberate attempt to pass the ball to a teammate, resulting in retention of possession.
Successful tackles (as % of team tackles)	A physical act made by the analyzed team that results in halt of play, until the attacker returns to their feet.
Ball Carries	An attempt of the attacking team running the ball towards the defense, gaining meters and getting tackled. Stipulated by a halt of play, resulting in retention of the ball.
Line breaks (as % of total team carries)	An attempt of the analyzed team running the ball towards the defense resulting in a breach of the opposition's defense. This action is classified by no halt in play and no increase in the tackle count.
Points for	An action that results in addition of points to the scoreboard for the analyzed team. When either a try, conversion, drop goal or penalty kick is signaled by the official in charge
Points against	An action that results in the addition of points to the scoreboard of the non-analyzed team. When either a try, conversion, drop goal or penalty kick is signaled by the official in charge
Attacking errors	An action by the analyzed team that results in a hand over of possession. Classified by a knock on, forward pass, offside, out of bounds or false play of the ball at the referees discretion.
Defensive errors	An action by the analyzed team that results in penalization and a reset of the tackle count. Actions include high tackles, dangerous tackles, failure to release attacker and defensive line not receding 10 meters as deemed by the referee.
Incidence of injury	Any pain or disability endured by a player, which results in assessment by the manager immediately or after the match. With particular significance on the timing of injury and who (tackler or tackled).
Send offs	An illegal action that results in a player of the analyzed team being penalized by a yellow card (10 minute absence) or dismissal (sending off) as deemed by the referee.

Table 1. Key Performance indicators identified in junior rugby league

## Reliability

Discrepancies of <5% error were achieved, consistent with previous studies (Hughes & Barlett, 2002; Nevill, Atkinson, Hughes, & Cooper, 2002), to prove the reliability of the analysis.

Intra-observer reliability was assessed through repeat analysis of three games. Discrepancies of <5% error were achieved, consistent with previous studies (Hughes & Barlett, 2002; Nevill, Atkinson, Hughes, & Cooper, 2002) to confirm reliability.

## Data Analysis

Descriptive statistics present the frequency of each performance indicator. An independent t-test was conducted to establish whether a significant difference existed between groups. Effect size and magnitude measures described the strength (Drinkwater, Hopkins, McKenna, Hunt, & Pyne, 2007).

Player injuries, successful passes and successful tackles were displayed as percentages. As CRL and CLBRL duration differed by 30 minutes, percentage data allowed comparisons to be drawn. To be comparable with previous studies, the injury rate per 1000 hours (IR) was calculated using the equation found in Phillips et al. (1998).

## RESULTS

Table 2 shows the descriptive statistics regarding the performance indicators of both college and club rugby league. There were significant differences for level played.

Ball carries showed a significant difference between CRL (M=85, SD= 12) and CLBRL (M=138.8, SD=10.6),  $t(7) = -7.3$ ,  $p = 0.0001$ ). The incidence of injury was significantly different for level, with CRL (M=1.4, SD=1.1) and CLBRL (M=4.4, SD=2.1),  $t(6) = -2.8$ ,  $p = 0.029$ . Mean passes were significantly different between the levels, with CRL (M=70, SD=1.6) having less than CLBRL (M=132.8, SD=18.1),  $t(8) = -5.8$ ,  $p = 0.0004$ . College mean tackles – CRL (M=80.2, SD=11) – was less than club, with CLBRL (M=136.8, SD=26.6),  $t(5) = -4.4$ ,  $p = 0.006$ . Although there was a large magnitude of difference for attacking errors – CRL (M=7-6, SD=1.9) and CLBRL (M=10.2, SD=1.9),  $t(8) = -2.1$ ,  $p = 0.067$  – it was not significant.

Performance Indicators	College		Club		t	f	P value	Effect size
	Mean	SD	Mean	SD				
Attacking Errors	7.6	1.9	10.2	1.9	-2.1	8	0.067	LARGE
Defensive Errors	5	3.8	5.8	2.2	-0.4	6	0.697	SMALL
Ball Carries	85	12	138.8	10.6	-7.3	7	0.0001*	LARGE
Injury	1.4	1.1	4.4	2.1	-2.8	6	0.029*	LARGE
Passes	70	16.2	132.8	18.1	-5.8	8	0.0004*	LARGE
Points against	4.8	2.6	4.2	2.8	0.4	8	0.733	SMALL
Points for	7.4	3.8	9.8	6.4	-0.7	7	0.494	SMALL
Send offs	0	0	0.2	0.4	-1.0	4	0.374	MODERATE
Tackles	80.2	11	136.8	26.6	-4.4	5	0.006*	LARGE

Table 2. Mean and standard deviations of performance indicators enabling comparison between college and club rugby league

The majority of injuries occurred in the second half (Fig. 1) – 71% and 73% for college and club competitions respectively. Of the 71% of all injuries that occurred in the second half (Fig. 2) during the college competition, 43% were sustained by the tackling player (TKR). This differs from the club competition, where of the 73% of injuries that occurred in the second half, 46% were sustained by the tackled player (TKD).

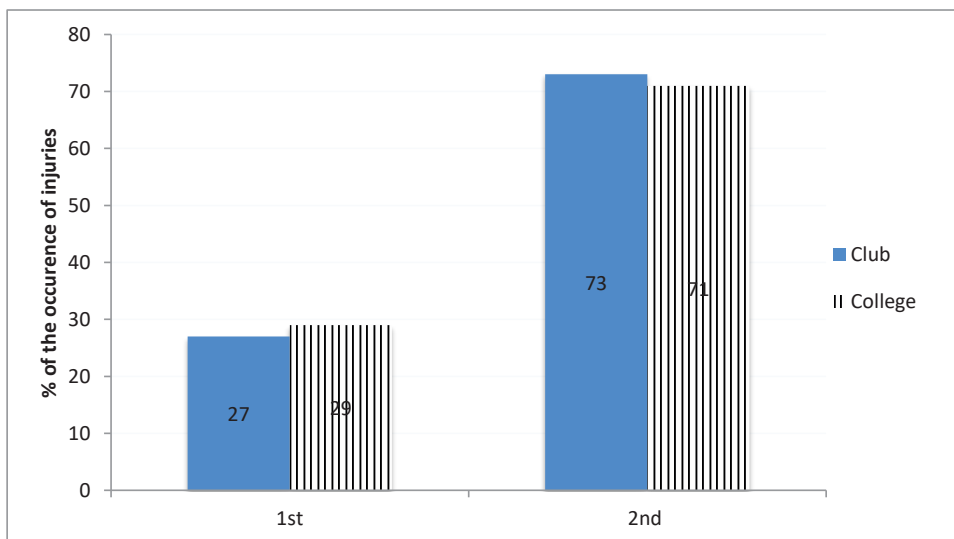


Figure 1. Percentage of injuries in the first and second half regarding college and club rugby league

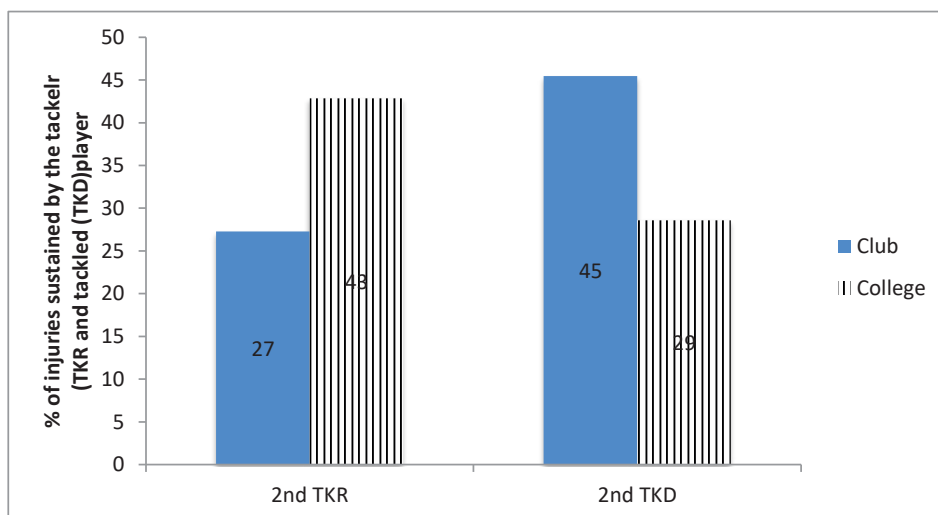


Figure 2. Percentage of injuries sustained by the tackler and tackled player in the second half

There was significant increase in IR for club players (IR = 254.4) compared to college (IR = 129.7); the club IR is almost double the college IR (Fig. 3).

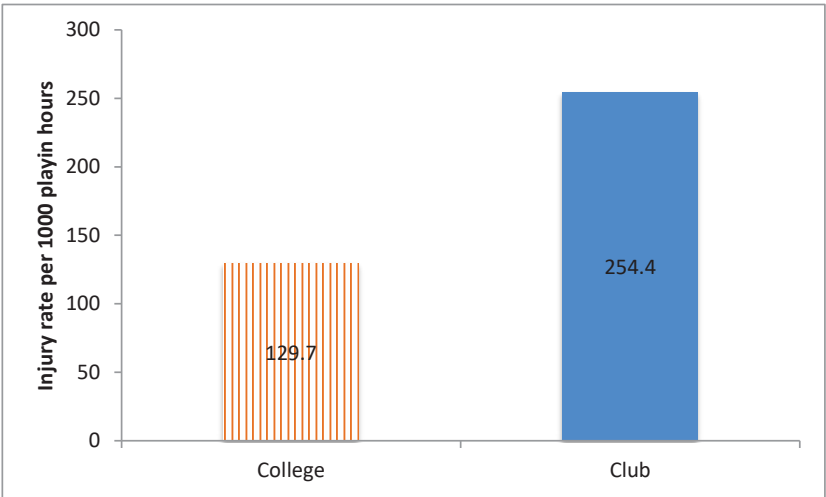


Figure 3. Injury rate of college and club rugby league per 1000 hours of play

Figure 4 compares the percentage of successful tackles in the first and second halves for the college and club competitions. Reductions in the percentage of successful tackles are shown in four out of the five games analysed in the CLBRL competition. However, findings from the CRL competition show that players are equally likely to increase or decrease the rate of successful tackles, indicating that no correlation exists.

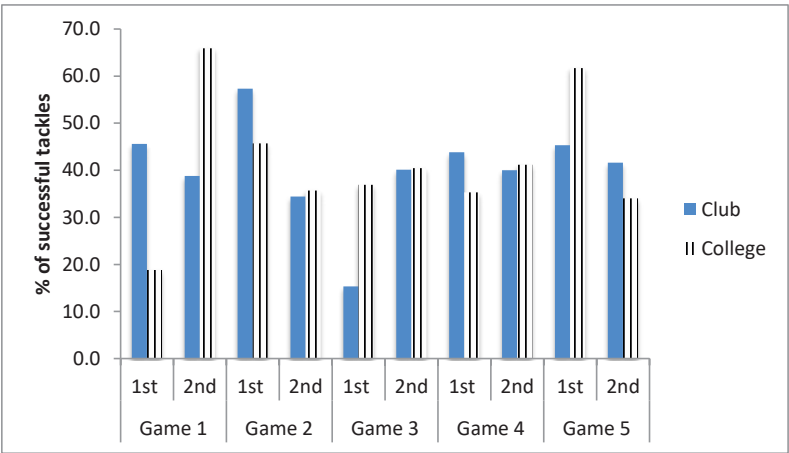


Figure 4. Percentage of successful tackles in the first and second half regarding college and club rugby league

Figure 5 highlights the consistent reduction in the number of successful passes from the first to the second half in both college and club rugby league. Out of the five games played in CRL, four showed decreases in successful passes. The highest percentage reduction was found in game 3 (55%) and the lowest in game 5 (28%). Similar results were found in CLBRL, where the highest decrease in successful passes was shown in game 4 (36%), and the lowest in game 2 (6%).

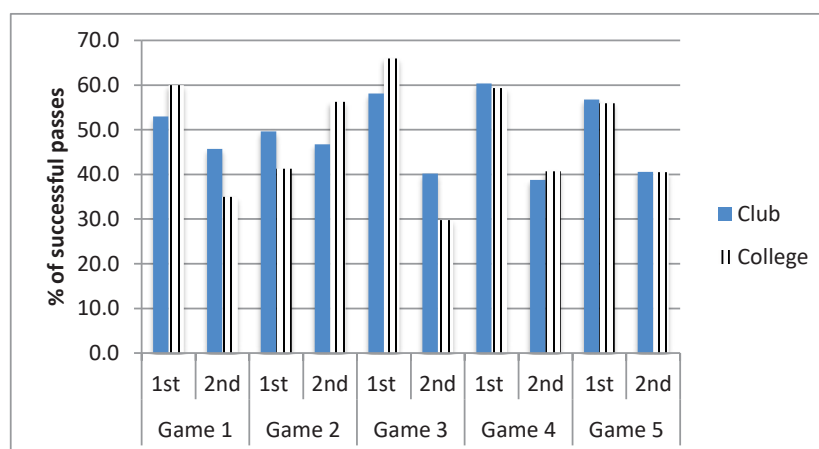


Figure 5. Percentage of successful passes in each half during college and club rugby league

## DISCUSSION

The purpose of the present study was to identify the key game-related statistics that would enable comparisons between college (CRL) and club rugby league (CLBRL) in New Zealand. Our investigation specifically explored the performance indicators that directly influenced the quality of game play and incidence of injury, using a combination of frequency and percentage data for each indicator (Hughes & Barlett, 2002). The present study suggests that changes to the duration of play significantly impact the incidence of injury and quality of game play in junior rugby league. Further studies investigating the consequences of extended game time on player fatigue, impacting the quality of play and incidence of injury in junior rugby league, are warranted.

### Incidence of Injury

Research into the incidence of injury in junior rugby league is limited (Gabbett, 2014; Johnston et al., 2013). Data that is not collected and analysed in a standardised fashion is not easily comparable. Therefore, previous studies have expressed the incidence of injury in terms of the number of injuries per 1000 hours of play (Phillips, Standen, & Batt, 1998).

The present study shows that the incidence of injury in CLBRL (254.5 injuries per 1000 hours) is higher than that of CRL (129.7 injuries per 1000 hours). A comparable study conducted by Gabbett (2000) showed that amateur rugby league players display an overall injury rate of 160.6 injuries per 1000 hours of play. Although this result is comparable to injuries sustained in CRL (24% increase), the CLBRL format displayed a 58% increase in injury rate compared to the study by Gabbett (2000). Similar research by Gabbett (2002) showed an incidence of injury in amateur Australian rugby league players of 283.5 per 1000 hours, which echoes the results of the present study when compared to CLBRL (254.5 injuries per 1000 hours). Interestingly, the incidence of injury in professional and

semi-professional rugby league has been reported at 346 (Hodgson-Phillips et al., 1998) and 824.7 (Gabbett, 2003) per 1000 hours respectively.

The increased injury rate of semi-professional players compared to amateur players could be expected as a result of the inferior physiological capabilities of players in amateur grades (Gabbett, 2002B; 2003). This is confirmed by findings in previous studies, which suggest an increased playing intensity during games which subject players to higher injury rates (Gabbett, 2004; King et al., 2006). Interestingly, the results of the present study suggest that junior players in CLBRL are comparable with amateur (Gabbett, 2002B) and semi-professional (Gabbett, 2003) rugby league players in this respect.

Although both groups were investigated using the same integrity, the only differences between groups were playing times. The CRL played a total of 50 minutes, a modified version of the National standard of 80 minutes under which the CLBRL completion was governed. This resulted in the CLBRL completing an extra 30 minutes of play, which would provide biased data. However, injury rates were standardised to calculate the number of injuries per 1000 playing hours. Therefore, it is conceivable that the playing intensity of CLBRL is significantly higher than that of CRL (King et al., 2006), which would explain the significantly higher incidence of injury.

The increased period of play allotted to players in the CLBRL is designed for professional players who typically dedicate 5-6 days to improve their power, strength and muscular endurance (Phillips et al., 1998). Their physiological adaptation to training allows professional players to compete at a high standard for a prolonged period of time. It can be suggested that junior rugby league players lack the physiological characteristics to maintain a high quality of play over 80 minutes of play. The results of the present study and previous literature suggest that junior rugby league players who are subjected to 80 minutes of play show dramatic increases in the risk of injury.

### Timing of Injury

The present study found that 71% and 73% of all injuries sustained in CRL and CLBRL occurred in the second half of play respectively. These findings agree with Gabbett (2000), who showed that approximately 70% of injuries in amateur games occurred in the latter half of play. King et al. (2006) suggest that muscular fatigue induced by increased game time is likely to contribute to injuries in amateur rugby league. Contrarily, injuries sustained in the second half are significantly lower (38%) in semi-professional matches (Gabbett, 2003). The reduced injury rate of semi-professionals in the second half indicates the important role that aerobic fitness plays in reducing injuries related to fatigue (Gabbett, 2005). At the same time, studies of professional rugby league prove that players are equally likely to sustain injuries in either half (Stephenson et al., 1996).

To the authors' knowledge, there is no existing study investigating the incidence and timing of injury in junior rugby league. Johnston et al. (2013) is the only study that investigates the influence of muscular fatigue in junior rugby league over a five-day competition. The study revealed that the highest rates of fatigue occurred in the final days of competition. The findings of all the studies discussed here, including the present study, suggest that as the playing standard increases, the rate of fatigue and potential injury decreases (Gabbett, 2000; 2002; 2003). The present study clearly shows that the majority of injuries occur in the second half of competition, similar to findings for amateur matches.

Consistent with the findings of prior studies of amateur (Gabbett, 2002B) and professional (Gissane et al., 2002; Stephenson et al., 1996) rugby league players, the current study found that the majority of injuries were sustained during tackles. We concluded that 57.1% of injuries during tackles were sustained by the tackler (TKR) in CRL. This is consistent with the work of Gabbett (2001), who found that the majority of injuries to amateur rugby league players were sustained by the TKR. However, these results differ from CLBRL, where 59% of injuries were sustained by the tackled player (TKD). This finding is more consistent with professional rugby league players, where the majority of injuries were sustained by the TKD (Gissane et al., 2002; Hodgson-Phillips, 2000). Interestingly, this suggests that the intensity of play in CLBRL is comparable with the professional standard. Further analysis of the

breakdown of injuries in Figures 1 and 2 shows that of the 71% of injuries that occurred in the second half, 43% of them were sustained by the TKR in CRL. This is a blatant indicator proving that as muscular fatigue increases, the rate of injury increases (Gabbett, 2000; 2002; 2003). This finding also demonstrates that increased fatigue correlates to incremental reductions in tackling technique for junior and amateur players (Gabbett, 2008; Johnston et al., 2013).

Results from the CLBRL contradict these findings, as 63% of injuries in the second half were sustained by the TKD. Based on previous research investigating the contribution that fatigue plays in increasing injury rates (McLellan et al., 2011; Twist et al., 2012), this finding suggests that players in the CLBRL competition possess superior aerobic fitness and muscular characteristics, which could in turn be attributed to them performing more frequent higher-intensity trainings sessions, allowing the adaptations acquired from training to improve physical performance. Conversely, the CLBRL players may have been subjected to a higher standard of defensive coaching – more specifically, tackling technique. This could explain the high incidence of injury to the TKD players in CLBRL.

### **Effect of Fatigue on Defensive Skill**

Our findings regarding CRL are in agreement with Gabbett (2008), who show that muscular fatigue results in incremental reductions in tackling technique. Gabbett's study goes on to assert that participants who showed superior tackling technique during the non-fatigued state exhibited the highest decrement in technique in fatigued conditions. This information is vital to coaches and players concerned with preventing injuries due to tackling. Drills focusing on improving tackling should be performed in the fatigued state, rather than in a non-fatigued state. The present study highlights these findings by showing that the majority of injuries sustained by the TKR occurred in the second half in CRL. Gabbett (2013) showed that notable reductions in physical performance occurred in the second half of play (compared to the first half) in junior rugby league. This finding reflects the work of Johnston et al. (2013A), who measured the physiological responses of players during three games of rugby league over five days. This investigation showed steady detriments in successful tackles performed in game 1 (82%), game 2 (82%) and game 3 (72%). These results are in agreement with Johnston et al., (2013B), who showed similar detriments in successful tackles in junior rugby league starting from game 1 (87%), game 2 (84%), game 3 (72%), game 4 (76%) and game 5 (81%). Our findings for CLBRL are congruent with these previous studies, showing consistent reductions in successful tackles from the first to the second half in four of the five games played (Figure 4).

Interestingly, the results of our study indicate that no particular trend could be found for successful tackles in CRL. Figure 4 shows the increases in successful tackles in games 1, 3 and 4, as well reductions in games 2 and 5. This could be credited to the duration of game time allotted to each competition. The CLBRL players experienced a full 80 minutes of play, compared to the modified 50 minutes allotted to CRL. The shorter game resulted in a reduced injury rate and increased quality of play, allowing players in the CRL to maintain a dynamic game. It is well documented that increased duration and intensity of game play correlates to increased rates of fatigue, which in turn reduces players' physical capabilities during games and training (Cormack et al., 2008; Gabbett, 2008; McLellan et al., 2011; Tee et al., 2002; Twist et al., 2012). Our findings suggest that 80 minutes of play is not a suitable format for junior rugby league players to be competing in, due to the increased rate of injuries experienced later in the game. However, further research into muscular fatigue and its associations with injury in junior rugby league is required.

### **Effect of Fatigue on Attacking Skill**

Because decreases in physical performance during tackling have been attributed to the effects of fatigue, it is conceivable that attacking skills suffer similar detriments (Gabbett, 2008). Although there are few studies investigating the effects of fatigue on attacking skills in rugby league (Gabbett, 2013; Johnston et al., 2013A; Johnston et al., 2013B), a plethora of evidence is available in other sports such as tennis, football and water polo (Davey et al., 2002; McMorris & Graydon, 1997; Rampini et al., 2009; Royal et al., 2006).

As shown in Figure 5, our results display a consistent reduction in the percentage of successful passes from the first to the second half in both CRL and CLBRL. The results agree with Davey et al. (2002), who found a 69% and 30%

decline in accuracy for the ground stroke and shots to the right-hand side respectively in fatigued tennis players. This corresponds to the study by Rampini et al. (2009), who showed a decrease in short passes performed from the first to the second half due to fatigue. However, the percentage of successful short passes remained unchanged. This is consistent with Royal et al. (2006), who found a 43% deterioration in technique efficiency in a fatigued state in men's water polo shooting, but with no effect on accuracy. The studies completed by Rampini et al. (2009) and Royal et al. (2006) assessed the performance of highly skilled elite athletes whose bodies have adapted to maintain performance at higher exertion rates. Junior rugby league presents a very different scenario. The physiological immaturity of the players in the present study may explain why, in our findings, the success rate for passes is incrementally reduced as the game progresses.

The combined evidence suggests that attacking and defensive skills are equally affected by muscular fatigue in rugby league and other sports. It is suggested that junior players are more susceptible to injuries due to their immature muscular skeletal system (Hoskins et al., 2006). Evidence of major decreases in distance covered, repeated sprint ability and low-speed running (Gabbett, 2013) concur with the present study's findings of reductions in attacking and defensive skills due to fatigue. Any prolonged period of play is likely to stimulate and increase the rate of muscular fatigue and therefore injuries, subsequently reducing the quality of play in fatigued conditions (Johnston et al., 2013A).

## CONCLUSION

This study provides useful insights into the quality of game play when comparing college and club rugby league in New Zealand. It is evident that the incidence of injury in club rugby league is significantly higher than that of its college counterpart. Our findings show that the rate of injury for the CLBRL is comparable to that of semi-professional players. Our study also investigated the timing of injury. Agreeing with previous studies investigating amateur matches, we found that the majority of injuries occurred in the second half of play in both college and club matches.

To the authors' knowledge, the present study is the first to investigate the effect of fatigue in both defensive and attacking skills in junior rugby league. We have shown that muscular fatigue induced by game play progressively reduces the number of tackles performed, from the first to the second half of play, and produces incremental decreases in tackling technique, thus increasing the risk of injury to the tackling player. In alignment with the previous literature, we found that the percentage of successful tackles diminishes when comparing the first and second half of play in junior rugby league.

## Application

Our findings underlined the correlation between detriments in player performance and muscular fatigue induced by game play. If coaches are able to reduce the effects of fatigue through match-specific training programs over a given period of time, the physiological adaptations achieved would reduce game-related fatigue and subsequently the incidence of injuries during tackles and later in the game. Consistent with the previous literature, we found that muscular fatigue plays a vital role in the progressive reduction of both attacking and defensive skills. Fitness programs focused specifically on increasing muscular strength and endurance may play a protective role here, allowing players to endure physical contact and minimise muscular fatigue respectively. Gabbett (2008) showed that players with the best tackling technique in a non-fatigued state showed the greatest reduction in technique under fatigued conditions. Our study suggests that similar detriments exist for attacking skill. Thus it is essential that training focused on improving both defensive and attacking technical skills be performed in the fatigued state, simulating game-specific environments.

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