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— NEW ZEALAND —

New Zealand Blackcurrant extract supplementation does not improve repeated sprint ability

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ABSTRACT

Blackcurrants are an excellent source of antioxidant and anti-inflammatory agents, and recent studies have found them to facilitate performance and recovery in aerobic activities. However, limited research exists in intermittent or anaerobic settings despite known oxidative and inflammatory stresses. Therefore, we examined the effects of New Zealand Blackcurrant (NZBC) on repeated sprint ability (RSA) and recovery parameters. Sixteen recreationally active females were supplemented with either NZBC (1.6mg.kg⁻¹ anthocyanin content; ViBERi, Timaru, New Zealand) or a matched placebo (artificial sweetener) for 7 days in a randomized, double-blind, parallel-group design. On day 7 participants performed the RSA test which consisted of ten 30m shuttle sprints interspersed with a 30 second recovery period. Blood lactate was assessed 1-, 3-, 5-, and 10-minutes post-test. The same protocol was then replicated the following day. NZBC improved mean sprint time from baseline by 2.0% and fastest sprint time by 2.7%. Placebo also improved sprint time by 2.3%. Compared to the placebo group the NZBC group typically performed better in all RSA test outcomes, however the differences were deemed unclear and non-significant. Lactate responses post RSA on average tended to be higher on both days for the NZBC group compared to placebo group (15.1 – 32.5%). A moderate difference (ES: -0.64) was observed between groups post 7-days of supplementation for lactate clearance from 5-minutes to 10-minutes post-test with NZBC leading to a decrease of 23.7%. In conclusion, NZBC supplementation for 7-days does not improve repeated sprint ability when compared to placebo.

1. Introduction

New Zealand Blackcurrant (NZBC) supplementation has received growing attention from the sports science community, alongside a boom in other plant-derived compounds such as capsaicin, menthol and tart cherry juice (Best et al., 2020; Kuehl et al., 2010; Rosenbloom, 2016; Stevens & Best, 2017), often termed functional foods (Knab et al., 2013; Milivojevi et al., 2013). NZBC is a rich source of the flavonoid pigments anthocyanins which are responsible for the characteristically purple color of NZBC and are purported to confer health and performance benefits (Konczak & Zhang, 2004; Milivojevi et al., 2013).

NZBC supplementation has been shown to improve cycling performance (Cook et al., 2017a; Murphy et al., 2017; Willems et al., 2014), volume of high intensity running in repeated sprint protocols (Perkins et al., 2015; Willems et al., 2016), and recovery from exercise (Lyall et al., 2009; Murphy et al., 2017; Willems, Myers, Gault, & Cook, 2014). Mechanistically, NZBC supplementation elicits improvements in fat oxidation, total hemoglobin, lactate clearance, lactate production and vasodilation (Cook et al., 2017a; Cook et al., 2017b; Perkins et al., 2015; Willems et al., 2014). More specifically, flow mediated dilation may be increased following anthocyanin supplementation, with a

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possible increase of nitric oxide availability and a concomitant impairment of NADPH oxidase (Rodriguez-Mateos et al., 2013). Interestingly, these improvements occur across a range of exercise intensities and exercise modalities, suggesting that the beneficial effects of NZBC supplementation whilst far reaching may pertain to energy system predominance. This is further supported by NZBC ability to modulate oxidative responses to exercise (Cook et al., 2017a).

To date research has primarily investigated NZBC supplementation at predominantly aerobic intensities, with the maximum controlled intensity being 110% $v\text{VO}_{2\text{max}}$ (Perkins et al., 2015). Whilst time trial data have also been presented (Cook et al., 2017a; Murphy et al., 2017), these are also aerobic in nature, with time to completion approximately 6 – 30 minutes (Cook et al., 2017a; Lyall et al., 2009; Murphy et al., 2017). Classical evidence shows that aerobic fitness improves athletes' rate of lactate clearance but not lactate production (Donovan & Brooks, 1982; Sahlin & Henriksson, 1984), whereas recent evidence shows an increased reliance upon anaerobic metabolism is positively correlated with repeated sprint outcomes (Miloni et al., 2017). NZBC supplementation affects both lactate production and clearance (Willems et al., 2015), suggesting investigation into anaerobic activities and NZBC supplementation is warranted. Such investigation expands NZBC supplementation beyond endurance activities, with only two papers published to date in an intermittent or team setting (Perkins et al., 2015; Willems et al., 2016).

The optimal dose of NZBC supplementation has not currently been reported; however, studies have indicated dose dependent effects (Cook et al., 2017a). Absolute doses have been explored (typically $300\text{mg}\cdot\text{day}^{-1}$), yet many commonly used sports nutrition interventions typically employ relative doses. The exploration of a relative dose encourages personalization of NZBC supplementation strategies and may elucidate a minimal worthwhile dose.

The aim of this study is to examine the effect of 6 and 7-days' supplementation of a relative dose of NZBC on variables pertaining to repeated sprint ability against a dose matched placebo treatment. It was hypothesised that mean sprint time would be lower in the NZBC group, potentially via an attenuation of sprint time decrements in the latter stages of exercise due to lower rates of lactate accumulation and a possible increase in aerobic contribution.

2. Methods

2.1. Participants

Sixteen recreationally active females were recruited for this study. Utilizing a customized spreadsheet (Hopkins, 2010) all participants were allocated to either the blackcurrant or placebo group using minimization of means. Allocation was based on the rank order according to the mean sprint result of the 10 sprints of the repeated sprint ability (RSA) test performed during baseline testing. Three participants in the blackcurrant group (3 out of 8; 37.5%) and one participant in the placebo group (1 out of 8; 12.5%) withdrew from the study owing to injury or illness throughout the supplementation period. Characteristics for the participants that completed the supplementation period and all RSA testing sessions are summarized in Table 1. All participants provided informed voluntary consent and completed a health screen prior to physical testing. This study was approved by the Institute's Human Research Ethics Committee.

Participants attended three sessions within 16 days. The first session acted as a baseline testing session to determine group allocation. Sessions 2 and 3 were test trials conducted on consecutive days, 6- and 7-days post supplementation. Each participant completed all sessions at the same time (6:00 – 8:00 a.m.) and with the same environmental conditions ($15.2 \pm 1.8^\circ\text{C}$ temperature and $67.0 \pm 8.5\%$ relative humidity) to minimize the influence of circadian variation. Testing was conducted indoors at a recreational training facility. Participants were required to wear comfortable running shoes and sportswear.

2.2. Protocol

Utilizing a double-blind parallel group study design, participants were supplemented with either NZBC ($1.6\text{mg}\cdot\text{kg}^{-1}$ anthocyanin content; ViBERi, Timaru, New Zealand) or a matched placebo (artificial sweetener) for seven days. NZBC and placebo supplementation was administered in opaque gelatine capsules, which were provided to each participant in sealed envelopes, to maintain double blinding. Supplementation commenced six days prior to the first RSA test trial and ended following the completion of the first RSA post-test allowing for a total of seven doses on consecutive days. This design was intended to reflect a weekend tournament in team sports, or a heat and final taking place on consecutive days.

Table 1: Participant characteristics in NZBC and placebo supplement groups. Values are mean \pm standard deviation.

	Blackcurrant (n = 5)	Placebo (n = 7)
Age (years)	25 \pm 4	31 \pm 7
Body mass (kg)	61 \pm 9	65 \pm 9
Height (cm)	165 \pm 5	167 \pm 4
Training (sessions/week ⁻¹)	5 \pm 1	8 \pm 1

Participants were instructed to consume the supplementation as part of their morning eating regime. Participants were recommended to moderate habitual exercise intensity for the 48 hours prior to exercise and consume their habitual diet. Dietary manipulation or restriction of anthocyanin-rich foods was not part of this instruction, so as to not introduce bias before study commencement. Whilst dietary controls were not stringent, the use of consecutive testing days may serve to further minimise any potential confounding brought about by bioavailability or lack thereof, as anthocyanins remain in circulation for as long as 48 hours post-consumption (Kay, Mazza, & Holub, 2005).

Prior to commencing the RSA test, participants completed a standardised 15 min warm-up consisting of low-intensity shuttle runs, directed dynamic stretching and self-selected static stretching. A pre-test lactate measure was then taken (fingertip (non-preferred ring finger); Lactate Pro 2 LT-1730, Arkray Factory Inc., Japan).

The RSA test consisted of ten 30-m shuttle sprints (15-m + 15-m), each with a single change of direction of 180° interspersed with a 30-second recovery period (Padulo et al., 2016). The test required participants to begin on the start line with their self-selected front foot placed behind a marker in a split stance. The start marker was placed 0.5-m behind a set of wireless timing light gates (SpeedLight V2 timing gates, Swift Performance Equipment, Queensland, Australia) to avoid participants prematurely breaking the infrared beam. Participants then sprinted as fast as possible to the 15-m turning line, touching the line with one foot, turning and sprinting back through the gate at the start line. Participants then decelerated to a walking pace to the baseline (5-m) and back to the start line ready for the next sprint in 30 seconds. Recovery time was monitored via a hand operated stopwatch when the participant returned past the start line. Remaining recovery time was verbally indicated to the participants by the research practitioner at 10 seconds then 3, 2, 1 and zero seconds. At time zero a “Go” command was verbally provided. Verbal encouragement was provided by the research practitioner to the participants throughout the RSA test to motivate maximal effort.

The outcomes derived from the RSA test were mean sprint time of the 10 sprints, fastest sprint time from the 10 sprints, slowest sprint time from the 10 sprints and a fatigue index. The fatigue index was considered as a % decrement in performance, calculated according to Oliver (2009):

$$\% \text{ decrement} = \left(\frac{\text{mean sprint time} - \text{fastest sprint time}}{\text{fastest sprint time}} \right) \times 100$$

Following completion of the RSA-test at testing sessions two and three, post lactate measures were taken. Participants remained seated throughout the collection period (~15 min), with samples taken at 1 minute, 3 minutes, 5 minutes, and 10 minutes post completion of the RSA-test. During this post-test period, only water was permitted. No food or other beverages were permitted.

Subjective responses in the form of rating of perceived exertion (RPE) were recorded during the recovery period at the completion of each shuttle sprint at all testing sessions.

2.3. Statistical Analyses

Utilizing the comparative methods of Hopkins (2006) and using a spreadsheet for the analysis of post only trials, comparisons were made between trials for repeated sprint ability outcomes and blood lactate responses for each supplementation group. These analyses allowed for Cohen effect sizes, 90% confidence intervals (CI), *p* values and qualitative inferences to be presented, which is considered a meaningful practice for statistical use in sports medicine and the exercise sciences (Hopkins et al., 2009). Specifically, differences between trials are expressed as a percentage via analysis of log-transformed values using natural logarithms. To make inferences about the true values of the percentage differences and effect sizes between trial metrics, the uncertainty in the percentage differences and effect sizes are expressed as 90% confidence intervals and as likelihoods that the true value of the difference is substantial (Batterham & Hopkins, 2006). A difference is deemed unclear if its confidence interval of the effect statistic overlaps substantially positive and negative values and the threshold for the smallest worthwhile effect, otherwise, when a result is above the threshold for the smallest worthwhile effect the results are given as: 0 – 0.2 trivial; 0.2 – 0.6 small; 0.6 – 1.2 moderate; 1.2 – 2.0 large; 2.0 – 4.0 very large. An effect size of 0.2 was chosen to be the smallest worthwhile difference in the means in standardized (Cohen) units as it gives chances that the true effect would at least be small. A *p* value of <0.05 was considered significant. Chances of benefit or impairment induced by the supplement were assessed as follows: <1%, almost certainly not; 1 - 5%, very unlikely; 5 - 25%, unlikely; 25 - 75%, possible; 75 - 95%, likely; 95 - 99%, very likely; >99%, almost certain.

Further statistical analyses compared the change scores in repeated sprint ability outcomes and blood lactate responses between the NZBC and placebo supplement groups. Mean nett effects, *p* values and nett differences of training were calculated using a spreadsheet for the analysis of pre-post parallel groups’ trials (Hopkins, 2006). Inferential statistics were based on interpretation of magnitude of effects (differences) (Batterham & Hopkins, 2006). The likelihoods of the effect were interpreted using the Cohen scale of magnitudes with 0.2 being chosen as the smallest worthwhile difference in the means. A difference was deemed unclear if the confidence interval of the effect statistic substantially overlapped positive and negative values, and the threshold for the smallest worthwhile effect.

3. Results

Upon completion of the final trial participants were asked if they thought they had consumed either NZBC or placebo, with 40% (2 out of 5 participants) of the NZBC group and 71% (5 out of 7 participants) of the placebo group guessing correctly. This indicated successful blinding in the NZBC group but not the placebo group.

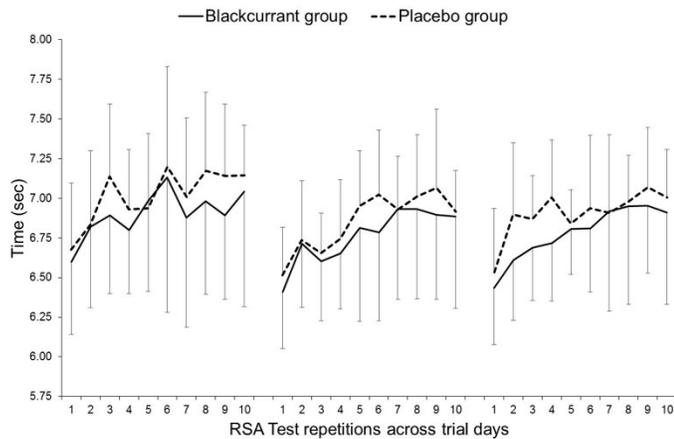


Figure 1: Mean \pm SD Sprint time for all 10 sprints for all 3 trials (Baseline, 6-days of supplementation and 7-days of supplementation; left to right respectively).

3.1. Repeated Sprint Ability (RSA) outcomes

Mean sprint times for all sprint repetitions on all trial days are presented in Figure 1. The effect of NZBC supplementation on RSA test outcomes are shown in Table 2. Compared with baseline, after 6-days of supplementation the NZBC group participants improved their mean sprint time by 2.0% (CI = -3.6 to -0.3%) and their fastest sprint time by 2.7% (CI = -4.3 to -1.0%).

Of the five participants in the blackcurrant group, four demonstrated an improved mean sprint time (see Figure 2)

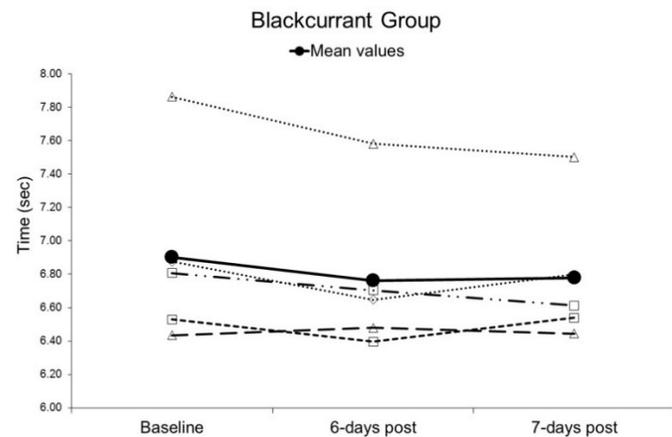


Figure 2: Individual and mean data for RSA mean sprint time in the Blackcurrant group before (Baseline), after 6 days (6-days post) and after 7 days (7-days post) of supplementation.

whereas all demonstrated improved faster sprint times (-2.7%, CI = -4.3 to -1.0%; $p = 0.027$). No additional substantial differences in mean sprint time, fastest sprint time or any other RSA test outcomes were observed from 7-days of NZBC supplementation. Similarly, compared with baseline, after 6-days of supplementation the placebo group participants improved their mean sprint time by 2.3% (CI = -4.8 to 0.4%). Of the seven participants in the placebo group, five demonstrated an improved mean sprint time (see Figure 3). Compared to the placebo group the NZBC group typically performed better in all RSA test outcomes on all trial days (see Table 2). However, the differences in outcomes between groups were unclear and not significantly different.

3.2. Blood Lactate Responses

Substantial decreases (smallest worthwhile effect as a standardized Cohen's effect size of 0.20) in blood lactate responses as a result of NZBC supplementation was possible to likely probable (see Figure 3). *Small to moderate* decreases (effect size range -0.24 to -0.93) were observed between 6-days and 7-days of supplementation for blood lactate responses at 1 minute post-test (-11%, CI = -23.2 to 3.1%), 3 minutes post-test (-13.0%, CI = -30.7 to 9.2%), 5 minutes post-test (-19.8%, CI = -39.1 to 5.6%) and 10 minutes post-test (-22.1%, CI = -39.3 to 0.1%). Similar decreases between days were observed for the placebo group leading to *unclear* differences when comparing lactate responses between NZBC and placebo groups (see Table 3). Lactate responses on average tended to be higher on both days for the blackcurrant group compared to placebo group (see Figure 4).

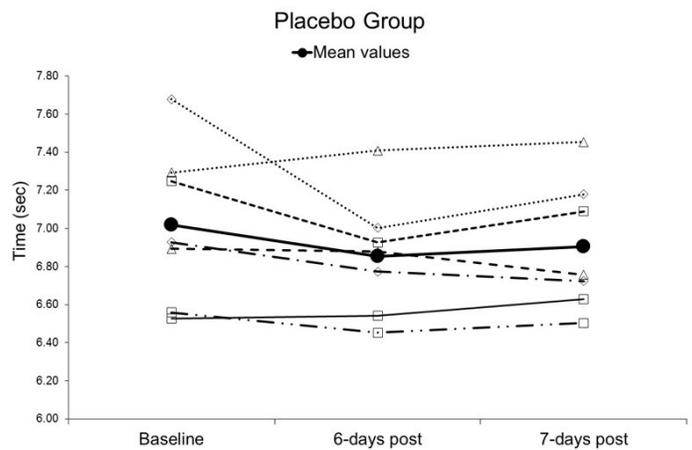


Figure 3: Individual and mean data for RSA mean sprint time in the Placebo group before (Baseline), after 6 days (6-days post) and after 7 days (7-days post) of supplementation.

Table 2: RSA outcomes (Mean \pm SD) and corresponding mean changes (%) for NZBC and placebo groups, and nett difference (% \pm 90% confidence limits) of these changes.

		NZBC	Placebo	Change in Measure (%)			
				Comparisons	NZBC	Placebo	% Difference, \pm 90% CL
MST (s)	Baseline	6.90 \pm 0.67	7.02 \pm 0.42	6-d vs. BL	-2.0	-2.3	0.3, \pm 2.9
	6-days	6.76 \pm 0.47	6.85 \pm 0.32	7-d vs. BL	-1.7	-1.6	-0.1, \pm 2.7
	7-days	6.78 \pm 0.42	6.90 \pm 0.34	7-d vs. 6-d	0.3	0.7	-0.4, \pm 1.9
FST (s)	Baseline	6.58 \pm 0.47	6.65 \pm 0.42	6-d vs. BL	-2.7	-3.0	0.3, \pm 2.7
	6-days	6.40 \pm 0.36	6.45 \pm 0.26	7-d vs. BL	-2.3	-1.9	-0.4, \pm 2.8
	7-days	6.43 \pm 0.36	6.53 \pm 0.40	7-d vs. 6-d	0.4	1.1	-0.7, \pm 2.4
SST (s)	Baseline	7.23 \pm 0.78	7.48 \pm 0.48	6-d vs. BL	-2.7	-3.9	1.2, \pm 5.1
	6-days	7.02 \pm 0.54	7.19 \pm 0.42	7-d vs. BL	-2.3	-4.1	1.9, \pm 4.8
	7-days	7.05 \pm 0.55	7.17 \pm 0.39	7-d vs. 6-d	0.5	-0.3	0.7, \pm 2.3
FI (%)	Baseline	4.8 \pm 2.8	5.5 \pm 1.4	6-d vs. BL	18.1	9.7	7.6, \pm 28.9
	6-days	5.5 \pm 2.5	6.3 \pm 2.4	7-d vs. BL	11.5	0.0	11.5, \pm 33.5
	7-days	5.4 \pm 3.3	5.8 \pm 2.6	7-d vs. 6-d	-5.5	-8.9	3.7, \pm 38.2

Note: MST: Mean Sprint time; FST: Fastest Sprint time; SST: Slowest Sprint time; FI: Fatigue Index; NZBC: New Zealand Blackcurrant.

Table 3: Blood lactate responses (Mean \pm SD) and corresponding mean changes (%) for NZBC and placebo groups, and nett difference (% \pm 90% CL) of these changes.

		NZBC	Placebo	Change in Measure (%)			
				Comparisons	NZBC	Placebo	% Difference, \pm 90% CL
Pre-test	6-days	1.1 \pm 0.2	1.3 \pm 0.2	7-d vs. 6-d	45.9	-4.5	52.7, \pm 70.0
	7-days	1.7 \pm 0.6	1.5 \pm 1.0				
1min Post	6-days	12.1 \pm 3.9	9.8 \pm 4.4	7-d vs. 6-d	-11.0	-26.7	21.4, \pm 21.6
	7-days	10.8 \pm 3.4	7.2 \pm 3.8				
3min Post	6-days	12.1 \pm 4.2	9.8 \pm 4.4	7-d vs. 6-d	-13.0	-24.4	15.1, \pm 35.6
	7-days	10.5 \pm 3.9	7.7 \pm 4.4				
5min Post	6-days	12.3 \pm 2.3	10.5 \pm 5.4	7-d vs. 6-d	-19.8	-39.5	32.5, \pm 38.6
	7-days	10.4 \pm 3.7	6.8 \pm 3.6				
10min Post	6-days	10.1 \pm 3.4	8.6 \pm 4.3	7-d vs. 6-d	-22.1	-33.5	17.2, \pm 36.0
	7-days	7.7 \pm 2.2	6.5 \pm 3.6				

Note: NZBC: New Zealand Blackcurrant.

3.3. Subjective responses

RPE responses are shown in Figure 5. As expected RPE increased gradually between sprints from sprint 1 to sprint 10 irrespective of trial day or group, with non-significant differences between trials and between groups for RPE.

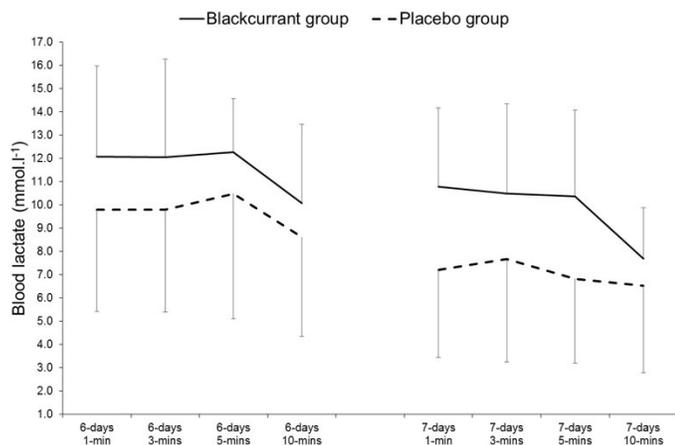


Figure 4: Blood lactate responses post RSA test after 6-days and 7-days of supplementation (Mean \pm SD).

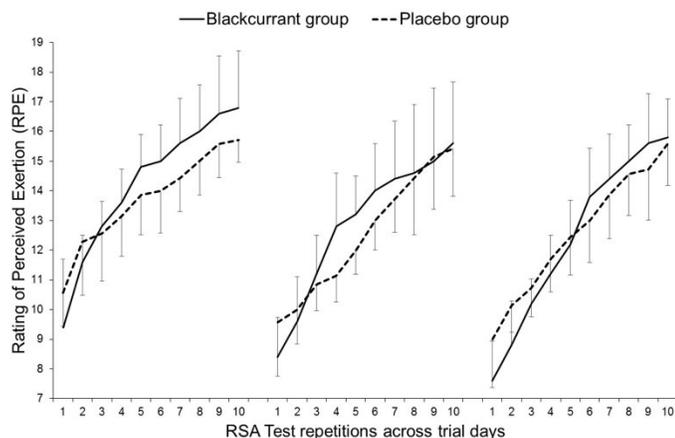


Figure 5: Mean \pm SD of RPE scores post sprint for all 10 sprints for all three trials (Baseline, 6-days of supplementation and 7-days of supplementation; left to right respectively).

4. Discussion

Our work produced three key findings. Firstly, that NZBC supplementation tends to promote higher lactate accumulation during repeated sprint activity, irrespective of time point (Figure 3). Secondly, NZBC supplemented athletes consistently displayed faster MST and FST than placebo supplemented athletes, although the magnitude of change between groups is similar (Figure 1; Table 2). Thirdly, NZBC supplementation produces a

statistically significant reduction of circulating lactate during recovery (between 5- and 10-minutes post-exercise) in a subsequent testing session (Figure 3).

We are the second group to show that supplementing with NZBC may elicit higher lactate values during exercise. Typically following NZBC supplementation lactate production is either lower (Willems et al., 2015), or shows no change (Cook et al., 2017a; Cook et al., 2017b; Murphy et al., 2017; Willems et al., 2014; Willems et al., 2016), possibly due to increased fat oxidation (Cook et al., 2017a). We tasked participants with performing each sprint at a maximal effort, with a combined mean sprint duration of 6.97 ± 0.46 sec; this contrasts starkly with prior research which has examined exercise durations of 6-28 minutes, and 40-80% peak power output (Cook et al., 2017a; Cook et al., 2017b; Murphy et al., 2017; Willems et al., 2014; Willems et al., 2016). Even in previous NZBC repeated sprint/ team sport research (Willems et al., 2016), a large aerobic contribution likely exists due to the prolonged nature of the testing session (>90 minutes) and variability of running speeds. An increased fat oxidation for these activities would concomitantly lower glycolytic contributions and thus lactate production, which may be advantageous during prolonged exercise, but may involuntarily impair single and repeated efforts of high-intensity work (Stellingwerff et al., 2006).

An increase in fat oxidation would also lower RER during exercise and recovery, which has been shown to differentiate between athletes' training status (Hetlelid et al., 2015). Well-trained athletes exhibit *very likely* larger levels of fat oxidation at quicker running speeds, despite comparable levels of carbohydrate oxidation during interval training (Hetlelid et al., 2015). Such an increase in fat oxidation may have benefitted our participants when most glycogen depleted (Gollnick et al., 1973), hence the faster rate of lactate clearance seen on Day 7. However, this would not have been beneficial during RSA testing, as carbohydrate metabolism may also have been impaired. Whilst statistically significant, this faster clearance is likely of limited practical importance or consequence.

There are several pertinent limitations to address in the present study. First being the recreational level of the participants. Despite matched rank allocation following baseline testing we did not quantify participants' fitness levels beyond their RSA. This is perhaps responsible for the similar magnitude of change seen between groups over the course of the study, whereby both groups improved by the same percentage and stabilized, despite the NZBC group being faster at each time point. Whilst differences in absolute time exist between groups, both groups demonstrated an initial improvement followed by a lesser improvement or plateau in MST and FST performance. A washout period and crossover design would ascertain whether this is in fact a consistent response in as much as the participants cannot run any faster, or if NZBC is simply a better placebo, than a placebo. Secondly, whilst dietary protocols to minimise confounding anthocyanin containing foods do exist and are mechanistically sound, they lack ecological validity due to their broadly restrictive nature (Bell et al., 2015; Cook et al., 2017). We acknowledge that athletes' habitual diets certainly have the potential to affect RSA (and in this case MST and FST), most likely through substrate availability, employing

such a dietary protocol may further limit study completion due to adherence or attrition beyond the levels already reported. Thirdly, testing was conducted early in the morning, which may have circadian implications with respect to the circulating hormonal milieu and affected substrate oxidation (Parr, Heilbronn, & Hawley, 2020) and performance of all participants, irrespective of NZBC supplementation. This timing was due to facility availability, but readers should be encouraged that high intensity work could still be performed at this time of day, given some recreational athletes may be time-poor and thus early morning training is a necessity. We would also like to acknowledge the high-rate of participant attrition; participants attributed this to injury or illness not caused by participation, but occurring throughout the supplementation period. Other factors such as timing or testing, supplementation protocol, and family commitments (Abel et al., 2001) may have further compounded the reported reasons for participant withdrawal.

The metabolic climate of NZBC supplemented athletes suggests a need for further NZBC research in intermittent and team sports athletes, preferably with a trained comparator group, employing a replicated crossover design or in an extended tournament setting. In aerobic disciplines, future research should focus on exercise tasks in the severe domain (Burnley & Jones, 2016), where an increased lactate production, as observed in the present study, may improve performance via priming (Ingham et al., 2013). When assessing female participants, menstrual cycle phase should also be considered and where possible controlled for too, due to potential oestrogen-mediated antioxidant and glycogen sparing effects (McNulty et al., 2020).

5. Conclusion

The examined dose in the present study was insufficient to demonstrate previously documented responses to NZBC supplementation. At 1.6mg/kg, ~100mg anthocyanins were provided, this is similar to the loading protocol used by Murphy et al. (2017) who provided seven days of 105mg anthocyanins prior to an acute dose of 300mg which improved repeated cycling performance. A chronic, low dose of anthocyanins may confer cardiovascular benefits comparable to the vascular effects observed by Cook et al. (2017a) and George et al. (2012), but is unlikely to improve repeated sprint performance, in the absence of an acute dose of ≥ 300 mg anthocyanins.

Conflict of Interest

The authors declare no conflict of interests.

Acknowledgment

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An evaluation of internal and external workload metrics in games in women's collegiate lacrosse

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ABSTRACT

The purpose of this study was to statistically evaluate internal and external workload metrics in women's collegiate lacrosse games. Twelve Division I collegiate female lacrosse players wore a heart rate (HR) monitor and microtechnology during 17 intercollegiate games. Seven measures were used to determine game workload: two internal measures (mean HR and training impulse [TRIMP]) and five external measures (total distance, high-intensity distance [HID], average speed, accelerations, and decelerations). Principal component analysis (PCA) was used to determine which metrics were most associated with each game segment. A permutation test validated the number of components retained for each PCA, and a bootstrap ratio test validated which measures significantly loaded on each component. For the whole game and each half all variables significantly loaded as factors onto only one principal component. For the whole game, the workload variables explained 54% of the variance ($p < .001$). The same metrics explained 53% of the variance for the first half ($p < .001$), and 58% of the variance for the second half ($p < .001$). External workload measures were highly intercorrelated and internal measures provided less information to the structure across all three PCAs analyzed. Analyses showed similar factor-loading patterns for the three PCAs indicating very little difference in importance of workload variables by game section. The loaded metrics should be compared to a complementary analysis for drills to ensure that training workload metrics are similar.

1. Introduction

The use of global positioning systems (GPS) microtechnology and heart rate (HR) monitors have simplified and improved training load monitoring in athletes from various sports. The outputs from these devices and software systems are vast, and allow for specific measures of external training load (e.g., total distance, high-intensity distance, sprints, accelerations, decelerations, sprint speed zones, metabolic equivalent distance, player/athlete load) and internal training load (e.g., maximum HR, average HR, training impulse [TRIMP], and ratings of perceived exertion [RPE]). Previous literature has evaluated similar data for a variety of elite male athletes playing rugby (Weaving et al., 2014; Weaving et al., 2017) and football (Akenhead & Nassis, 2016),

and a meta-analysis (McLaren et al., 2018) was conducted with various sports including: Australian Rules football, soccer, and basketball. Typical analyses include principal component analysis (PCA) to evaluate factor loadings, importance of the metrics, and redundancy between metrics. PCA is a method of variable reduction and has been used in sport science to evaluate the number of variables necessary to explain workload (Bunn et al., 2021; Weaving et al., 2014, 2019; Weaving et al., 2017). These studies have helped shed light on the most important external and internal metrics to evaluate within each specific sport, which helps sport scientists monitor training load and coaches conduct training sessions to be more game-specific (Akenhead & Nassis, 2016; McLaren et al., 2018; Vanrenterghem et al., 2017; Weaving et al., 2014; Weaving et al., 2017). Steps for sport scientists to mimic

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the analyses with their own data have also been published (Weaving et al., 2019). Overall, much of this literature has shown that workload in these sports are often best evaluated using both internal and external load variables. PCA outcomes typically show internal and external metrics associated with different components suggesting they are not redundant measures. While these data are useful, they likely have little cross-over into women's athletics or sports different from what have previously been analyzed.

Lacrosse is a rapidly growing sport in men's and women's athletics with a steady increase in the number of players in youth and collegiate leagues (National Collegiate Athletic Association® Sports Sponsorship and Participation Rates, 2019). This is accompanied by an increasing number of publications evaluating player profiles and game and training load statistics (Akiyama et al., 2019; Alphin et al., 2019; Devine et al., 2020; Hauer et al., 2019; Polley et al., 2015). The men's and women's games have different rules with restraining line implementations, play time is constructed in quarters in men's games and in halves for women, and there is reduced contact in the women's game, which results in different game and training load profiles for these athletes. Available literature allows game profile comparisons between elite male athletes (Akiyama et al., 2019) and collegiate female athletes (Devine et al., 2020). Men and women tend to cover similar total distances during match play, apart from male midfielders moving less total distance than female midfielders. Male lacrosse athletes logged higher distances at high speeds than female athletes, and more accelerations and decelerations.

While it is important to know and understand the game and training profiles of lacrosse athletes, the literature has yet to determine which internal and external metrics are most important for evaluation. Bunn et al. (2021) recently evaluated the load metrics of different drill types during four months of pre-season training in women's collegiate lacrosse. The PCA showed that internal and external workload metrics loaded similarly between different drill types, and all drill types emphasized a greater importance for external metrics, as they loaded onto the first component, and a secondary emphasis on the internal metrics which loaded on the second component. This provides important information for sport scientists and coaches to guide training, but there is no evidence regarding how this information compares to their competitive games. The primary purpose of the present study was to statistically evaluate the relationship of internal and external workload metrics in women's collegiate lacrosse games. Comparing the results of game data in the present study with training data from previous literature (Bunn et al., 2021) will provide coaches and sport scientists greater clarity in understanding important variables for measuring workload and a concept of training modes that translate best to game style of play. A secondary purpose was to evaluate workload differences between the first and second halves of women's collegiate lacrosse.

2. Methods

2.1. Participants

Twenty-five female Division I collegiate lacrosse players were enrolled in this study, but data from only 12 key players ($19.9 \pm$

1.1 years, 166.4 ± 5.4 cm, 64.5 ± 5.4 kg) were utilized. These individuals were identified as key players by their coaches based upon minutes played and team contribution. Eligibility criteria for study participation included: 18 years of age or older, member of the varsity roster, clearance for full participation provided by a certified athletic trainer and team physician and contributing to at least 50% of the game minutes played. Athletes were excluded if participation was limited by injury or if they contributed to fewer than 50% of the game minutes played. These criteria were set up to exclude players who did not play much and spent much of the game time on the sideline. This study was conducted in accordance to the Declaration of Helsinki and approved by the Campbell University Institutional Review Board. All participants completed written informed consent prior to all data collection.

2.2. Design

This was a longitudinal observational research study design. Data collection took place during a three-month competitive season of National Collegiate Athletic Association (NCAA) Division I women's lacrosse play. A total of 17 games were recorded, resulting in 200 total observations, averaging 16.7 ± 0.7 games per player.

2.3. Procedure

Training load metrics were collected using VX Sport microtechnology units and HR monitors (Wellington, New Zealand). The GPS microtechnology unit sampled at 10 Hz and included a tri-axial accelerometer, tri-axial magnetometer, and tri-axial gyroscope. This unit has been shown to have an acceptable level of accuracy and reliability (Alphin et al., 2020; Malone et al., 2014).

Seven total metrics were evaluated in this study – two internal and five external. The internal load metrics included average HR expressed as beats per minute (bpm), and training impulse (TRIMP) expressed in arbitrary units (AU). The external load metrics included total distance in meters, high-intensity distance (HID) in meters, average speed in $\text{m}\cdot\text{min}^{-1}$, decelerations (frequency), and accelerations (frequency). HID was the distance run at greater than 60% of maximum sprint speed. Accelerations and decelerations were counted when there was a change in acceleration of greater than $7 \text{ m}\cdot\text{s}^{-2}$. These metrics were chosen to align with previous work with elite male rugby athletes (Weaving et al., 2014; Weaving et al., 2017), and previous literature in collegiate women's lacrosse (Alphin et al., 2019; Bunn et al., 2021; Devine et al., 2020). Explanations of each metric and methods for measurement were previously provided by Bunn et al. (2021).

GPS units and HR monitors were distributed to participants prior to each game. Players utilized the same unit and monitor for each game. Units and monitors were collected at the end of each game for upload and data trimming and splitting. Inactive times were removed from the data, and games were split according to warm-up, first half, and second half. Only the first half, second half, and whole game data were analyzed. Time spent in warm-up, half-time, and cool down were trimmed out of the data.

2.4. Statistical Approach

For the primary aim of this study, PCA was used to determine which of the seven measures were most associated with load in the first and second halves and whole game data. PCA takes the set of observed variables, which are possibly correlated, and converts them into a set of linearly uncorrelated variables called principal components (Abdi & Williams, 2010). Seven measures were taken to determine load: the two internal measures included average HR and TRIMP, and the five external measures included total distance, average speed, HID, accelerations, and decelerations. The number of principal components in a PCA is equal to the number of input variables, but few of these are likely to be useful. Therefore, a permutation test with 5000 iterations was used to validate the number of components that were retained for each PCA. Permutation tests have been shown to be more reliable than other stopping rules when the population distribution is not known, the variables are correlated or the sample size is small (Devine et al., 2020; Hauer et al., 2019), as with the present data. Additionally, because the sample distribution was unknown, a bootstrap ratio test was used to validate which measures significantly loaded on each component. A bootstrap ratio test is significant when the contribution of the variables is consistent across the bootstrap samples. Thus, the bootstrap was used to determine the stability of the contribution of each of the variables to each component (Beaton et al., 2014). An alpha threshold of .05 was used to determine significance. PCA and subsequent analyses

were done in R (R Core Team, 2013) using the InPosition statistical inference package.

Means and standard deviations for all key players were calculated for the first half, second half, and whole game. Differences between first and second half internal and external load variables were evaluated using paired samples t-tests to evaluate the secondary aim of the present study. Cohen’s d effect sizes were calculated to determine the magnitude of differences between halves. Interpretation of effect sizes were small (0.2 – 0.49), moderate (0.50-0.79) and large (≥ 0.80) (Cohen, 1988). These data were analyzed using jamovi (The jamovi project, 2020).

3. Results

Figure 1 shows the results of the PCA for the first half (A), second half (B), and whole game (C). Each analysis extracted only one significant principal component, and all variables loaded significantly on the first component. For the first half, all loaded variables accounted for 52.8% ($p < .01$) of the variance. In the second half, the variables explained 57.9% ($p < .01$) of the variance. Finally, for the whole game, the variables explained 53.6% ($p < .01$) of the variance.

Table 1 shows the factor scores, bootstrap ratios, and loadings for each principal component for each aspect of the game analyzed. As previously stated, all variables loaded onto the first component for the first and second halves and the whole game.

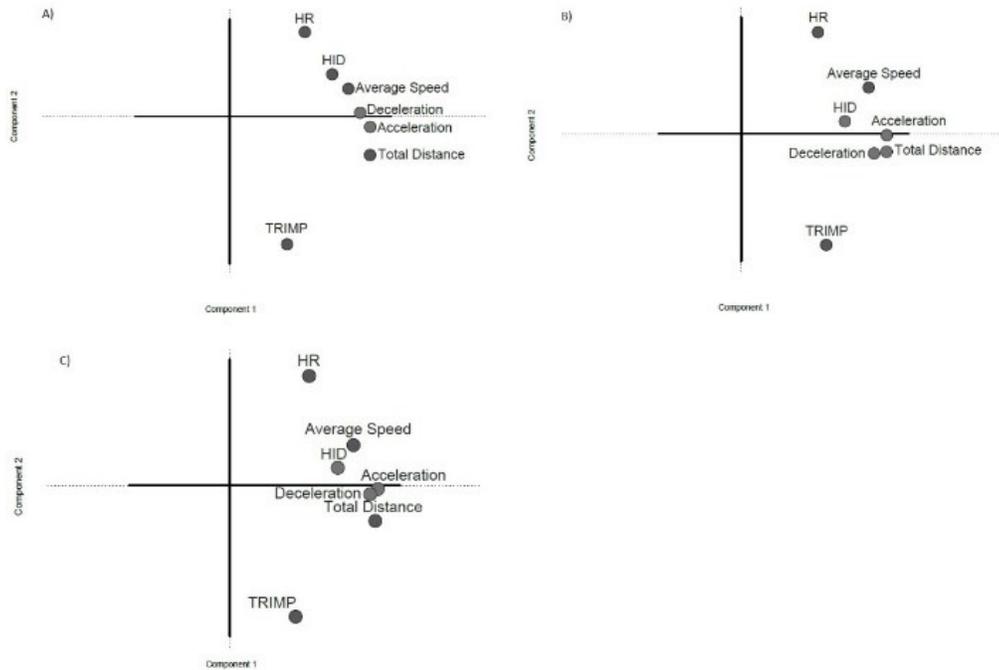


Figure 1: Results of the PCA for each component of the games analyzed, A) First half, component 1 contained 52.8% of the variance, $p < .01$, component 2 was not significant, proportion of variance explained = 16.2%, $p = 0.74$. B) Second half, component 1 contained 57.9% of the variance, $p < .01$, component 2 was not significant, proportion of variance explained = 14.9%, $p = 1.00$ C) Whole game, component 1 contained 53.6% of the variance, $p < .01$, component 2 was not significant, proportion of variance explained = 17.49%, $p = 0.11$.

Table 1: PCA component 1 and 2 factor scores, bootstrap ratios, and loadings. Values in bold represent significant results where the bootstrap ratio exceeds +/- 1.96.

Component 1							
	HR (bpm)	TRIMP (AU)	Total Distance (m)	Average Speed (m·min ⁻¹)	HID (m)	Accelerations (reps)	Decelerations (reps)
1st Half							
Factor Score (BSR)	6.50 (3.70)	4.96 (4.89)	12.13 (6.78)	10.26 (4.80)	8.87 (7.62)	12.15 (6.66)	11.28 (7.60)
Loading	0.48	0.37	0.90	0.76	0.66	0.90	0.84
2nd Half							
Factor Score (BSR)	6.59 (4.16)	7.30 (8.15)	12.49 (8.88)	10.95 (6.17)	8.91 (7.91)	12.50 (8.29)	11.41 (9.12)
Loading	0.49	0.54	0.93	0.81	0.66	0.93	0.85
Whole Game							
Factor Score (BSR)	6.55 (3.80)	5.43 (6.71)	12.00 (8.33)	10.21 (5.17)	8.91 (7.69)	12.50 (7.14)	11.59 (8.02)
Loading	0.49	0.40	0.89	0.76	0.66	0.91	0.86
Component 2							
1st Half							
Factor Score (BSR)	7.28 (6.91)	-11.08 (-6.07)	-3.36 (-2.80)	2.38 (2.47)	3.62 (4.04)	-0.93 (-0.92)	0.30 (0.29)
Loading	0.54	-0.82	0.249	0.18	0.27	-0.07	0.02
2nd Half							
Factor Score (BSR)	8.71 (7.44)	-9.56 (-7.27)	-1.56 (-1.35)	3.96 (3.12)	1.06 (1.07)	-0.14 (-0.14)	-1.70 (-1.59)
Loading	0.65	-0.71	-0.12	0.294	0.08	-0.01	-0.13
Whole Game							
Factor Score (BSR)	9.04 (7.51)	-10.84 (-5.84)	-2.93 (-2.79)	3.33 (3.16)	1.46 (1.55)	-0.30 (-0.28)	-0.73 (-0.82)
Loading	0.67	-0.80	-0.22	0.25	0.11	-0.02	-0.05

Abbreviations: High-intensity distance (HID), average heart rate (HR), training impulse (TRIMP), boot strap ratio (BSR)

This table also shows variables that significantly loaded onto a second principal component, but none of these second components were statistically significant. HR, TRIMP, and average speed consistently loaded onto the second component for each game segment. The first half also showed total distance and HID with significant loadings. The second half had no additional loadings. Additional loadings for the whole game included only total distance.

The means and standard deviation for each metric for the first half, second half, and whole game are shown in Table 2. Paired samples t-tests indicated differences between halves for all the metrics tested, with reduced player output in the second half. All effect sizes were considered large except for HR and TRIMP which were moderate.

4. Discussion

This study used PCA to assess which internal and external variables were associated with different portions of a women’s collegiate lacrosse game. To date, this is the first study to statistically evaluate game workload metrics in lacrosse or among female collegiate athletes. Analyses revealed one significant principal component for each of the three game sections analysed. These data indicate that game performance is best evaluated by both internal and external workload variables, but external workload variables tended to have higher factor loadings. This falls in line with the notion that external load variables show overall workload on the body from training or a game; whereas internal workload variables typically show response with alterations in training and fitness (Wing, 2018).

Results of the present study agree with previous literature suggesting that both external and internal workload measures should be used to understand the physiological load and variance experienced by athletes (Bunn et al., 2021; Weaving et al., 2014; Weaving et al., 2017). Bunn et al. (2021) previously evaluated these same metrics in relation to different training modes in lacrosse with the same population. The results of the present study are compared to this previous work in Table 3. Four training modes—individual skills, stick work, team drills, and conditioning—included two principal components with external workload variables significantly loading onto the first component and internal variables loading onto the second. Small-sided games

was the only training mode that included only one principal component with only external variables. Total distance, accelerations, and decelerations strongly loaded onto the first component extracted for all five training modes and all three game sections. HID loaded onto the first component for all three game sections, but only for the conditioning training mode. Average speed registered onto the first component for individual skills, stick work, small-sided games, team drills and onto the second component for conditioning. However, it only registered for the second half of games onto the first component. This is interesting because all game speed means were higher than most drill speed means (excluding conditioning). This may suggest the added importance of speed late in the game. According to the descriptive data in Table 1, the average speed is slightly lower in the second half, but the variance is higher. This may indicate that the speed of players in the games are typically near their maximum in the first half. There is greater variability in speed in the second half because players are more selective about when to use maximum speed which is supported by fewer accelerations in the second half as well. Lastly, TRIMP loaded onto the first component for all three game sections, but never for the five training modes. This may be due to the difference in n-size between the two studies. The present study selected only the key players from games, whereas the training study included a larger portion of the team. Further, the 12 players evaluated in games represented three different positions (attacker, midfielder, and defender, n = 4 for each position) playing different roles during the game, where they would all have been working in the same drill modes with the training study.

From a practitioner perspective it would be ideal if metrics from training aligned with the metrics from each game section. Because HID loaded onto the first component for all three game sections, but only one of the five training modes, alterations in training should be considered to incorporate more HID into training. Average speed was the only metric measured relative to time, and it loaded onto the first component for four training modes and all three game sections. Comparatively, the average speed is higher in games (50.5-53.2 m·min⁻¹) than the four training modes in which it loaded (35-44 m·min⁻¹). A practical consideration would be to increase average speed during training such as team drills and stick work to match that of game speed.

Table 2: Means and standard deviations of each metric for the first half, second half, and total game. Differences between the two halves (*p* < .05) are shown with * and effect sizes (ES) are shown with the paired t-test *p*-values.

	Distance (m)	Average speed (m·min ⁻¹)	HID (m)	HR (bpm)	Accelerations (count)	Decelerations (count)	TRIMP (AU)
First Half	3061.9 ± 645.7	53.2 ± 11.2	262.5 ± 118.9	161.1 ± 16.2	89.3 ± 27.7	15.6 ± 5.9	215.2 ± 18.7
Second Half	2651.7 ± 548.5	50.5 ± 10.5	191.5 ± 83.3	155.5 ± 16.0	69.1 ± 22.4	11.7 ± 4.2	204.5 ± 17.3
Total	6205.0 ± 1767.2	50.7 ± 11.5	454.7 ± 265.9	158.4 ± 42.6	160.1 ± 64.4	27.5 ± 14.0	465.0 ± 130.6
<i>p</i> -value (ES)	< .01 (2.13)*	.01 (0.82)*	< .01 (1.47)*	.04 (0.57)*	< .01 (2.31)*	< .01 (1.51)*	.02 (0.69)*

Abbreviations: High-intensity distance (HID), average heart rate (HR), training impulse (TRIMP), arbitrary units (AU)

Table 3: Comparisons between PCA loadings between games (shaded in gray) and training (Bunn et al., 2021).

	Whole Game	1 st Half	2 nd Half	Individual Skills	Stick Work	Small-sided Games	Team Drills	Conditioning
1st Component								
Total Distance	✓	✓	✓	✓	✓	✓	✓	✓
HID	✓	✓	✓					✓
Accelerations	✓	✓	✓	✓	✓	✓	✓	✓
Decelerations	✓	✓	✓	✓	✓	✓	✓	✓
Average Speed	✓	✓	✓	✓	✓	✓	✓	
TRIMP	✓	✓	✓					
HR	✓	✓	✓					
2nd Component								
HID							✓	
Average Speed							✓	✓
TRIMP				✓	✓		✓	✓
HR					✓			

Abbreviations: High-intensity distance (HID), average heart rate (HR), training impulse (TRIMP)

Previous work in sports science suggests prioritizing training metrics that contribute to alterations in performance and fitness (Akubat et al., 2012; Manzi et al., 2009). If making selections in metrics based from game factor loadings, prioritizing total distance, HID, accelerations, decelerations, and TRIMP would be sensible. Creating focal points with aims to meet certain threshold values for each external metric during training would likely then result in positive changes in fitness and therefore TRIMP. As fitness improves, TRIMP would decrease, and it would respond appropriately to other stimuli such as physiological stress and recovery.

In addition to providing analyses to evaluate important variables within women’s lacrosse, these data also add to the small body of literature available for match profiles within this sport (Devine et al., 2020; Hauer et al., 2019). Devine et al. (2020) provided data for collegiate female lacrosse game profiles and Hauer et al. (2019) provided similar data for elite international competition in women’s lacrosse. The microtechnology equipment (VX Sport) and population of study were the same between Devine et al. (2020) and the present study. Comparing game profiles, the present study indicated higher total distance and accelerations than Devine et al. (2020), but lower HID. Compared to Hauer et al. (2019), the present study showed greater total distance, accelerations (zone 4), and decelerations (zone 4). Accelerations, decelerations, and total distance were all defined similarly between the three studies and indicated variation with these metrics. Further research should be conducted to assess if this is due to talent or skill differences or is more related to different styles of play

One limitation of this study was that playing time of the athletes during games or by half was not monitored. In the game of lacrosse, substitutions occur freely, so tracking playing time without the use of video assistance was problematic. This could have affected the differences noted in metrics between the first and second halves if the substitution strategy was different between the two halves. The small n-size utilized in this study

may also be a limitation for PCA of games due to the different roles of the three lacrosse positions.

Training and game workloads in collegiate women’s lacrosse are not yet well-understood. These data highlighted the importance of the internal and external metrics in women’s collegiate lacrosse games, and that factor loading patterns were different between games and different training modes. The results of this study suggest metrics related to external workload with the addition of TRIMP may be most useful in representing load during competition. The variation in first to second half workload suggest an imbalance most simply attributed to conditioning. A more thorough understanding of workload during competition may assist sports scientists in planning training programs better suited to meet the demands experienced during competition. Lastly, it is difficult to predict if the results of the present PCA analyses would be identical for other women’s collegiate lacrosse teams, but this is at minimum a starting point for narrowing important metrics and providing ideas for analyses. Further research should be conducted to compare load metrics over multiple seasons and across multiple teams to determine the validity of the current findings.

Conflict of Interest

The authors have no conflicts of interest to declare.

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Sub-phase analysis of the modified 5-0-5 test for better change of direction diagnostics

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ABSTRACT

The aim of this study was to determine whether the utilisation of three timing gates could reliably measure different sub-phases of the modified 5-0-5 COD test, and whether these sub-phases were inter-related. The modified 5-0-5 COD test was adapted, and additional timing gates were placed at 2 m and 4 m, enabling acceleration, deceleration, 180-degree turn and reacceleration 1 and 2 to be measured independently. Ten elite female netball athletes (age: 24.9 ± 5.0 yrs, height: 180.1 ± 6.5 cm, weight: 81.3 ± 15.0 kg) completed three sessions, consisting of three trials, separated by one week. Pearson correlation coefficients were used to determine the strength of association between variables, and absolute and relative consistency was assessed using coefficients of variation (CV) and intraclass correlation coefficient (ICC), respectively. Correlations between variables ranged from 0.28 to 0.94, with the 180-degree turn having the greatest shared variance ($R^2 = 88.4\%$) with total time. The greatest shared variance between sub-phases was 68.9% between deceleration and reacceleration 2 and was the only variable to explain more than 50% of shared variance between sub-phases. All CVs were less than 10% and all ICCs were greater than 0.77 indicating acceptable absolute consistency and 'good' to 'excellent' relative consistency. These findings suggest firstly that these sub-phases are all independent qualities, and therefore should be measured as such. Secondly, this advanced diagnostic protocol can measure each of these sub-phases reliably.

1. Introduction

The ability for an athlete to perform a change of direction (COD) is an important physical quality in many team sports, including soccer (Little & Williams, 2003), volleyball (Gabbett & Georgieff, 2007) and netball (Chandler, Pinder, Curran, & Gabbett, 2014). For example, in netball, a player performs on average 64 COD manoeuvres (Fox, Spittle, Otago, & Saunders, 2014), and a top-class soccer player performs, on average, 726 changes of direction during a match (Bloomfield, Polman, & O'Donoghue, 2007). Due to this high volume of direction changes performed by athletes, it is important to have valid and reliable tests to measure an athlete's COD ability.

The modified 5-0-5 (beginning from a stationary start 0.5 m behind the first timing gate) COD test is one such test used to assess an athlete's ability to rapidly accelerate, decelerate, turn 180-degrees and reaccelerate again. These physical qualities are important for most multidirectional sports (Dos' Santos, McBurnie, Thomas, Comfort, & Jones, 2020). Traditionally, the modified 5-0-5 COD test uses one set of timing gates to assess an

individual's ability to sprint 5 m, perform a 180-degree COD and sprint 5 m back through the timing gates. This test produces a total time (s) for the athlete's performance; however, this test does not provide insight into the performance of the different phases/qualities listed previously.

To provide more useful information to practitioners, it would be beneficial to have measures that differentiate between the different phases of the modified 5-0-5 COD test (acceleration, deceleration, 180-degree turn and reacceleration). Total time may give some insight into COD performance; however, it fails to provide an isolated measure of each phase. For example, an athlete may have great acceleration and poor 180-degree turn ability, but still produces a good total time. Knowing the contribution of each phase will provide higher levels of diagnostics to better inform COD speed development and programming. Similar research has been conducted by Forster and colleagues (2021) for the pro-agility COD test with male high school athletes. The test was adapted, with the addition of timing gates 1 m from each COD line, enabling acceleration, deceleration, and COD performance to be isolated. The authors of this study

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reported acceptable absolute consistency (coefficient of variation [CV] <10%) for nearly all variables and ‘poor’ to ‘good’ relative consistency for all variables from days 1-2 and days 2-3 comparisons (intraclass correlation coefficient [ICC] = 0.13 to 0.86). The acceleration 2 and 4 split had the highest variability for both day 1-2 and 2-3, however the COD 1 split had the lowest relative consistency (ICC = 0.13). It is of importance to explore both absolute and relative consistency, to get a full understanding of a test’s reliability (Hopkins, 2000). Similar procedures should be explored for the modified 5-0-5 COD test to provide greater diagnostic value.

If there is a high degree of shared variance between phases of the modified 5-0-5 COD test, then there is not a solid rationale for separately measuring these athletic qualities. Therefore, the first purpose of this study was to determine the strength of the relationship between the different sub-phases of the modified 5-0-5 COD test. If these sub-phases have a shared variance (R²) lower than 50%, then the qualities are thought to be reasonably independent of each other (i.e., there is more unexplained variance than explained variance) and therefore it needs to be established whether these sub-phases can be measured accurately and consistently. Thus, quantifying the variability associated with the sup-phase analysis provided the second purpose of this article.

2. Methods

2.1. Experimental approach to the problem

Ten elite female netball athletes performed three maximal effort trials (each leg) of the modified 5-0-5 COD test, over three testing occasions, separated by seven days. Timing lights were placed at 0, 2 and 4 m and the start line was placed 0.5 m back from the first timing gate, to accommodate for a forward lean and eliminate false triggering of the timing lights. This enabled five distinct sub-phases to be established in order to more accurately detect acceleration, deceleration, and COD performance. Shared variance was established via coefficients of determination. The variability of the sub-phases/qualities were quantified using CVs and ICCs.

2.2. Participants

Ten elite female netball athletes (age: 24.9 ± 5.0 years, height: 180.1 ± 6.5 cm, weight: 81.3 ± 15.0 kg) participated in this study. Athletes competed in the New Zealand netball premiers league and had a minimum of six years netball experience. Participants were required to be healthy and free of injury at the time of testing. All participants were provided with an information sheet and were required to fill out a written consent form prior to participating in this study. Participants were notified that they were free to withdraw from the study at any point. This research was approved by the Auckland University of Technology Ethics Committee (20/402).

2.3. Measures

Dual beam timing gates (Swift Performance Equipment, New South Wales, Australia) were used to quantify COD performance. Gates were set at 0, 2 and 4 m to isolate the phases of the 5-0-5 COD test (acceleration, deceleration, 180-degree turn and reacceleration). These distances were piloted, and the authors found that if the last timing gate was any closer to the turn line, then subjects body parts would prematurely break the timing gates. Timing gate height was set at 1 m, in approximate line with centre of mass. This set up produced five different splits, as well as total 5-0-5 COD performance time. These times corresponded to the different phases of the modified 5-0-5 COD test as outlined in Table 1.

Testing was conducted on an indoor netball court. Athletes were instructed to wear the same clothing and footwear for all three sessions. The athletes perform the modified 5-0-5 test on a weekly basis as part of their normal programming and therefore did not require a familiarisation session. Testing was conducted seven days apart, at the same location and time of day. Each testing session was 40 minutes and athletes performed a standardised warm up consisting of lower body activation such as banded walks and squats, a series of different jumps (vertical and horizontal bilateral and unilateral countermovement jumps), dynamic flexibility of the hamstrings, quads, hips and calves, and progressive sprint (5, 10 and 20 m) and COD drills, building the intensity up to maximum effort.

Table 1: The different splits in the modified 5-0-5 COD test and the name and explanation of the sub-phase.

Split	Name	Explanation	Quality
1	Acceleration	From start line to first timing gate (2 m)	Concentric first step quickness
2	Deceleration	From second timing gate to third timing gate (2 m)	Eccentric strength and SSC
3	180-degree turn	One step before and after the 180-degree turn. From third timing gate to turn line (2 m)	Lateral reactive strength (SSC) and isometric strength
4-5	Reacceleration	From third timing gate to finish (4 m)	Concentric strength and SSC
1-5	Total time	5-0-5 COD test total time (10 m)	All qualities

2.4. Procedures

For the modified 5-0-5 COD test, athletes were required to start 0.5 m back from the first timing gate. Athletes were instructed to sprint 5 m and touch their foot on or over the COD line, perform a 180-degree turn on a specific leg and sprint 5 m back through the first timing gate. Three trials within each testing session were performed on each leg. Three minutes of rest was provided between trials to limit any fatigue effects. Athletes were instructed to begin behind the start line in a two-point stance and could begin the test whenever they were ready. To ensure each athlete touched the line, the researchers observed each trial. If the athlete had a mistrial, they were given a retrial after three minutes of rest.

2.5. Statistical Analysis

As there were no significant differences found between left and right COD times, the data was pooled, and all analyses thereafter was performed on the averaged data. Outlier and normality analysis was implemented on the pooled data and means, and standard deviations were reported for all variables of interest, with 95% confidence limits (CL) used where appropriate. Pearson correlation coefficients were used to determine the strength of association between variables and coefficients of determination (R^2) were used to quantify shared variance. Absolute consistency between sessions was quantified using CV, where measures less than or equal to 10% were deemed acceptable (Uthoff, Oliver, Cronin, Winwood, & Harrison, 2018). Relative consistency between sessions was determined using ICC using a two-way random average measures model (Koo & Li, 2016). Classification of ICC was deemed as follows: ‘very poor’ (< 0.20), ‘poor’ (0.20 - 0.49), ‘moderate’ (0.50 - 0.74), ‘good’ (0.75 - 0.90) or ‘excellent’ (> 0.90) (Buchheit & Mendez-V., 2013). Statistical analysis was performed using IBM SPSS statistical software package (version 27.0, IBM Corporation, New York, USA).

3. Results

The strength of association between each split for the modified 5-0-5 COD test are presented in the correlation matrix (Table 2).

Correlations between variables ranged from 0.28 to 0.94. In terms of the relationship with total time, the 180-degree turn had the greatest shared variance ($R^2 = 88.4\%$) whereas the lowest shared variance was during the reacceleration phases ($R^2 = 42.2\%$). Correlations between sub-phases ranged from 0.28 to 0.83. The greatest shared variance between the sub-phases was 68.9% between deceleration and reacceleration 2 and was the only variable to explain more than 50% of shared variance between sub-phases. The lowest shared variance, (7.8%) was between reacceleration 1 and reacceleration 2.

The inter-session variability of split times and total time for the modified 5-0-5 COD test can be observed in Table 3. The average change in mean (0.35%) between days was 1.08% (days 2-1) and 1.43% (days 3-2). There appeared no systematic change between the variables, the largest change was observed between days 3-2 for the reacceleration 2 phase (-2.4%). In terms of absolute consistency, all CVs were less than 10% (1.1 - 6.6%) the greatest variability found in the 180-degree COD. With regards to rank-order consistency, all but one variable had ICC’s greater than 0.77, the lowest relative consistency found in reacceleration 1.

4. Discussion

The purpose of this study was to firstly, determine the strength of inter-relationship between the sub-phases of the modified 5-0-5 COD test, and to determine whether any of the sub-phases were better predictors of COD total time. Also, we wanted to quantify the inter-relationship between sub-phases to determine if they were relatively separate motor qualities. A secondary aim was to determine the variability of the sub-phase qualities. The main findings were: 1) the 180-degree had the greatest shared variance with total time ($R^2 = 88.4\%$); 2) only one of the correlations between sub-phases explained more than 50% of the shared variance (i.e., deceleration and reacceleration), indicating that these sub-phases are for the most part measuring relatively independent neuromuscular qualities; and, 3) in terms of percent change in the mean, absolute consistency and relative consistency, no systematic bias was observed and most of the measures very stable between testing occasions.

Table 2: Pearson correlations (r) between the splits for the modified 5-0-5 COD test.

	Acceleration	Deceleration	180-degree Turn	Reacceleration 1	Reacceleration 2	Total
Acceleration	1.0					
Deceleration	0.65*	1.0				
180-Degree Turn	0.67*	0.59	1.0			
Reacceleration 1	0.38	0.34	0.57	1.0		
Reacceleration 2	0.50	0.83**	0.50	0.28	1.0	
Total	0.74*	0.80**	0.94**	0.65*	0.69*	1.0

Note: * $p < 0.05$, ** $p < 0.01$

Table 3: Inter-session variability of split times.

Variable	Mean ± SD			% Change in mean (95% CL)		CV (95% CL)		ICC (95% CL)	
	Day 1	Day 2	Day 3	Day 2-1	Day 3-2	Day 2-1	Day 3-2	Day 2-1	Day 3-2
Acceleration	0.55 ± 0.03	0.55 ± 0.03	0.54 ± 0.02	-0.8 (-2.3 – 3.57)	-1.2 (-0.81 – 1.31)	1.5 (1.0 – 2.8)	2.5 (1.7 – 4.7)	0.94 (0.78 – 0.98)	0.82 (0.44 – 0.95)
Deceleration	0.51 ± 0.03	0.52 ± 0.04	0.51 ± 0.04	2.1 (-1.0 – 5.4)	-1.2 (-3.1 – 0.7)	3.1 (2.2 – 5.8)	1.9 (1.3 – 3.6)	0.84 (0.39 – 0.96)	0.95 (0.78 – 0.98)
180-degree Turn	0.63 ± 0.09	0.64 ± 0.08	0.64 ± 0.09	1.8 (-2.8 – 6.5)	-1.0 (-7.2 – 5.6)	4.6 (3.2 – 8.6)	6.6 (4.5 – 12.3)	0.90 (0.64 – 0.98)	0.78 (0.29 – 0.94)
Reacceleration 1	0.63 ± 0.03	0.64 ± 0.02	0.65 ± 0.05	0.8 (-2.2 – 3.9)	1.7 (-2.4 – 5.8)	3.0 (2.1 – 5.6)	4.1 (2.8 – 7.6)	0.57 (-0.09 – 0.88)	0.77 (0.26 – 0.94)
Reacceleration 2	0.43 ± 0.02	0.43 ± 0.03	0.42 ± 0.03	0.2 (-2.2 – 2.7)	-2.4 (-5.6 – 0.9)	2.4 (1.7 – 4.5)	3.3 (2.3 – 6.2)	0.83 (0.43 – 0.96)	0.78 (0.31 – 0.95)
Total Time	2.75 ± 0.14	2.77 ± 0.17	2.74 ± 0.17	0.8 (-0.7 – 2.2)	-1.1 (-2.2 – 0.0)	1.4 (1.0 – 2.6)	1.1 (0.8 – 2.0)	0.95 (0.79 – 0.99)	0.97 (0.88 – 0.99)

An interesting finding was that 180-degree turn was the best predictor for total time, which indicates that having good COD ability is the main factor for producing a good modified 5-0-5 total time. Previously it had been suggested that an athlete with good linear speed, but poor COD ability could perform well in a traditional 5-0-5 COD test as their linear sprinting ability could mask any COD deficiencies (Nimphius, Callaghan, Spiteri, & Lockie, 2016), given the greater proportion of time linear sprinting in that test. It would seem from the results using elite netball female athletes that the modified 5-0-5 may be a truer measure of COD ability given the effects of linear speed seem of lesser magnitude.

From the inter-correlations between sub-phases, it is clear that each of the motor qualities were relatively independent of one another, and only one sub-phase explained more than 50% of the shared variance, indicating that each phase for the most part was in fact measuring relatively different neuromuscular capabilities. Reacceleration 2 and deceleration had the greatest shared variance between sub-phases ($R^2 = 68.8\%$). Interestingly, the lowest shared variance was found between reacceleration 1 and reacceleration 2 ($R^2 = 7.84\%$). This suggests that although these two sub-phases are both reacceleration, they are in fact measuring different qualities. The authors hypothesised that reacceleration 1 would require greater concentric strength, whereas reacceleration 2 would be relying on greater reactive strength. To the authors knowledge, this is the first study to perform a sub-phases analysis on the modified 5-0-5 COD test, therefore there is limited literature to compare results with.

A majority of the research on the variability of the modified 5-0-5 COD total time, has focused on within-session variability (Thomas, Comfort, Chiang, & Jones, 2015; Thomas, Dos'Santos, Comfort, & Jones, 2016), however this information is of limited use as it does not indicate whether the test is variable across testing occasions. Barber and colleagues (2016) reported high relative within-session consistency (ICC = 0.97) for the modified 5-0-5 COD test, however they did not report absolute consistency. In this study, total modified 5-0-5 COD time was found to have excellent (ICC = 0.95 & 0.97) relative consistency and acceptable absolute consistency (CV = 1.4% & 1.1%), between days 2-1 and 3-1 respectively. These results were similar to previous research for this test (Barber et al., 2016; Gabbett, Kelly, & Sheppard, 2008).

All sub-phases were found to have good to excellent relative consistency (ICC = 0.77 to 0.98) and acceptable absolute consistency (CVs < 5%), except for acceleration 1 that was found to have moderate (ICC = 0.57) relative consistency between days 2-1. To the authors knowledge, there is currently only one study that has attempted to isolate and determine the variability of different sub-phases for a COD test. Forster and colleagues (2021) measured different components of COD performance during a pro-agility COD test, by including three sets of timing gates. Interestingly, this research reported acceleration 1 to be the only variable with acceptable relative and absolute consistency (ICC = 0.71 to 0.79, CV = 5.16 to 5.39%). It was suggested that this may be because reacceleration phases may be influenced by COD, as post-COD acceleration or reacceleration can be influenced by the body and force orientation (Dos'Santos, Thomas, Comfort, & Jones, 2018). This may have been the case for this research, as the reacceleration 1 phase was shown to have the lowest absolute and relative consistency (CV = 3.0% and 4.1%, ICC = 0.57 and 0.77),

however these values are still acceptable and considered reliable. There was very little systematic bias between sessions, however, it needs to be noted that the participants were elite athletes that performed the modified 5-0-5 test on a regular basis and did not require any familiarisation.

4.1. Conclusion and Practical Applications

It appears that the modified 5-0-5 COD test can successfully be split into sub-phases, and each sub-phase can be measured consistently using dual-beam timing gates. It is clear that these sub-phases are relatively independent qualities, and therefore should be measured as such. Although educated guesses can be made as to which neuromuscular qualities are most at play during these sub-phases, further research is needed to solidify this. Furthermore, readers should be cognizant that the findings of these results are specific to well-trained netball athletes, and more research is needed with different athletic populations. This advanced modified 5-0-5 COD diagnostic protocol can enable strength and conditioning coaches and sports scientists to reliably track sub-phase performance and identify areas of strengths and weakness of their athlete, thereby providing specific information related to athletes which can be used for training specificity. Intuitively this should improve COD performance, however, such a contention needs to be validated using longitudinal designs.

Conflict of Interest

The authors declare no conflict of interests.

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Injury as an occupational hazard in professional rugby union: A qualitative analysis of interviews with ex-professional rugby players

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ABSTRACT

The focus of this study was to interview retired professional rugby union players (≤ 10 years since retirement) to discuss their careers in the game of rugby union. These interviews explored their experiences of being a professional rugby player, with respect to physical injury, concussion incidence and concussion management. In addition, the aims were to ascertain how retired rugby players retrospectively viewed physical injury, concussion incidences in their careers, and the effects that professional rugby had on their physical and mental health while playing and in retirement. Twenty-three retired ex-professional rugby players were interviewed, 61% had represented their countries at full international test level rugby. Two major themes were identified, 1) the realities of being a professional rugby player, 2) concussion and physical injury as an occupational hazard in the professional game. These were further divided into categories and subcategories. The interviews highlighted that players saw themselves as commodities and were motivated by many factors, including financial reward. Players openly stated that they accepted injury and concussion incidences as an occupational hazard of professional rugby. Many of the players admitted to having both undiagnosed and undisclosed concussions. Changing the perception of how concussion is disclosed and using this to influence future generations may be a practical means to guide athlete and coach education in collision sports.

1. Introduction

Rugby union has been a professional sport since 1995 when the International Rugby Football Union Board (now World Rugby) permitted players to be paid to play (Hill et al., 2018). Up to this time, the game was considered an amateur sport, meaning that payments or ‘material benefit’ to players were not permitted. Professionalism in sport has a notable cost, for example, it has been reported that salaries for marquee professional players in the United Kingdom and Ireland during the 2018-2019 season were more than £600K (NZ\$1.1M) (Esportif Intelligence, 2018-19). Finance from private sources in addition to lucrative broadcast incentives means that professionalism has changed the game permanently (Nauright & Collins, 2017). With the increase in the monetary value in the game, there are notable financial pressures for players, coaches, and club owners (Nauright & Collins, 2017).

Rugby players are highly trained professional athletes that are required to be in peak physical condition to meet the rigorous

demands of the game. Since the introduction of professionalism, players have evolved anthropometrically into larger and more powerful athletes (Quarrie & Hopkins, 2007), inherent in these physical changes are an increased injury risk that is an ever-present threat to the modern player (Williams et al., 2017). Since 1995, rugby players currently see elite rugby as a legitimate career path, and it has been speculated that modern players accept injury risk as being an occupational hazard of participating in collision sports (Malcolm, 2009).

In comparison to amateur players, the injury risk trend is higher in players in the professional game (Yeomans et al., 2018). When looking at physical injury and concussion incidence rates in professional players, the Professional Rugby Injury Surveillance Project report from the UK (2017-18 season) recorded an incidence rate of 17.9 head injuries per 1000 hours of match play (England Professional Rugby Injury Surveillance Project Steering Group, 2018). This equates to 16% of all players experiencing at least one concussion, with 39% of players

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returning to play within seven days of the injury. Although there is evidence to suggest that there is sufficient knowledge and awareness regarding concussion symptoms and treatment among playing population (Kraak et al., 2019), it has been suggested that there is considerable underreporting of concussion in the game (Clacy et al., 2019).

Many professional rugby players are highly competitive individuals who may choose to disregard their personal health in pursuit of achieving success at the highest levels of the sport (Block et al., 2016). This can manifest in athletes choosing not to disclose their concussion symptoms, as they may experience an internal or external pressure to maintain a silence regarding concussion (Mathema et al., 2016). In this respect, physical injury and concussion can be viewed as an occupational hazard as it almost inevitable that a concussion or repeat concussions will happen to a rugby player during their playing careers (Eagle et al., 2020).

The focus of this qualitative research was to explore the undisclosed realities and lived experience of being a rugby player in the professional era. Central to this research was to ascertain how retired rugby players retrospectively viewed injury in their playing careers. With a focus on the effects that professional rugby had on their physical and mental health. Furthermore, these interviews assessed their perception of concussion and what knowledge they had about the potential long-term effects of the physical injury.

2. Methods

2.1. Study Design

For the purposes of this study, a reflexive thematic analysis was implemented (Braun & Clarke, 2013). A semi-structured individual-interview design was developed to interview retired professional players who had played rugby union to ascertain their physical injury experiences, concussion experiences and concussion knowledge. The interview questions were designed to elicit responses on their playing background that would determine their opinions to physical injury and concussion experience. Participants were sought from various countries and hemispheres to get broad comprehensive perspectives.

2.2. Ethics and Procedures

Ethical approval, according to The Declaration of Helsinki, was granted to this study via the Research Sub-Committee of Academic Council of Galway Mayo Institute of Technology (GMIT; RSC_AC_23062020). The initial cohort of participants were identified via the lead researcher by issuing an invitation alongside a participant information sheet, to participate in the study. The preliminary discussions were an opportunity for participants to discuss the aims of the study and how the information would be confidentially managed. Each participant provided informed consent before their interview. Data were collected during interviews ranging from 25 to 70 minutes in duration. It was established that all information would be treated confidentially and anonymised for the purposes of the study.

2.3. Participant Characteristics

The participants ($n = 23$) had retired from professional rugby union within the last 10 years at the time the data were collected. The mean age of the players interviewed was 35.5 ± 4.7 years (range 29 to 43 years old). From the cohort of players ($n = 23$), 14 had represented their countries at full international test level rugby (61%). The following nations were represented; Ireland ($n = 17$), England ($n = 1$), Scotland ($n = 3$) and Australia ($n = 2$). The average career span was 9.3 ± 2.7 years and the average age at the time of retirement from professional rugby was 30.8 ± 2.9 years. The playing positions when separated into 'forwards' and 'backs' were 70% and 30% respectively. Within these two divisions, the following breakdown occurred in the 'forwards' division: front row ($n = 6$), second row ($n = 2$) and backrow ($n = 8$). Within the 'backs' the distribution per population was as follows, winger ($n = 2$), centers ($n = 3$) and scrum half ($n = 2$).

2.4. Sampling and Eligibility Criteria

An exponential non-discriminative snowball sampling method was utilised whereby the first participant recruited to the sample group provided multiple referrals (Biernacki & Waldorf, 1981). Participants were informed that they did not have to provide any other potential participants. In many instances, participants provided referrals to other ex-players who were interviewed for this research. The semi-structured interviews allowed a standardised sequence of responses across the participants. This enabled the researchers to identify common themes and/or responses from the participants.

2.5. Data Collection and Data Analysis

The responses to the semi-structured interview questions were used to gather evidence regarding their personal awareness of physical injury and concussion whilst they were actively playing professionally. Additional questions were used to establish any perceived impact on their physical and mental health. This study sought to add the 'player's perspective' to the information that national sporting organisations are providing in relation to concussion management and associated symptoms (acute and chronic). These data will provide research aimed at informing current and future players who participate in collision sports about the associated risk of concussion in the short and long term.

Data were analysed thematically according to the reflexive thematic analysis approach developed by Braun and Clarke (2006, 2013) following an update to their original thematic analysis approach. A critical realist framework was utilised to identify and make sense of the players' descriptions of their experiences in professional rugby (Braun & Clarke, 2013).

2.6. Transcription

After each interview, every participant was given time to review their interview and offer comments on their personal recording. The audio recordings of the interviews were transcribed verbatim by the lead researcher (ED). These transcripts were cross checked for accuracy against the original audio recordings to edit the

transcripts. This involved an initial familiarisation with the content of each transcript by reading and re-reading each transcript to ensure the questions and responses correlated with the audio files of the interviews, this was completed on 4 separate occasions per interviewee. All corrections to transcripts were finally cross checked for trustworthiness by an independent researcher (LR). All efforts were made by the research team to ensure quality in relation to clarity in the transcription, manuscript organization, with accuracy in the final manuscript drafts.

2.7. Coding

Coding, focusing on both semantic and latent meanings was undertaken by the first author (ED) and reviewed with another author (LR). Codes included positive and negative experiences of being a professional rugby player. Theme development was led by the first author in consultation with another author (LR). Initially concussion injury management and safety in the game were scoped as potential themes. The lead researcher identified categories and subcategories for all 23 interview transcripts. During this process, the original list of identified themes were examined, and a quantity were amalgamated as subcategories to reduce the overall number of themes within the study (see Table 1). During the analytic process a flexible and open coding system was utilised to allow for open engagement with the data

2.8. Researcher Background

The research team nominated ED as the primary interviewer to collect data. This was based on his previous experience of being part of a professional rugby organisation. It was determined that the ex-professional players would be more responsive and/or more open in their interview responses when compared to other members of the research team. This approach was reinforced as it would be a male interviewer (ED) that would be conducting the interviews with male participants. This was viewed as a positive aspect with respect to the recruitment of participants for the study

3. Results

In this study, two major themes emerged: 1) The realities of being a professional rugby player; and 2) Concussion and injury as an occupational hazard in the professional game. These were further separated into categories and subsequently into subcategories (see Table 1).

3.1. Theme 1 - The realities of being a professional rugby player

3.1.1. Players as commodities & financial incentives

Comments discussing contract negotiations were central to the overall theme of players seeing themselves as commodities while they were playing professional rugby. Many of the remarks related to the fears about being injured or carrying injuries into contract negotiations, for example:

“...It's amazing how much one injury could put you on the back foot in those things (contract negotiations)”.

In tandem with physical injury or being perceived as a player who was prone to injury. Other fears were equally prevalent relating to concussion or more accurately, having to disguise concussions to maintain a contract:

“Because I was out of contract at the end of that season, and I'd had concussions.... I needed to get back and play these games.... It's a horrible predicament to find yourself in”.

Many players were reliant on their contracts as a source of income, with respect to this, certain physical dangers were expected and accepted:

“I think I'd had like 10 operations in three years; ...then I stopped playing because I wasn't offered another contract”.

The physical toll was constant as many contracts were linked to seasonal performance.

“You can get really good money which was hard to get at that stage.....but for me it was pretty short, I had four or five good years”.

The consequences of continued involvement meant that the dangers were perpetual, for example:

“My career came to an end because of a very bad hip injury which required a hip replacement, it's a difficult way to end your career”.

On average most players involved in these interviews were retired before the age of 31 predominantly due to physical injury or concussion frequency.

Being a fringe player (i.e., not a first-choice player) can result in playing contracts that are tenuous and bring their own level of internal or external pressures. The fringe players (n=8) interviewed for this study considered themselves as not being a core player in the team:

“I wasn't fortunate enough to be one of the bigger names. I was not guaranteed to be picked every week.... I could never relax” or “I always had to be ready..... it was mainly external pressure.....there is pressure put on you (by coaches), ‘are you OK, it's a big week for you this week’. Putting all the burden back on you (the player)”.

It is interesting to note that players felt like commodities to be traded depending on the players ability to remain injury free.

“I mean you're a commodity; that's the way it is going in the modern game. And if you know a player X is earning a couple of hundred grand a year, an' he's missing six months of the season..... because of a concussion, it's difficult for clubs to standby players financially”.

This is exacerbated when financial pressures impact on the personal lives, when the future for themselves and their families were reliant on remaining free from injury:

".....I didn't have a contract until about three weeks ago and we're moving there now, mentally it can be quite difficult sometimes".

3.1.2. Sacrifice vs. public perception

Many players expressed opinions that were at odds with what they felt the general public perceived about professional rugby:

"You're reasonably well paid when you get to a certain level, but what you put your body through (it's) not too much" or "I had four or five good years and my head was gone, it became a chore".

The ex-players were vocal about how much they had personally 'sacrificed' to become a professional player:

"It's rather time consuming, putting in your effort as a professional athlete, you know there are a lot of choices you need to make about the fallout" and "this thing (professional rugby) decides everything in your life, especially when family holidays don't coincide with school" illustrating that it was all-consuming vocation or a "24/7 kind of job".

Another aspect that many participants stated was how they continued to play while experiencing concussive symptoms. For example, one participant stated that:

"I saw a noticeable decline in my performance because of them (concussions), a notable decline in my health, my mental health, my physical health I was drinking a lot more, I was taking painkillers".

This manifested as a willingness to compete while being physically injured and declaring themselves fit to play while physically injured:

"But like if a coach asked me could I play the following week (while injured)? I think I did!".

The physical impact of the game was exhibited in a more subtle manner during their careers:

"You see guys who are getting physically sick after games" and when they reflected on their careers post retirement "not being able to come down the stairs in the morning without using handrails is nice, you're not constantly stiff and sore".

Life as a professional rugby player came at a notable personal cost to themselves and those around them:

"...and I just felt you end up giving an awful lot to the sport and my whole life was almost dominated by it" or "talking to people who have played this sport or are involved in this sport and underestimate what it is, and how aggressive and physical it is".

There was an underlying sense that retirement was closure on a meaningful part of their lives. This was reflected in how they spoke about their overall rugby career:

"It is just like an extension to your school days, because it's almost like you go in and get to have a good time with your school mates every day, and even better still, you're getting paid for it".

Nearing the end of their careers provided higher levels of self-awareness for many of the participants:

"You have a certain amount of credit in the bank (as an established professional player) but, as I said, it's amazing how that goes quickly if you get a long-term injury".

Nearing the end of their careers, if they made decisions to seek a contract with different clubs or play in lower leagues, there was a sense of delaying the inevitability of retirement from the game:

"So, I tore my bicep about two weeks (before a contract renewal); I wouldn't say that was the final nail in the coffin, but it definitely gave me further cause for consideration to hang up the boots or not."

The decision to retire and remove themselves from the professional rugby fraternity was also difficult as:

"Over the space of a few years, where it was, if I'm being honest with myself, it was like delaying the inevitable kind of in a way".

3.2. Theme 2 - Concussion and injury as an occupational hazard

A second theme that emerged during the interviews were that concussion and physical injury were accepted as an occupational hazard. During the interviews, there was a sense of accepted inevitability of physical injury risk and concussion risk from all players interviewed.

3.2.1. Accepted risk of a career in professional rugby

Rugby has inherent risks, and it was clear that many players have been positively conditioned to this cultural aspect of the game; and in many cases this conditioning began at an early age. For example:

"I fell in love rugby around 9-10 years of age" or "you know you play the game because you love it".

This fraternal culture was reinforced during their careers in terms of viewing professional clubs as an extension of 'school days'. As a consequence, a cultural narrative emerged which acted as an enabler to connect successive generations of rugby players:

"The wealth of experience and knowledge that I come into as a young man, that was unbelievable, and I don't think you realize it when you're doing it at the time".

This culture pertained to players not wanting to let fellow players down or the club as illustrated by:

"If you were able to stand up and play on, tackle the fellow in front of you..... you're not concussed enough to go off like. It kind of goes back to the point, that unless you're asleep on the field, and can't actually stand up, you're staying on, and you play on was the attitude".

An interesting point is how prevalent a self-correcting / self-policing environment was created with the playing groups of which they were members:

“But that's not just from the coaches, that's just from your peers, your older players, because that's what they used to do. You just suck it up (play injured or concussed) and get on with it”.

Supporting the ethos of playing through injury and being dismissive of concussion; players commented on whether they had ‘official’ or ‘unofficial’ diagnosis. In many instances, comments related to this were highly dismissive, either by the language used or the casual manner that concussion was discussed:

“I may have gotten an undiagnosed one, where I got a bang in the head and then two weeks later, played (another game), that's why I don't have any memory of it”.

Some players comments were illuminating in relation to direct knowledge of how concussions occur:

“I've no doubt there's been times where I failed under pressure and blacked out.....and within a couple of seconds you're like ‘oh geez’, it means that's a concussion”.

It's likely that these comments remain the prevalent view towards concussion as rugby is seen as confrontational and demurring from this within a squad context is not acceptable:

“Guys put pressure on themselves to keep playing and toughen up and you know that is rugby for sure”.

The retired players were vocal about what needs to change in the context of the culture of the game:

“I think people are going in the right direction, like the whole culture around it (concussion) has changed, I would have remembered years ago, you could have staggered (from concussion), and then it was played in front of the (player)meeting as a bit of a gag like, laughing”.

Players are cognisant that change needs to be implemented beyond a superficial level as:

“There needs to be a change, and I think it needs to be cultural change; you stop accepting that this (playing while concussed) needs to be part of it.....getting back on a field that is not necessary. But yeah, the difference between bravado and being an idiot, really”.

The primary focus of these cultural changes is for the wellbeing of the players. More clearly stated in an alternative manner is how player safety is managed with ongoing revisions to the game and the laws of the game:

“The kind of culture that we need is to make this game as safe as possible, it's never going to be safe like every time, but you kind of have to have the emphasis that we're doing our best to make it safer”.

Further comments related to these types of changes may be expressed with increased reporting rates and improved concussion recognition protocols:

“I think why concussion is more prevalent now. It's because, we're actually recognizing it with a lower bar than what would have happened 15-20 years ago or more”.

Within these comments, there was a consistent expression of frustration around the injury, namely that it's not a visible injury like a musculoskeletal injury and therefore subject to an undefined recovery time:

“The frustration with concussion is that it's just unnerving and frustrating, you don't know where the finish line is, so if I ruptured my ACL, I know I'm probably out for about 9 months, give or take a month or two, but with concussion you just don't know, and that's what I find so frustrating about the actual injury”.

Alternatively, some players expressed added frustrations as to how professional players were cleared to return to play much quicker than their equivalent amateur players. This type of ‘fast track’ recovery for professionals remains an anomaly with the professional game:

“A guy can get knocked out on a Saturday and if he starts his RTP (return to play) on a Sunday with no symptoms, then he can play again the following Saturday and I don't think that that's right. Like if a guy has visibly lost consciousness or has come close to losing consciousness, I don't see how it's acceptable that he's back on the field seven days later”.

The participants accepted that they had a ‘job’ where they got compensated for financially. This was expressed as a proud fulfilment of a long-held ambition using terms such as being ‘fortunate’, ‘lucky’ or that it was a ‘dream’ career since boyhood. For example:

“I've been very lucky with rugby, it's been extremely good to me” or “I got exposed to good coaching as I was growing up, that's why I love the game and I was lucky enough that I could make a living from it as well”.

Based on these comments and how ingrained rugby culture is in these players, it is understood that the profession has accepted occupational hazards:

“I think it (professional rugby) will just continue to be an occupational hazard and people just have to accept that”.

It was repeatedly stated that players accepted these hazards when they signed contracts to play professionally:

“I think if you sign on the line (contract) to get paid to play rugby. It's your choice and you have to face the consequences”.

As a result, they accepted injury risk and concussion in the short term, along with possible consequences for their long-term health:

“But like call a spade a spade, if you're messing with someone's brain, you'd stop” or “what else can we do to reduce it (concussion)? It's going to happen. It's a contact sport and it's (the game) unpredictable”.

Table 1: Results of thematic analysis of retired professional male rugby players perceptions of physical injury and concussion as an occupational hazard (n = 23)

Themes	Categories	Subcategories	Sample Quote	
1. The realities of being a professional rugby player	Players as commodities	Pressure around contract negotiations	“Just every injury came at the wrong time...it's amazing how much one injury could put you on the back foot in those things (contract negotiations)” (P6)	
		Dangers of professional rugby	“I had neck surgery in 2014. Bilateral stenosis, which is bone growth of both the discs on the C6-C7... I'll get pain in my arms or maybe loss of sensation and it can get quite cramped up a times.” (P9)	
		Being a fringe player	“I was not guaranteed to be picked every week.... dreading the team announcement on Tuesday...I could never relax” (P25)	
	Financial incentives	Rugby as a business	And it's difficult because it's a business and you know if you're not pulling your weight and your and you're making good money, it's you're going to be on the chopping block.” (P12)	
	Sacrifice vs. public perception	Physical Impact		“You know not being able to down the stairs in the morning without using the handrails is a nice thing, (P6)
			Public perception	“I was retired less than a week and I was back working out in an oil refinery.” (P13)
		Self-awareness	“...that's fine when you're, you know you're a teenager, early 20s and but when you're in your prime and then you're in a position again, I wasn't prepared to do it again.” (P22)	
	2. Concussion and injury as an occupational hazard	Accepted risk of a career in professional rugby	Culture of the game	“Remember, being in the changing rooms and I'd come after 20 minutes, and I was in my tracksuit after the game and being like what happened, and they were laughing at me.” (P5)
			Dismissive of concussion	“...on Tuesday or Wednesday before I thought ‘I might be concussed here’. It's actually quite subtle... there wasn't a big distinction between maybe being concussed and may just a really rough game.” (P21)
Cultural changes in the game			“I think it needs to be cultural change; you stop accepting that this needs to be part of it...getting back on a field that is not necessary. But yeah, the difference between bravado and being an idiot, really.” (P16)	
Unquantifiable nature of concussion			The frustration with concussion thing that is just unnerving and frustrating about it is, you don't know where the finish line is, so if I ruptured my ACL, I know I'm probably out for about 9 months, give or take a month or two, but with concussion you just don't know and that's what I find so frustrating the actual injury.” (P14)	
Accepting the consequences of playing pro rugby			So, I think if you sign on the line to get paid to play rugby. It's your choice and you have to face consequences I think.” (P10)	

4. Discussion

The primary aim of this study was to clarify the realities and the lived experience of professional rugby from the perspective of ex-professional rugby players. The interviews highlighted that players saw themselves as commodities and were motivated by many factors, including financial reward, adulation of the spectators and latent pressures from coaches or fellow peers. Many players described it as a 'brotherhood' or similarly compared it to 'school days'. In this context, professional rugby provides an unusual dynamic where fellow professionals that are your teammates; can concurrently be direct competition for starting positions or contracts. For example, when teammates got injured, it presented an opportunity to fellow squad members for a starting position.

Intertwined with this dynamic is that the realities of the game are far removed from the public perception. The participants alluded to a misunderstanding of realities associated with professional rugby by the public. The general public didn't see the personal sacrifices, the physical pain or the struggles associated with retaining a contract. These perceptions present a difficult position to rationalise, but it can be partially explained by the veracity that rugby is a highly competitive and lucrative business (Nauright & Collins, 2017).

The Irish Rugby Football Union at the end of the 2018/19 season reported an income surplus of €27.9M (NZ\$45.2M) in its consolidated financial statement (The Irish Rugby Football Union, 2019). Financial consequences give rise to increased pressures that are transmitted to coaches, directors of rugby, support staff and eventually to the players. Players are valuable assets to the club as they aim to bring success in a sporting sense on the field of play and in a commercial manner off the field of play. The ex-professional players suggested that disclosures of injury or accumulating a series of injuries may be seen in a negative light by the coaching staff or club owners. In this study, many players were fearful of not having contracts renewed because of a current injury (concussion or otherwise) or being perceived as injury prone.

These conditions manifested in players accumulating additional stresses because of fear of being injured around contract negotiations and consequently, at risk of losing their contract. The concept of playing while hurt was supported by important others (i.e., coaches and peers) in many instances. This added additional status for the player when they played while injured, and in effect legitimized any of the short-, or long-term health risks associated with their decisions (Roderick et al., 2000). Other concerns highlighted by the participants were that certain players were treated as 'commodities' due to the highly competitive and pressurised environment. In many instances, players chose not to disclose their concussions to medical staff due to a lack of concussion knowledge and fear of pressures around disclosure that can occur in other sports organisations (Baker et al., 2013). Some participants in this study employed this strategy to retain a contract as their injury status could have directly affected their livelihood, and in these instances, many players opted for silence.

Many of the participants were dismissive about concussion, it was an afterthought and not deemed a severe injury. It was interesting to hear how many participants admitted that they had experienced an 'official' or 'unofficial' concussion diagnosis. JSES | <https://doi.org/10.36905/jses.2022.01.04>

This awareness of 'official' or 'unofficial' diagnosis was intrinsically linked to disclosure or non-disclosure of a concussion (Ruston et al., 2019). A salient point connected to this categorisation (i.e., official, or unofficial) was how obvious a concussion was to medical teams, or whether the incident was captured on live TV during coverage of matches.

It was evident that most of the participants interviewed did not fully consider the cumulative effects of concussions or sub-concussive impacts (Pearce, 2016). They may not have been aware of the cumulative effect of impacts on their brain health due to a misunderstanding of what is deemed to be a concussion.

This is common in other sports like soccer, where players may have a moderate knowledge about concussion yet continue to demonstrate unsafe behaviour (Williams et al., 2016). Most of the participants were candid about the gaps in their concussion knowledge. Some were unclear about the mechanism of concussion and were equally unclear about recovery times associated with concussion. It appeared that the most inconvenient aspect of being concussed, was the absence of defined timescale for recovery and how intangible the injury remains. They could not fully understand and accept a recovery period associated with a musculoskeletal injury. However, concussions were invisible, therefore very difficult to define and quantify, that often led to frustration at not being able to compete (Moreau et al., 2014).

The participants used the word 'sacrifice' during the interviews with reference to the commitment it took to be an elite athlete (Fletcher et al., 2012). This phenomenon is not unique to elite rugby, as it is common in other sports relating to issues around social expectations and personal identity outside of professional sport (McEwen et al., 2018). The sacrifices required to be a professional rugby player were hidden from the public domain and this duality is conveyed in the language used to describe professional rugby players. In the public consciousness, elite rugby players are described as 'heroes' or 'warriors' where winning is everything (Douglas & Carless, 2014). The same aspect was evident in this research where it was family members who saw the true constraints of being an elite athlete (Burlot et al., 2018). The realities of professional rugby included concussion risk and being uncertain of employment at the end of any given season. These risks were compounded by the ever-present level of physical danger, as the participants repeatedly stated that there are ongoing exposures to physical risk. These risks are common during the game as it is a collision sport, however, these incidents can occur during training sessions and in competitive fixtures due to the dynamic nature of the game (Fraas et al., 2014).

4.1. Limitations

At the outset of this study, it was envisaged that interviews would be conducted with elite female rugby players however this did not occur. Research into female players and their experiences of concussion is an area that warrants further research. This research included players who had retired in the past ten years and may not be reflective of current practice.

It is also worth acknowledging that the team involved in this research are all coming from a background in sport and therefore the interpretation of the findings is through the lens of those with

an understanding and previous experience of working in professional rugby.

4.2. Implications

A number of implications can be drawn from this study. In professional sports terms, rugby remains a relatively young sport, which can be influenced and shaped to create a safer sport. Changing the perception of how concussion is disclosed could have important positive consequences for medical staff and may be a practical means to guide athlete education and the cultural narrative in collision sports. Players must see concussion as an injury and not be dismissive of it. This may require cultural changes in sporting organisations that can be driven by coaches, medical staff, and support staff.

4.3. Conclusion

The players interviewed do seem to accept concussion as an occupational hazard of playing rugby. Players viewed themselves as commodities who needed to be ‘good value’ for the business (of rugby) and were dismissive of the long-term implications of repeat concussions. Given the increasing awareness of the potential impact of concussion on cognitive health it is imperative that rugby is safe at all levels (professional and amateur) and remains a viable option for future players whether this is a full contact sport or non-contact version of the game.

Conflict of Interest

AJP currently receives partial research salary funding from Sports Health Check charity (Australia). AJP has previously received partial research funding from the Australian Football League, Impact Technologies Inc. (Australia), and Samsung Corporation, and has provided expert testimony to courts on concussion injury.

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Daily protein distribution patterns in professional and semi-professional male Rugby Union players

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ABSTRACT

Recent research in healthy adults suggests an even distribution of protein throughout the day may result in greater stimulation of muscle protein synthesis compared to a disproportionate intake, with 0.4g.kg per meal at a minimum of 4 eating occasions proposed to optimise anabolism. In rugby players, this may be of benefit to exercise adaptations, recovery, and performance. In the present study, semi-professional forwards ($n = 19$), semi-professional backs ($n = 6$) and professional ($n = 10$) rugby players recorded dietary intake for seven days. Both absolute (g) and relative to body mass (g.kg) protein intake was calculated across six eating occasions. Relative protein intake at breakfast, AM snack, lunch, PM snack, dinner and evening snack were 0.3, 0.1, 0.4, 0.2, 0.6 and 0.1g.kg, respectively. Total protein intake was significantly different between groups ($p < 0.05$). All groups demonstrated differences in protein intake between eating occasions ($p < 0.01$). Protein intake was highest at dinner in all athletes, with professionals consuming significantly greater protein than semi-professionals. Rugby players do not appear to meet the recommended per-meal protein dose of 0.4g.kg at a minimum of 4 eating occasions. Consumption of additional protein outside of main eating occasions as snacks may be beneficial to optimise muscle protein synthesis stimulation and thus adaptation, recovery and performance.

1. Introduction

Rugby Union (“rugby”) players are exposed to unique demands during matches and training that can influence energy and nutrient requirements. The sport can be classified as an intermittent team sport, with teams of 15 engaging in repeat-sprints, jumps and collisions (Duthie, Pyne, & Hooper, 2003). Additionally, rugby is unique in that large positional variation is observed in both the match demands and body composition of the players (Zemski et al., 2019). It is recommended that rugby players focus on building fat-free soft tissue muscle to meet the demands of the sport and maintaining an appropriate body composition profile is critical for individual players to fulfil their roles on the pitch (Zemski et al., 2019). For example, a greater fat-free mass in the prop position

(94.4 ± 7.9 kg) is considered advantageous due to the requirement to exert greater force than the opponent whilst contesting the ball whereas lower fat-free mass in inside back positions (78.8 ± 8.2 kg) can allow for greater agility and mobility (Smart, Hopkins, & Gill, 2013). While engaging in high-volume training and competition, rugby players nutritional strategies require careful consideration (Argus et al., 2009).

Rugby players can expect significant physiological, psychological, and endocrine disruption in response to matches (Slimani et al., 2017). The repetitive high-intensity efforts and collisions invokes exercise-induced muscle damage and cellular disruption (Naughton, Miller, & Slater, 2018). Metabolic, endocrine, and neuromuscular function may not return to baseline for up to 36 hours following a rugby match. Moreover, mood

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disturbances are apparent for up to 12 hours post-match, possibly due to competitive stress or fatigue (West et al., 2014). A longer period of disequilibrium as denoted by an impairment of 10m sprint performance, and elevated creatine kinase following a full match was observed in amateur-level rugby players (da Silva et al., 2020). Data from professional players demonstrate the magnitude of muscle damage may be predicted by the number of collisions and high-speed running performance (Jones et al., 2014). With the potential for high training volumes players risk inadequate recovery between matches and training sessions (Argus et al., 2009). As such, ensuring dietary intake is designed to support optimal recovery is of the utmost importance.

Protein intake is an important consideration for athletes to support optimal performance, recovery, and health (Kreider & Campbell, 2007; Phillips, Chevalier, & Leidy, 2015). Rugby players engage in activity encompassing both strength and endurance demands, which may require both mitochondrial and myofibrillar adaptations along with preventing amino acid oxidation in response to prolonged and intense activity (Lemon, 1994; Kato et al., 2016). Researchers have sought to quantify protein requirements for athletic populations and various position statements have been published through organisations such as the International Society for Sports Nutrition (ISSN) (Jäger et al., 2017) and the American College of Sports Medicine (ACSM) (Thomas, Erdman, & Burke, 2016). These position statements provide a comprehensive and critical review of the literature on protein intake in healthy, exercising individuals to determine requirements. Ranges such as 1.4-2.0g.kg.d and 1.2-1.7g.kg have been proposed as sufficient for most endurance and/or strength-trained individuals within the ISSN and ACSM position statements, respectively. It is important to note that these values are unlikely to consider the unique demands experienced by rugby union athletes, and most of the research in the consensus statements utilised resistance or endurance-training protocols. Nonetheless, rugby athletes appear to consume protein in excess of the recommendations (Jenner et al., 2019) with common intakes above 2.0g.kg.d.

Protein ingestion has the potential to stimulate muscle protein synthesis for two to three hours, after which the process begins to decline (Layman et al., 2015). A positive balance between muscle protein synthesis and breakdown, termed an anabolic response (Kim et al., 2018), is a determinant of protein within a muscle and may be crucial to allow for the repair and re-modelling of damaged muscle tissue following exercise (Tipton et al., 2018). Investigations have reported that ingestion of 20g high-quality protein following leg-based resistance exercise is sufficient to stimulate a positive protein balance greater than no ingestion of protein, however 40g induced similar protein synthesis rates but greater amino acid oxidation (Moore et al., 2009; Witard et al., 2013). Conversely, Macnaughton et al. (2016) observed a greater anabolic response in resistance-trained males following full-body resistance training with ingestion of 40g compared to 20g. Collectively, researchers (Morton, McGlory, & Phillips, 2015; Schoenfeld & Aragon, 2018) suggest a per-meal relative protein dose of 0.4g.kg may be optimal for anabolic stimulation.

With consideration to the influence of protein ingestion on the anabolic response in the physically-active general population, recent investigations have aimed to identify an optimal daily

protein distribution pattern. Over a 12-hour post-exercise period, Areta et al. (2013) noted the anabolic response to 80g of protein was greatest when 20g was consumed at 3-hour intervals compared to 10g at 1.5-hour intervals or 40g at 6-hour intervals. When matched for energy and protein, Mamerow et al. (2014) demonstrated that an even distribution of protein across three eating occasions (breakfast, lunch, dinner) resulted in a greater muscle protein synthetic response than a skewed protein intake, with the bulk consumed in the evening meal.

The timing of protein and per meal doses throughout the day may be of greater importance to the rugby player than total intake however limited research has explored protein intake and distribution in these athletes. MacKenzie et al. (2015) reported that rugby players engaged in 3.8 eating occasions daily wherein 20g or greater protein was consumed. Protein intakes of this amount may not be optimal for the athletes in the study. At a bodyweight of 100.2 ± 13.3 kg, this would result in a relative dose of 0.2g.kg which does not reach the current proposed threshold of 0.4g.kg for maximally stimulating muscle protein synthesis (Morton et al., 2015). Mackenzie et al. (2015) noted that individual per meal protein target was 30.0 ± 4.0 g however it is not known how much protein was consumed at each sitting. The purpose of the present study was to observe and quantify dietary protein distribution patterns across the day in professional and semi-professional rugby athletes. Based on previous research in athletes (Anderson et al., 2017; Gillen et al., 2017) we hypothesised that rugby athletes would consume protein in a disproportionate pattern across the day.

2. Methods

2.1. Participants

Thirty-five participants were recruited from a semi-professional rugby club in New Zealand. The sample size was based on the availability of players in the team and players were initially approached by the strength and conditioning coach of the club. If interested, participants were briefed further by the lead researcher. Data was granted from a parallel project in professional players due to the current project exploring different parameters. As such, a further ten players from a separate professional club were included in the dataset.

During briefing, the participants were informed that they were required to record their dietary intake for analysis, that their participation in the study was voluntary and that they were able to withdraw at any time without providing a reason. Following briefing of the purpose of the study, participants signed informed consent forms. This study was approved by the University of Waikato Human Research Ethics Committee (HREC(Health)2020#06).

2.2. Protocol

Prior to data collection, participants height (Stadiometer, SECA, Hamburg, Germany) and body mass (Electronic Flat Scale, SECA, Hamburg, Germany) were recorded. Data was collected during the 2020 national provincial pre-competition season (August-September).

Dietary intake data was collected over a seven-day period for each player using MealLogger (Wellness Foundry, Helsinki, Finland). The application allows for a secure and private connection between the researcher and the participants.

Participants were briefed in person and provided with materials to assist with providing appropriate data for analysis. Participants were asked to take photographs of all food, supplements and fluid consumed. A photograph before and after consumption (if a food or meal was partially consumed) allowed for analysis of the total amount of food consumed. Participants were asked to place a hand or other object next to their plate/bowl as a reference of the size of the meal and to ensure the photograph was from an angle that allows for easy identification of the components and quantity of the meal. The morning after each collection day, participants were contacted by a member of the research team to enquire about any items they may have forgotten to log and to provide further clarification to logged meals if required.

Participants were asked to provide details about the food and/or meals consumed with photo upload. The inclusion of details such as brand labels, measurements, cooking methods and items within meals was encouraged. Participants were asked to weigh food and/or ingredients if possible, to reduce possible measurement error.

2.3. Dietary Analysis

Photographs were analysed for nutrient intake using FoodWorks (Version 10, Xyris Software, Brisbane, Australia). The information was entered manually into FoodWorks by a single member of the research team to ensure consistency. Participants' food intake was separated into six main eating occasions throughout the day, as described previously by other groups (Anderson et al., 2017; Gillen et al., 2017). Simply, participants were able to indicate which meal was consumed when uploading photographs with a corresponding timestamp on each photo. The main meals were recorded as 'breakfast' 'lunch' and 'dinner'. Items consumed between 'breakfast' and 'lunch' were recorded as 'AM snack'. Items consumed between 'lunch' and 'dinner' were recorded as 'PM snack'. Finally, items consumed after 'dinner' were recorded as 'evening snack'.

2.4. Statistical Analysis

Statistical analysis was performed on SPSS Statistics (Version 26, IBM, Chicago, Illinois, USA). Descriptive statistics are displayed as means ± SD. Total (absolute) and body mass adjusted (relative) values for protein intake were calculated. Significance was set at $p < 0.05$. Frequency graphs were created to display distribution of relative protein intake in all participants at each eating occasion. Semi-professional participant data was analysed by position (forwards and backs).

Data was deemed to be non-normally distributed using a Shapiro-Wilk test. As such, non-parametric tests were used for the analysis of data. To analyse protein intake between eating occasions, the Related-Samples Friedman test was applied. In the event of a significant result, post-hoc analysis was applied using Wilcoxon signed-rank test and Bonferroni adjustment for multiple tests. Multiple Independent-Samples Kruskal-Wallis Tests were applied to analyse differences in eating occasions and total protein intake between groups, with post-hoc analysis conducted using Wilcoxon signed-rank test and Bonferroni adjustment for multiple tests.

3. Results

3.1. Participant Characteristics

Of the 35 recruited semi-professional participants, 25 were included with 10 professional rugby union athletes included in the final analysis. Ten participants were excluded for failing to provide adequate photographs and/or descriptions on ≥ three days to allow for analysis of the dietary information. Two semi-professional forwards and one semi-professional back provided six days of dietary analysis. Two professional athletes provided five days of dietary analysis. Participant characteristics are presented in Table 1.

Professional athletes had a greater age than both semi-professional groups ($p < 0.01$). Significant differences were observed between all groups for body mass ($p < 0.05$). Height was not different between groups.

Table 1: Participant characteristics

	n	Age (years)	Height (cm)	Weight (kg)	Total protein intake (grams.day)	Total protein intake (grams.kg.day)
Semi-professional						
Forward	19	24.2 ± 3.5	186.8 ± 7.9	114.3 ± 8.2*	151.5 ± 64.6**	1.4 ± 0.5*
Back	6	24.4 ± 4.7	185.5 ± 6.8	93.8 ± 6.2*	178.7 ± 47.3	1.9 ± 0.5
Professional	10	31.4 ± 3.0*	187.2 ± 9.3	104.9 ± 12.0*	203.7 ± 68.1	2.0 ± 0.6

Note: *Denotes significant difference from both other groups ($p < 0.05$); **Denotes significant difference from professionals only ($p < 0.05$)

Table 2: Per-meal protein intake in semi-professional and professional rugby players

	Breakfast	AM Snack	Lunch	PM Snack	Dinner	Evening Snack
Absolute protein intake (grams)	28.8 ± 18.6	13.6 ± 19.0	46.3 ± 30.7	17.1 ± 24.7	61.7 ± 34.7	7.9 ± 15.9
Relative protein intake (grams.kg)	0.27 ± 0.18	0.13 ± 0.18	0.43 ± 0.29	0.16 ± 0.23	0.58 ± 0.33	0.07 ± 0.14

3.2. Total Protein Intake

Daily total protein values are displayed in Table 1. For absolute values, semi-professional forwards consumed significantly less protein than professional participants ($p < 0.05$). Adjusted for body mass, semi-professional forwards consumed significantly less protein than both semi-professional backs and professional participants ($p < 0.05$).

3.3. Protein Intake Between Eating Occasions

Combined average protein intake between eating occasions for all participants are displayed in Table 2. Protein intake between the AM snack and PM snack at an absolute and relative level were similar. A significant difference ($p < 0.01$) was observed for protein intake between all other meals.

Total and body mass adjusted protein intake per meal between semi-professional forwards, semi-professional backs and professionals are displayed in Figure 1 and Figure 2, respectively. When comparing protein intake across eating occasions, lunch and dinner protein intakes were similar in semi-professional forwards and backs, with forwards also consuming similar protein amounts across the AM, PM and evening snack. Protein intake between PM snack – evening snack and breakfast – lunch was similar in professionals. Differences between all other meals were significant ($p < 0.05$). All differences were observed similarly following analysis of absolute and relative intake.

Frequency graphs are displayed in Supplementary Materials. At breakfast, lunch and dinner, ≥ 0.4 g.kg protein was consumed at 19.2, 52.0 and 70.3% of eating occasions, respectively. No protein was consumed at the AM snack, PM snack and evening snack for 45.9, 41.0 and 59.4% of potential eating occasions, respectively.

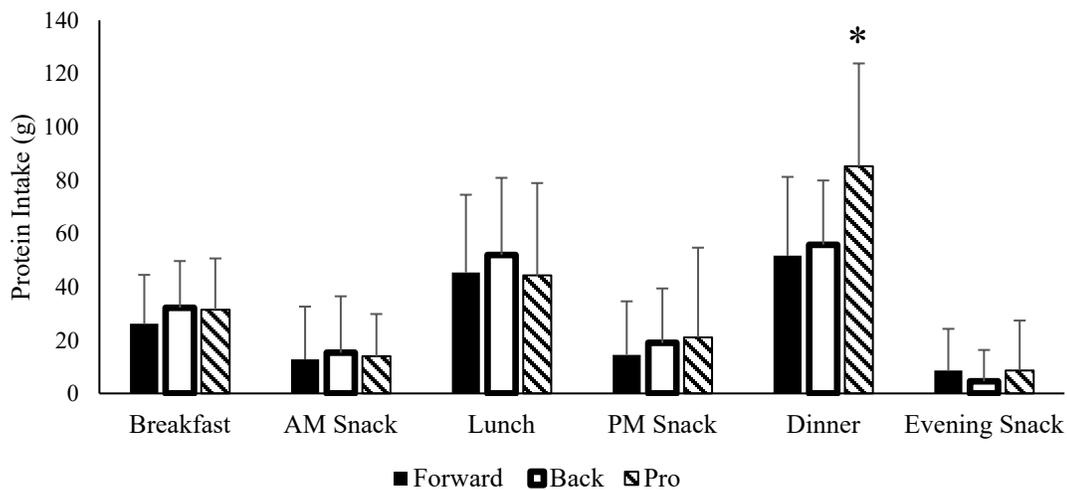


Figure 1: Absolute daily protein distribution. Note: * denotes a significant difference ($p < 0.05$) from both other groups at eating occasion. Values reported as means ± standard deviation.

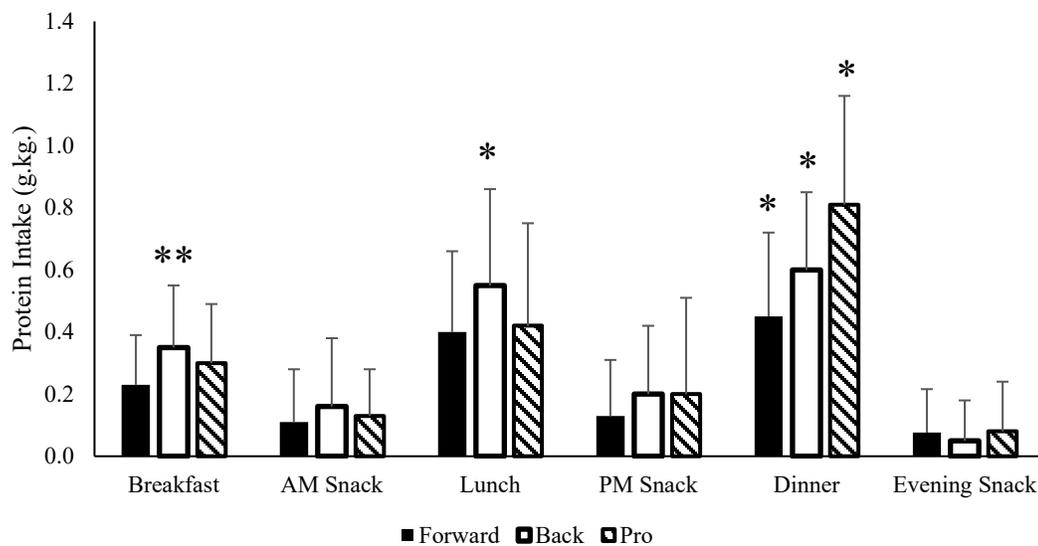


Figure 2: Relative daily protein distribution. Note: * denotes significance ($p < 0.05$) from both other groups at eating occasion. ** denotes a significant difference from semi-professional forwards at eating occasion. Values reported as means \pm standard deviation.

3.4. Protein Intake Within Eating Occasions

Semi-professional backs consumed significantly greater relative protein intake at lunch than semi-professional forwards or professional participants ($p < 0.05$). Differences between relative breakfast protein intake ($p < 0.01$) were observed between semi-professional forwards and backs. Additionally, differences in both absolute and relative dinner were observed ($p < 0.01$), with professional participants consuming greater absolute protein than either semi-professional group and all groups consuming different amounts of protein relatively.

4. Discussion

The purpose of this study was to observe and quantify dietary protein distribution patterns across the day in professional and semi-professional rugby athletes. In line with the original hypothesis, all groups consumed protein in a disproportionate pattern, with most protein consumed in the main evening meal compared to earlier in the day. Results from the professional cohort analysed suggest these players eat in a more disproportionate pattern than semi-professional athletes.

Total daily protein intake was lower in semi-professional forwards than professionals for absolute intake and both semi-professional backs and professionals for relative intake. Daily protein intake for semi-professional backs (1.9g.kg.d) and professionals (2.0g.kg.d) was towards the higher end of recommendations (Jäger et al., 2017). At 1.4g.kg.d, protein intake in semi-professional forwards is considerably lower than previously reported in rugby athletes at both professional and semi-professional levels (Jenner et al., 2019). Although 1.4g.kg.d is at the low end of recommendations set forth by ISSN (Jäger et al., 2017) (1.2-2.0g.kg.d) and the ACSM (Thomas, Erdman, &

Burke, 2016) (1.2-1.7g.kg.d) rugby players in particular may benefit from greater consumption of protein to facilitate recovery from intense exercise (Tipton, 2011) and support lean mass growth to meet the demands of the sport (Smart, Hopkins, & Gill, 2013). Additionally, lean mass loss can be offset with a high protein intake (Phillips & Van Loon, 2011) which would be beneficial for athletes seeking body fat reduction, with greater (2.4g.kg.d) requirements for greater energy deficits (Hector & Phillips, 2018).

Semi-professional players consumed similar protein at both lunch and dinner whereas professional players consumed protein in a disproportionate hierarchical fashion (dinner > lunch > breakfast) similarly to other investigations exploring daily protein distribution patterns in athletes (Anderson et al., 2015; Gillen et al., 2017). In the professional group, consumption of protein at dinner was similar to the total Recommended Dietary Allowance for adults (0.8g.kg.d, Phillips, Chevalier, & Leidy, 2016) with total and relative protein intakes of 85.6g and 0.81g.kg, respectively. A similar intake of protein at dinner has been observed previously in professional football players (Anderson et al., 2017). This large intake seems to be responsible for the disproportionate pattern of protein ingestion throughout the day as opposed to a compensatory lack of protein at earlier eating occasions. It is unknown whether a per-meal intake of the magnitude seen in the professional cohort is likely to confer additional anabolic benefits. Moore et al. (2009) demonstrated no significant benefit on MPS response following the ingestion of 40g vs. 20g whey protein following a leg-extension exercise session, the demands of which are much different to those of a professional rugby player. When measuring whole-body protein kinetics, Kim et al. (2016) found that a meal containing 70g protein increased protein balance over a meal containing 40g. This increase in whole-body protein balance is mainly attributed to a

greater reduction in protein breakdown. Greater protein intakes per eating occasion may promote muscle repair, re-modelling and development via reductions in muscle protein breakdown due to protein balance dictating the quantity of proteins in muscle (Tipton et al., 2018).

The frequency graphs indicate that no protein was consumed at 59.4% of evening snack eating occasions. This could be explained in some situations by players simply eating dinner later and possibly not having time or the desire to consume food afterwards or due to intentionally avoiding food after the main evening meal. Nonetheless, consumption of protein pre-sleep may be a useful strategy to optimise skeletal muscle re-modelling and recovery from exercise-induced muscle damage in rugby players. Research has consistently shown a benefit to consumption of post-sleep casein protein on the overnight whole-body protein synthetic response when resistance training was performed (Reis, Loureiro, Roschel, & da Costa, 2020) which certainly holds relevance to high level rugby players with congested training schedules. Regarding chronic responses, Snijders et al. (2015) found that a daily multi-nutrient supplement (27.5g casein protein + 15g carbohydrates) versus a non-caloric placebo consumed before sleep increased both upper and lower-body strength, quadriceps cross-sectional area and type II fibre size. Consumption of the supplement provided more daily total protein (1.9g.kg vs. 1.3g.kg) which may explain the findings however pre-sleep ingestion of protein is theoretically likely to confer some benefit to athletes. During sleep, muscle protein synthesis rates appear to be low and the body is able to digest and absorb protein efficiently, increasing amino acid availability and thus anabolism (Trommelen & van Loon, 2016). Rugby players may benefit from provision of protein prior to this long period of rest as lean mass levels are predicated by a prolonged positive protein balance (Tipton et al., 2018).

The supplemental frequency graphs indicate a large range of protein intakes at each meal. For example, mean total protein intake at breakfast was adequate to stimulate muscle protein synthesis according to Witard et al. (2014) (>20g,) at 28.8g. However, visualization of the frequency graphs indicates many participants did not appear to consume adequate protein at the breakfast occasion according to Morton, McGlory, and Phillips (2015) who suggest that a per-dose protein intake of 0.4g.kg is likely to maximally stimulate muscle protein synthesis in young men and 79.9% of potential breakfast eating occasions contained less protein than this threshold. Consuming adequate protein regularly throughout the day may not always be practical for high-level athletes due to various reasons including busy lifestyles and congested training schedules, appetite suppression due to intense exercise and fear of gastrointestinal disturbances (Burke et al., 2003) however this should be encouraged to stimulate and provide substrates for the anabolic processes required for supporting lean mass adaptations (Schoenfeld & Aragon, 2018).

It is important to consider the context of the results in relation to the current research. Enhanced muscle protein anabolism in response to an even distribution of protein throughout the day has been demonstrated in a limited number of studies in populations dissimilar to the one in the present investigation. In a cross-over study, MacKenzie-Shalders et al. (2016) aimed to identify whether the provision of protein between main eating occasions would increase lean mass in rugby players. Participants were provided with liquid protein supplements and instructed to

consume them either with or between main meals for six weeks. Participants were educated and instructed to consume at least 20g protein as part of their main eating occasions. The authors observed no difference in lean mass gains between groups, despite 5.9 ± 0.7 eating occasions of at least 20g protein in the distributed condition, compared to 4.0 ± 0.8 in the opposite condition. As such, it is currently inconclusive how increased protein distribution throughout the day may influence rugby players in the context of body composition and recovery improvements and further research is required to better understand these.

This is the first study to quantify protein intake per eating occasion relative to body mass in rugby players. This may be especially important as positional differences in rugby can lead to large variations in total and lean body mass, match demands and training volumes. Although 20g of protein is proposed to maximally stimulate muscle protein synthesis when consumed at four equal intervals over a 12-hour period compared to 40g at two intervals (Areta et al., 2013), this amount may not be sufficient for rugby players. When considered on a relative basis, 20g protein does not reach the threshold for young men to experience a maximal anabolic response (0.4g.kg.d) (Morton et al., 2015) in either an 80kg back (0.25g.kg) or a 120kg forward (0.16g.kg). As such, future research should focus on the anabolic response to protein ingestion between individuals of significantly different body compositions.

An acknowledgement of the limitations associated with the present study is warranted. Difficulties with practical research in athletes mean data from a subset of players from one semi-professional and one professional team are presented across a week. As such, the results cannot be generalised to all rugby players or even to the same population at different time-points. Additionally, such difficulties led to six days of dietary analysis being recorded for two semi-professional forwards and one semi-professional back and five days for two professional athletes. As with any dietary analysis study, the practice of collecting dietary intake via self-reported methods is prone to under and misreporting (Capling et al., 2017). Despite the method used for collecting dietary intake information due to its' low burden and favourability in athletic populations (Simpson et al., 2017) it is possible the athletes intentionally or unintentionally omitted food or beverages. There are numerous reasons for this, such as athletes' consuming foods and/or beverages they deem 'unfavourable', not being aware of ingredients in a meal from a restaurant or simply forgetting to log.

5. Conclusion

In conclusion, it has been demonstrated that the pattern of protein intake throughout the day is disproportionate in rugby union athletes at both the semi-professional and professional level. Whilst total protein intake is within ISSN and ACSM recommendations, promotion of an even distribution throughout the day would be beneficial for athletes, particularly those with large training volumes engaging in high-intensity impact sports. Future research should focus on the influence of protein distribution on body composition, performance and recovery in team sport athletes and how differences in body composition may affect the anabolic response to exercise and protein ingestion.

6. Practical Recommendations

1. Practitioners working with rugby players should encourage multiple feedings of protein across the day, with four feedings of 0.4g.kg per meal being a minimum target to optimise anabolism and thus recovery and adaptation.

2. Practitioner and athlete awareness of different absolute protein values to meet relative protein requirements is necessary. This will allow for individualised recommendations to be made for appropriate portion sizes.

3. A food first approach to protein intake is recommended as non-protein nutrients contained within protein-rich whole foods may potentiate the post-exercise utilization of amino acids for anabolic purposes (Burd et al., 2019). Nonetheless, batch-tested dietary protein supplements can assist athletes in meeting both total daily and per-meal protein requirements. Due to the convenience and palatability of supplements they may be preferred following training sessions or during congested schedules.

Conflict of Interest

Authors NG and KD provide support for the professional team. There are no other relationships between researchers or participants.

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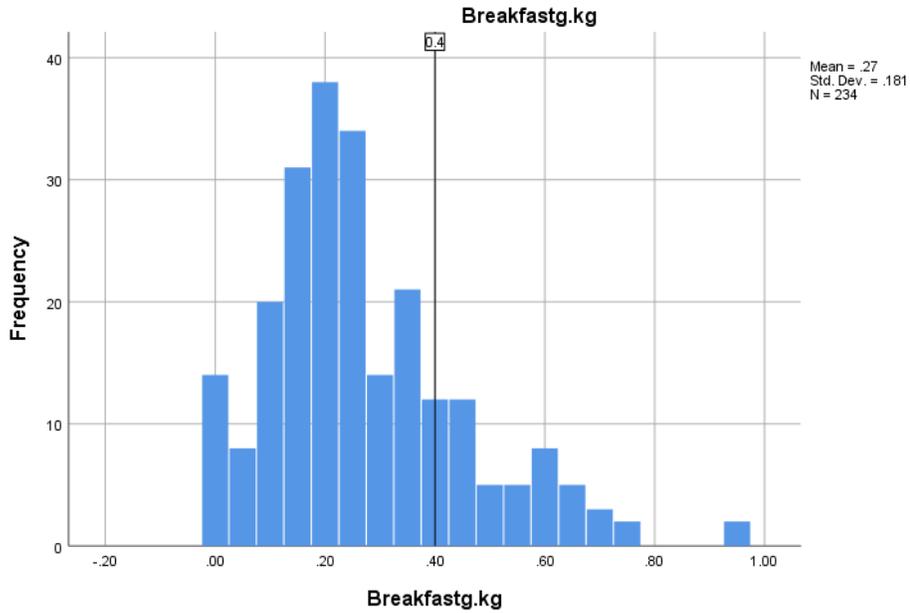
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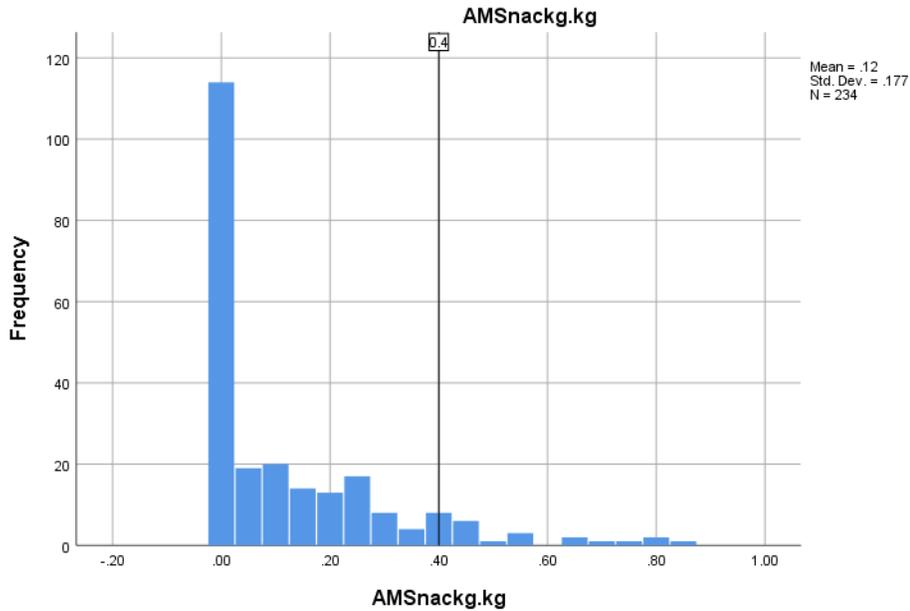
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Supplementary Materials

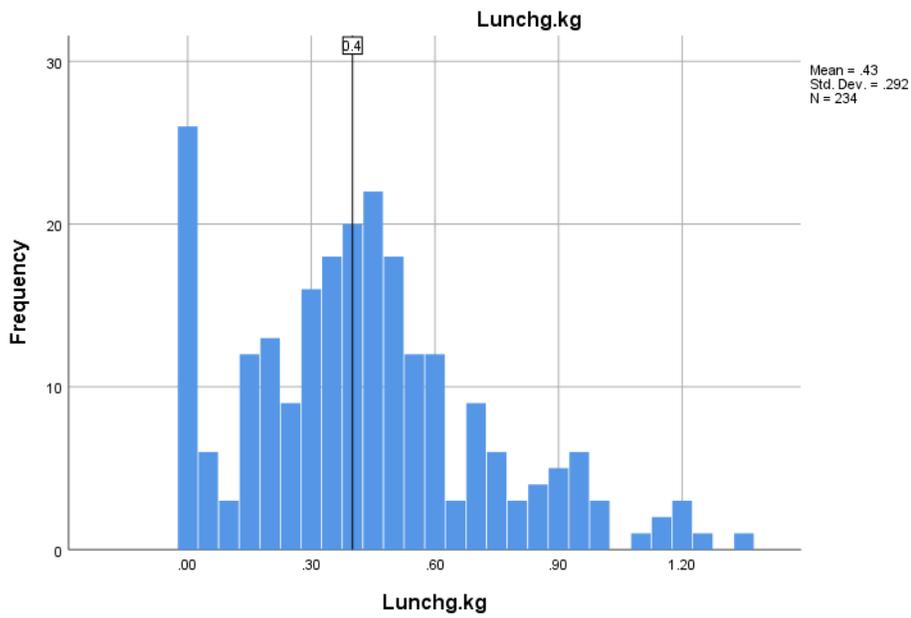
The frequency graphs below display the total number of eating occasions (y axis) that contained the relative to body mass dietary protein (x axis). N=234 indicates the total number of eating occasions for the meal. Reference lines on each graph highlight 0.4g.kg as a recommended per-meal protein dose (Schoenfeld & Aragon, 2018).



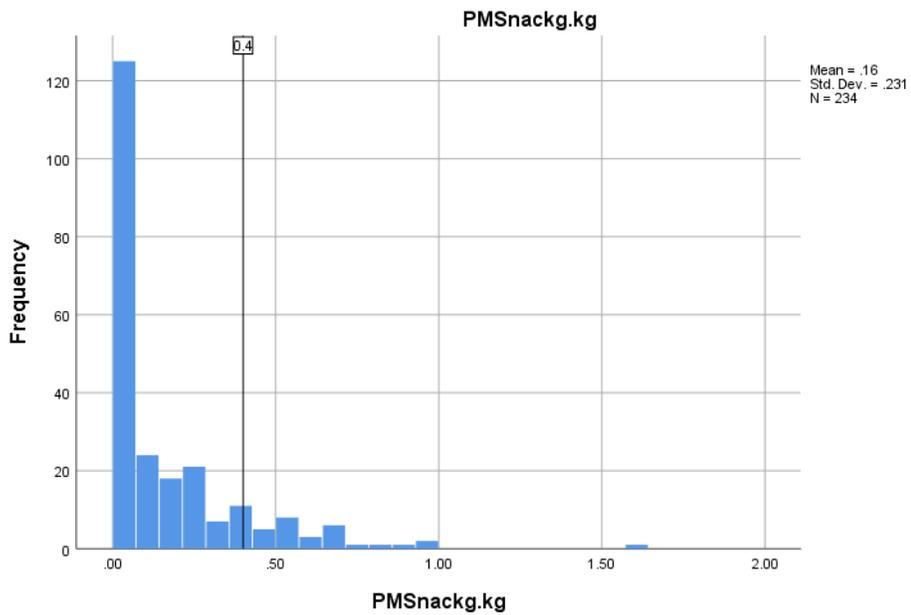
Supplementary Figure 1: Frequency of relative breakfast protein consumption (g.kg) across all eating occasions



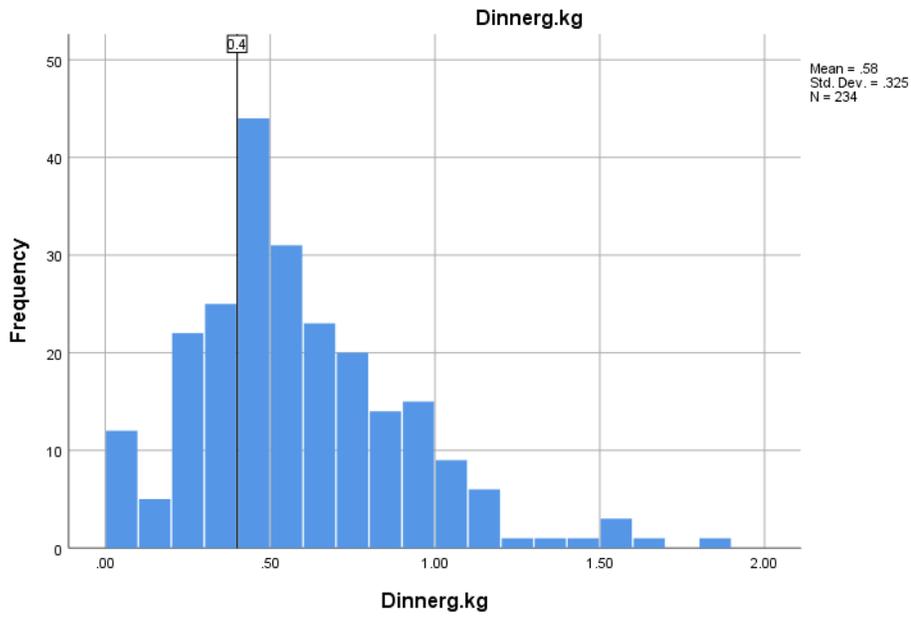
Supplementary Figure 2: Frequency of relative AM snack protein consumption (g.kg) across all eating occasions



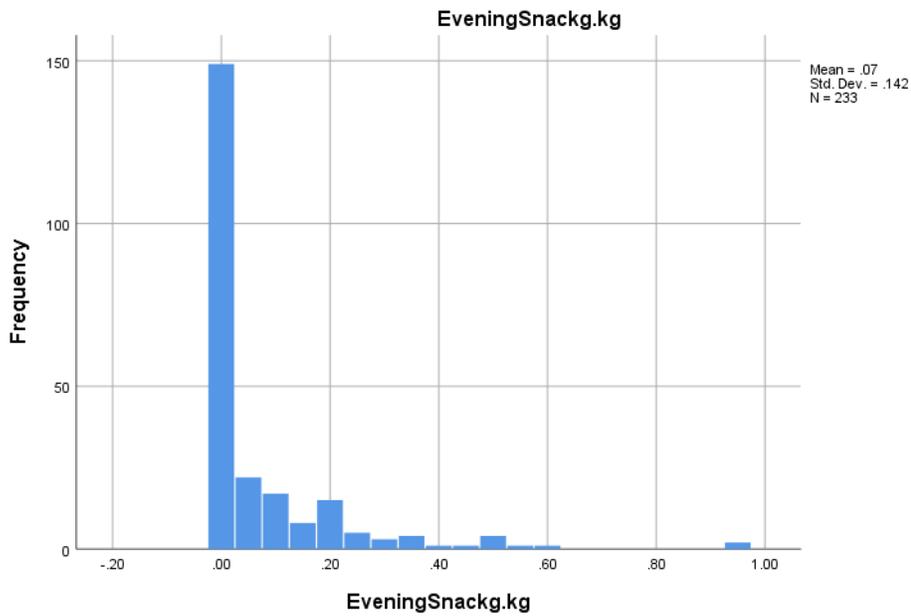
Supplementary Figure 3: Frequency of relative lunch protein consumption (g.kg) across all eating occasions



Supplementary Figure 4: Frequency of relative PM snack protein consumption (g.kg) across all eating occasions



Supplementary Figure 5: Frequency of relative dinner protein consumption (g.kg) across all eating occasions



Supplementary Figure 6: Frequency of relative evening snack protein consumption (g.kg) across all eating occasions

The impact of a player scoring system on cognitive, affective and behavioural outcomes of players in a talent identification and development environment

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ABSTRACT

Rule changes in sport are relatively common. They are typically instigated in response to concerns around player safety (e.g., tackle height in rugby), game flow and entertainment (e.g., shot clock in basketball), or to facilitate talent development processes (e.g., reduced team size in junior football). The purpose of this study was to monitor the impact of a modified scoring system created by the Rugby Football Union as a vehicle to shape desired cognitive, affective and behavioural outcomes in a talent development setting. We asked players to describe their learning experiences of the scoring system preceding competition, their approach to the scoring system, and its impact on their decision-making. Key performance indicators (Total Carries, Total Points & Points Per Carry) were collected to monitor player effectiveness across three competitive games. Semi-structured interviews and psychometric scales were used to gain insight into the players learning experiences, feelings, decision making and declarative knowledge. Our findings indicated that players learning experiences affected how well-prepared players felt to perform (affective); the acquisition and use of task-specific declarative knowledge (cognitive); and the effectiveness of players carrying the ball into contact (behavioural).

1. Introduction

Invasion team sports are known to follow a common set of concepts: there must be an opponent to play against, team mates to coordinate with, an opponent's camp to attack, and a home camp to defend (Grehaighe, Godbout, & Bouthier, 1999). Typically, these sports have one common goal, to outscore the opponent, but teams must operate within the boundaries of rules and laws that shape how a game is played (Suits, 1987). The rules are the root cause of problems that must be solved through a permissible menu of tactical, technical, mental and physical solutions (Ashford, Abraham, & Poolton, 2021a; Suits, 1987; Tee, Ashford, & Piggott, 2018). Given there is a clear connection from rules to player behaviour, rule changes in sport are relatively common. They are typically instigated in response to concerns around player safety (e.g., tackle height in rugby), game flow and entertainment (e.g., shot clock in basketball) or to facilitate talent development processes (e.g., reduced team size in junior football).

In short, rules play an important role in shaping the creative solutions players, teams, and coaches use to overcome problems posed by the sport (Arias, Argudo, & Alonso, 2009).

Williams et al. (2005) found experimental law variations (ELV's) introduced by World Rugby (Union) in 1999 resulted in an increase in passes, carries, phases of play and ball in play time. Law variations included restrictions on how defending players were allowed to challenge for possession of the ball following a tackle and the introduction of the 'sin bin', where players are expelled from the game for a ten-minute period following repeated infringements and/or foul play. ELV's were also trialled in professional rugby union in the Southern Hemisphere (Super 14 Rugby) in 2006 (Van den Berg & Malan, 2012). These variations were designed to increase the frequency and effectiveness of player actions (i.e., tackles, carries, passes) and decrease the number of set pieces (i.e., lineout and scrums). Performance analysis of match play found these ELV's to cause increases in tackles made and meters gained, evidenced by large

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effect sizes. Additionally, increases in the frequency of rucks, defenders beaten and passes made, were evidenced by medium effect sizes whilst large effect sizes were found for the reduced number of scrums and lineouts in matches (Van den Berg & Malan, 2012).

Empirical evidence therefore suggests that rule modifications to full competitive games can be engineered to affect positive changes in player behaviour (Montero, Vila, & Longerele, 2013; Van den Berg & Malan, 2012; Williams et al., 2005). While the research cited above was conducted in adult sport, competition is also widely considered as a central mechanism of Talent Identification and Development (TID) systems across sports, especially regarding the prospect of talent selection and perceiving player's characteristics when under competitive situations (Capranica & Millard-Stafford, 2011). Capranica and Millard-Stafford (2011) suggest that those governing youth competition at regional and national levels tend to abide by the main principle of scaling down their sport from adult competition models. Scaling down can refer to alterations of pitch and equipment dimensions, or the reduction of players on each team in order to create an environment that better meets the needs of the players' stage of development. For example, there has been a focus on constraining field size, reducing the number of players and shortening durations of play in soccer under the name of small-sided games across multiple age groups across a pathway (Bennett et al., 2018; Burgess & Naughton, 2010; Fenner, Iga, & Unnithan, 2016; Ortega-Toro et al., 2018; Silva et al., 2016; Unnithan et al., 2012). Findings from these studies have suggested that the modification of pitch parameters, goal size or the number of players on each team has been shown to directly and positively influence the behaviour of the player in possession of the ball, for example, an increase in touches of the ball (Ortega-Toro et al., 2018; Silva et al., 2016; Travassos et al., 2014).

Whilst desirable changes have been found as a result of small-sided games within soccer, this approach to rule adaptation may not be as useful within other team invasion sports. Small-sided games run the risk of removing too much of this important contextual demand thus reducing the reality of the performance environment (Ashford, Burke, Barrell, Abraham, & Poolton, 2020). This is particularly relevant in games like rugby where player numbers and specialist positions are crucial to reproducing reality for players. For example, a small-sided game that encourages more touches on the ball for all players may remove a full back or wingers' capacity to make effective decisions in the backfield.

An alternative perspective to viewing rule changes has been offered by Burton, Gillham, and Hammermeister (2011) who introduced the concept of competitive engineering. This approach is described as the process of modifying a competitive environment by altering a sport's structure, rules, facilities, or equipment to develop desired cognitive, affective and behavioural results. Rather than scaling a sport down from its adult form (Top-Down), it is an attempt to create a format that best meets the intended developmental outcomes (Bottom-Up). As is often the way in professional sport settings, practitioners are implementing ideas without necessarily being aware of academics who are

theorising in a very similar way. This was very much the case for the context providing the basis to this study.

1.1. The Wellington Academy Rugby Festival – An Example of Competitive Engineering

The Rugby Football Union (RFU), England's National Governing Body for Rugby Union, oversees a TID pathway made up of fourteen Regional Academies. Since 2016 all fourteen Regional Academies have attended the Wellington College Rugby Festival for the under sixteen age group.

The Wellington Rules were introduced in 2017 with the aims of engineering an increase of ball in play time, increasing ball movement (pass, offload, kick) and, in turn, increase decision-making opportunities for all players at the festival. In 2019, the RFU developed a player scoring system (See Table 1) intended to engineer players to be more effective in a single moment of the game, carrying the rugby ball into contact (Ashford et al., 2020). This scoring system was in addition to previous rule changes that stayed in place. Gregaigne et al. (2005) suggested that rules within team sports can be broken up into four categories: 1) players rights, 2) modes of scoring, 3) liberty of action and 4) physical engagement. The scoring system was introduced to increase a player's opportunity to elicit i) cognitive outcomes, specifically, players development of task-specific knowledge to perceive and respond to information available whilst carrying the ball; ii) affective outcomes, especially, player confidence in carrying the ball into contact and player understanding of the relevance of the scoring system to their development; and iii) behavioural outcomes, especially, technical and decision-making capability. Therefore, within the context of this TID environment, the scoring system does constitute a rule change (Grehaigne et al., 2005).

We have already reported on the impact of the rules introduced in 2017 (see Ashford et al., 2020). The goals of the rule changes were to increase the number of decisions players needed to make and thus the number of actions they needed to implement. Performance analysis data measuring the duration of ball in play and the number of passes, offloads and kicks per minute, were taken from all matches played between 2016 and 2019. The findings indicated that the introduction of engineered rule modifications resulted in desired increases via the time the ball was in play and ball movement (pass, offload & kick frequency). While this study displayed that competitive engineering aligned with an increase in desired behavioural outcomes, it was also limited by the nature of the observational descriptive nature of the data (Ashford et al., 2020).

While it is clear that rules alter the behaviour of players, how this behaviour change occurs will always be speculative if studies solely rely on descriptive methods to identify objective changes in performance measures (Ashford et al., 2020; Spencer & Brady, 2015; Van den Berg & Malan, 2012). Such methods rely heavily on the deductive reasoning of performance analysts to code behaviour and make sense of their observations (Spencer & Brady, 2015; Van den Berg & Malan, 2012). This approach overlooks the cognitive and behavioural impact of rule modifications from the players perspective (Clarke, Cushion, & Harwood, 2018; Messner

& Musto, 2014; Piggott, 2010; Pitchford et al., 2004; Weissensteiner, 2015). Weissensteiner (2015) has strongly articulated the need for sincerity in research design by incorporating inductive analysis of youth athlete perspectives (Tracy, 2010; Tracy & Hinrichs, 2017). By doing so, findings will generate more holistic coverage of a topic and uphold Brunswick’s (1956) concept of representative design. In sum, there is a need for descriptive research to be augmented by research that gives the participant a voice. For example, Johnstone and Morrison (2016) interviewed professional and semi-professional rugby league players to compare levels of game understanding and the perceptual capacity. The participants response to game images by eliciting descriptions and representations of the cognitive processes they would use when perceiving game information. Their findings highlighted that the professional group relied on pre-existing task-specific knowledge to inform their perceptual strategies, whilst lower-skilled players were driven by the information presented in the task. This finding is well corroborated by past studies with similar designs (e.g., Johnstone & Morrison, 2016; Lex et al., 2015; Mulligan, McCracken, & Hodges, 2011). Therefore, players who possess higher levels of task specific knowledge tend to actualise their knowledge in the game more effectively to make better decisions (Ashford, Abraham, & Poolton, 2021b). In giving players a voice, insight into the knowledge and cognitive processes underpinning decision making and player behaviour can be gleaned (Gleeson & Kelly, 2019; Johnstone & Morrison, 2016; Macquet & Kragba, 2015; Mulligan, McCracken, & Hodges, 2011).

While there is good reason to capture the cognitions of players with respect to the way they play a game, there is evidence to suggest that cognitions may not always be facilitative. Poolton et al.’s (2004) ‘rules for reinvestment’ suggest that the more task-specific knowledge players accrued during acquisition of skill the more likely they were to draw on this knowledge under pressure. With regard to the cognitive process of decision-making, the Decision-Specific Reinvestment Scale (DSRS) is a validated

means of capturing a tendency to consciously process decisions and to reflect on past poor decisions (Kinrade, Jackson, & Ashford, 2010; 2015). Furthermore, Poolton, Maxwell, and Masters (2004) modelled the relationship between task specific knowledge of a technical skill (a golf putt) and scores on the original Reinvestment Scale validated by Masters, Polman, and Hammond (1993).

Thus, the purpose of this study was to monitor the impact of the Wellington Festival engineered scoring system on cognitive, affective and behavioural outcomes through the voice of the player. To achieve this aim, the following research objectives were considered; (i) to consider the player’s perceptions of their Regional Academies approach to the player scoring system; (ii) to identify the individual player’s approach to the scoring system; and (iii) explore the impact of the scoring system on player decision-making.

2. Methods

2.1. Background Information and Preparation for Teams At 2019 Festival

The festival in 2019 lasted a week, with games played on Day 1 - Matchday 1 (2 x 42-minute games); and Day 6 - Matchday 2 (1 x 70-minute game). Six weeks before the festival, each Regional Academy was sent documentation with the regulations and expectations regarding the scoring system (See Table 1 for description of scoring system). Supporting videos were also sent to enhance clarity of understanding. Furthermore, the academies were informed that the scoring system would be trialled two weeks before the Wellington festival at smaller regional festivals. Finally, each Regional Academy analyst was educated on how to score players against the above criteria using SportCode Elite software (SportsCode Elite, V11, Hudl, Lincoln, Nebraska, United States of America).

Table 1: Player scoring system used at the 2019 Wellington Academy Rugby Union Festival

Points Awarded	Description of Action
1 point	Footwork before contact
2 points	Fend (hand-off); leg drive; change in speed into contact
3 points	Fight to work on the floor; hands through to make offload ¹
4 points*	Effective ball carry/make a line break

Note: *Players could score a maximum of 4 points per carry when at least one action (footwork, fend or fight) led to an effective ball carry or line break.

¹ In reference to this third point, players needed to demonstrate a fight in contact following the point of the tackle. Examples include; leg drive in contact, fighting the hands through the opponents tackle to create an offload opportunity or rolling on the floor to improve the presentation of the ball.

2.2. Participants

Ethical approval was granted for this study through Leeds Beckett University and the RFU. All fourteen Regional Academies were approached to take part in the Study on day 1 of the festival. 4 Regional Academies consented to take part, however due to time constraints only three completed the full data collection process. From these academies, players who were injured or ill on Matchdays were excluded. All players were approached to volunteer for a semi structured interview, yet due to the time allocated by the RFU and the busy schedule for each Regional Academy, there was only scope to interview 3 players from each team. In total, 9 players volunteered to take part in a single semi-structured interview on Day 4 of the festival (Age $M = 15.70$ years, Years playing $M = 9.40$ years). Table 2 indicates the positions played during the Wellington Festival of those interviewed. For the quantitative data collection procedure, all 87 players consented to take part (Age $M = 15.75$ years, Years playing $M = 8.21$ years), comprising 30 players from Team 1 (Age $M = 15.73$ years, Years playing $M = 8.37$ years), 26 players from Team 2 (Age $M = 15.81$ years, Years playing $M = 8.00$ years) and 31 players from Team 3 (Age $M = 15.71$ years, Years playing $M = 8.23$ years). As per the RFU's regulations, players within each Regional Academy were given equal game time across the three fixtures.

Table 2: Positions played at the 2019 Wellington Festival by took part in the semi-structured interview.

Player	Team 1	Team 2	Team 3
Player 1	Prop	Prop	Hooker
Player 2	Hooker	Full-back	Fly-half/Centre
Player 3	Centre	Fly-Half	Wing/Full-back

2.3. Semi-structured Interviews

A semi-structured interview guide was developed and refined in connection with each of the research objectives. The guide consisted of core open-ended questions that targeted the core themes of the study; (i) player's perceptions of their Regional Academies approach to the player scoring system (i.e., how did your coaches prepare you for the demands of the modified scoring system?); (ii) player approach to the player scoring system (e.g., what would you say is the most important take home message from the scoring system? How did you feel coming into the festival knowing you were being scored on your effectiveness whilst carrying the rugby ball?); and (iii) the impact on player decision-making (i.e., Could you talk me through the scoring system? Was the scoring system in your mind when you were making decisions?). Follow-up probes and prompts were planned for and used to allow expansion on key points (Patton, 2002). Interviews took place in a quiet space two days after the first matchday (i.e., Day 3). An information sheet and pre-briefing encouraged the players to reflect on their feelings and experiences

of the modified scoring system during Matchday 1. The first author conducted each interview which lasted 15-25 minutes and were audio recorded for subsequent analysis. All players were informed that their answers would be anonymized and not used for selection purposes before giving consent to take part.

2.4. Performance Analysis

In the 2019 Wellington Festival, Regional Academies played two games of forty-two minutes on Matchday 1 ($N = 6$ games) and one game of a seventy-minute duration on Matchday 2 ($N = 3$ games), on full size pitches and following the Wellington rules introduced in 2016 (Ashford et al., 2020). Every game was recorded by a video camera placed on the halfway line. The RFU used SportsCode Elite software (SportsCode Elite, V11, Hudl, Lincoln, Nebraska, United States of America) to analyse the performance indicator (PIs), frequency of carries for each player. The RFU requested that the performance analysts of individual teams also collect data for each player ($N = 87$) on the number of carries and number of points scored for each carry (see Table 1) for all games played ($N = 3$ games per team). From this, Total points and Total Carries for each player were computed as dependent variables, and player scores were normalised by calculating a Points Per Carry score ($PPC = \text{Total Points} / \text{Total Carries}$) which denoted the Key Performance Indicator (KPI). To assess the reliability of the data, the first author conducted analysis for 1 game for all three Regional Academies (Chronbach's Alpha; Total Carries = .98 & Total Points = .95).

2.5. Decision Specific Reinvestment Scale

Each player ($N = 87$) completed the Decision Specific Reinvestment Scale (DSRS, Kinrade et al., 2010). This scale comprises 13 items that measure an individual's propensity to engage conscious processing in decision-making (Decision Reinvestment, 6 items) and to reflect on past poor decisions (Decision Rumination, 7 items). Participants rated each item on a 5-point Likert scale from 0 (extremely uncharacteristic) to 4 (extremely characteristic). Players were asked to complete the DSRS with reference to the scoring system and the task of carrying the ball into contact. The scale was completed within the 48 hours following the first matchday of the festival.

2.6. Data Analysis

All interviews were audio recorded and transcribed verbatim. The first author read each transcripts numerous times to ensure familiarity and understanding (Taylor & Collins, 2019). Thematic data analysis was conducted using qualitative software (QSR NVivo12) to code player responses into meaningful units (Sparkes & Smith, 2014). Units were then further organised into higher and lower order themes employing an inductive approach initially which was then followed by a deductive approach (Macquet & Kragba, 2015; Taylor & Collins, 2019). Themes aligned to the prescribed themes of the interview: (i) players perceptions of their Regional Academies approach to the scoring system; (ii) player approach to scoring system; and (iii) the impact

on player decision-making. To ensure ‘rich rigour’ in our approach, the final author acted as a critical friend and consistently challenged the first authors interpretation of the data (Taylor & Collins, 2019; Tracy, 2017). Where disagreements occurred, discussion followed until mutual agreement was met.

One aim of this study was to understand how each Regional Academy approached the scoring system from a tactical and developmental point of view. As such, to ensure resonance in our approach, comparative quantitative analysis was driven by the qualitative findings (Smith & McGannon, 2018; Tracey & Hinrichs, 2017). Inductive analysis of semi-structured interviews demonstrated themes that were clearly reflective of team-based differences in approach to how the scoring system had been introduced to the players. Therefore, to triangulate the findings most effectively quantitative data analysis tested for between team differences (Tracey & Hinrichs, 2017). Firstly, we confirmed the assumption of parametric testing were met. Then, independent-samples t-tests were conducted to explore differences between each Regional Academy (with Bonferonni adjustments to protect against Type I error). The t-tests included Total Points, Total Carries, PPC, Reinvestment and Ruminations scores (0.05/3 between-team t-tests, $p < .014$). Effect sizes (Cohens D) were also be calculated. All statistical analysis was ran through SPSS (Version 16.0, IBM Corp. in Armonk, NY).

3. Results

3.1. Interview Data

In comparing the four Regional Academies, four higher-order themes were extracted from the analysis: players learning experiences; feelings towards the scoring system; knowledge of the scoring system; and impact of the scoring system on decision-making. Table 3 breaks down each higher order theme into lower order themes, with raw data examples provided for each.

3.1.1. Player Perceptions of Their Regional Academies Approach to the Scoring System

Learning experiences. Players from Team 1 reported receiving the RFU documentation and supporting videos through their Regional Academies online system. Each player also gave reference to the warm-up regional festival, where the player scoring system was trialled, with Player 3 stating “So, we all knew what we had to do”. Player 2 reported that a coach-led discussion occurred, and the players acknowledged that they had developed a base knowledge of the scoring system but described that their coaches believed they could already satisfy the requirements of it in performance. Whilst players from Team 1 acknowledged what was required in reference to the scoring system, each player describes that no preparation really took place. Players from Team 2 recounted that their training had been formed of small-sided and conditioned games in the six weeks leading up to the festival, where coaches held players accountable to the scoring system throughout. Additionally, each player from Team 2 referred to their coaches use of the online system as a reflective tool. Players described how coaching staff uploaded videos of training

alongside considered reflective methods to shape their learning experiences. Finally, each player from Team 2 detailed the benefit of receiving specific feedback from coaches toward the player scoring system, both positive, through praise, and negative, through corrective feedback allowing them to shape a clear understanding of what would be deemed ‘successful’.

Players from Team 3 expressed that they did not know about the scoring system until they arrived at the Festival. Player 1 from Team 3 reported having frequent conversations with coaches considering his effectiveness whilst carrying the ball into contact. He described these interactions as ones separate from the scoring system, where coaches instead focused solely on the technical and tactical feedback:

“So, instead of running directly into the player the aim was to get me to run into space so that’s been on my mind through the games so far. They showed it to me as a weakness.”

Our analysis of the interview data indicates that players from Team 1 were given complete information provided by the RFU regarding the modified scoring system but no opportunity to prepare. Conversely, players from Team 2 described being given multiple experiences of the scoring system in the lead-up to the festival. In addition to the RFU documentation, their players described learning within small sided and conditioned games; online review sessions; group discussions; and coaches use of specific feedback all in reference to the player scoring system. Finally, each player from Team 3 described that they had not received the documentation sent by the RFU and were not aware of the systems introduction until arriving at the festival.

3.1.2. Player Approach to Scoring System

Feelings toward the scoring system. Players from Team 1 described mixed feelings towards the scoring system. Player 3 indicated feelings of excitement as he felt that carrying was a strength of his, whilst others reported feelings of worry and nervousness before they played. Player 2 described negative feelings of confusion, as he did not understand the purpose of the scoring system. Players from Team 2 shared positive feelings towards the scoring system, expressing that they had feelings of confidence and focus heading into games. Players also gave reference to an awareness of how important the scoring system was for their player development. Players from Team 3 shared contrasting feelings towards the scoring system. Player 1 gave insight into how his coaches had identified his ball carrying ability as a factor that could prevent his future player development. In addition, he suggested that once he had arrived at the festival he developed feelings of worry, as his perceived weaknesses were now placed under increasing scrutiny. Conversely, Player 2 recalled that he had tried to push the scoring system from his mind completely, whereas Player 3 described positive feelings towards the scoring system, suggesting that his confidence had increased after noticing a clip of himself demonstrating an exemplar ‘4-point carry’ in the school café after Matchday 1.

Table 3: Player reflections on the introduction of a Player Scoring System at the 2019 Wellington Academy Rugby Festival.

Prescribed themes	Higher-order themes	Lower-order themes	Raw data examples
Regional Academy approach to scoring system	Learning experiences (8)	Online resource (RFU)	“We all got sent the video from the RFU and I watched it. I think I only watched it once.”
		Group discussion	“We talked about it once but didn’t actually go into any specifics about what it would look like. I don’t think we got any specific coaching or training before we came. I think it was maybe a tool to see how we adapt to it once we got here.”
		Playing in warm-up festival	“Before, our warmup festival – something like that. So we had that as a bit of a warm up. So we all knew what we had to do.”
		No preparation	“We didn’t prepare really, we just got sent this stuff on our online system, with the videos and PDF of what the scoring system would be from the RFU”
Team 1	Learning experiences (19)	Small-sided games	“We had in training some conditioned small-sided games, which obviously in training we had a point for each of the 4 f’s in little conditioned games.”
		Specific feedback by coaches	“The coaches gave plus and minus points in games which gave you a clear indication and knowledge that if you make a wrong decision you know the reason why.”
		Online resource (coach)	“Videos and scores were posted online so we could interact and comment on them. They had tagged little sections and clips where we had taken the right option in order to score highly.”
		Group discussion	“Started trying to implement it within games because we’d been talking through it in training about ‘what is it that makes a good example of that’. So, we’d developed a clear understanding of that over time then were able to implement it into the game.”
Team 2	Learning experiences (10)	No information provided	“They didn’t particularly prepare us for the scoring system particularly, I didn’t really know about it until I saw it on the screen once we got there.”
		Specific feedback by coaches	“It was bought up to me at the end of training and also when I was driving with them to a training session.”
		Group discussion	“Yep, I was trying to run into space and after went up to my coaches and we spoke about how effective it was”
		Online resources (player)	“Yes, erm I was definitely looking at footwork drills, and also watching loads of clips of positive examples both of myself and professional players”
Team 3	Learning experiences (10)	No information provided	“They didn’t particularly prepare us for the scoring system particularly, I didn’t really know about it until I saw it on the screen once we got there.”
		Specific feedback by coaches	“It was bought up to me at the end of training and also when I was driving with them to a training session.”
		Group discussion	“Yep, I was trying to run into space and after went up to my coaches and we spoke about how effective it was”
		Online resources (player)	“Yes, erm I was definitely looking at footwork drills, and also watching loads of clips of positive examples both of myself and professional players”

Player approach to scoring system			
Team 1	Feelings toward the scoring system (9)	Excitement	“Excited, knowing there was a score system for the carry that was a real positive thing for me as it’s a strong area of my game.”
		Nervousness & worry	“With the added scoring systems, I was definitely nervous. Yeah I was pretty nervous”
		Focussed	“Instead of overloading myself I just needed to focus on a few, by watching some videos of myself and watching what I do normally.”
		Confusion	“I didn’t really know what it meant. I didn’t know if you’d win games through that, or you’d be registered, or if you’d be looked more favourably upon by England selectors etc.. If you did those things, I wasn’t really sure”
Team 2	Feelings toward the scoring system (11)	Focussed	“I feel like it’s added a variety when we’re making decisions so, if you implement all those 4 F’s you’ve got a really strong basis to beat the defender and make decent amount of yards.”
		Confident	“But I would use these skills already, but can polish off certain things where I can make more metres or more of an impact.”
		Reflection on personal development	“You can absolutely tell why it makes a huge difference – as it leads to a direct linebreak. You can obviously see that it’s not just me or us – it benefits everyone.”
Team 3	Feelings toward the scoring system (8)	Nervousness & Worry	“I felt like it’s been an existing problem, and I’ll be honest I haven’t really wanted to face it as the way I’ve done it has always worked.”
		No feelings	“Erm, I didn’t really think to much about it if I’m completely honest. Pretty much just thought about playing normally to be honest.”
		Reflection on personal development	“I think the point system is a really good way to develop players for the game. Because when you’re on the field, you know you’re being video and then you see yourself up on the video’s in the café and you want to see like have you got the four points, it shows what you did and the F’s you did and then the impact it had on the wider game.”
Player decision-making			
Team 1	Knowledge of scoring system (3)	Full description	“So, fight, fend, footwork and forward leading to an offload/linebreak.”
		Conscious processing	“It has changed how I feel I make decisions. As I’m not really looking to like smash or bump off, it’s more like playing into space and getting the ball away.”
		Reduced options	“I think I was never really looking for the offload, as I think if I was consciously looking for the offload, I would have made more mistakes probably”

	More reactive	“Yeah definitely, I wasn’t pre-planning as much, and was more playing what was in front of me.”		
	Ignorance	“I think I just ended up pushing it out of my mind.”		
	Worry	“Because I was worried that I wasn’t running hard enough. I had too many things on my mind at that time, so I couldn’t get myself into the right position to be effective.”		
Team 2	Knowledge of scoring system (9)	Full description	“Fight, fend, footwork & forward.”	
		Importance	“It’s all about when, where and why. So, it’s one point for footwork, so footwork gets you into space for a 2 vs 1 so this can create an opportunity for you. There’s fend and fight was situational as it would earn you an extra point like if it was the fend got you out of the tackle then that would get you an extra point on top of the one. Or the fight as well, if you were going to be jackalled or turned over then you roll and you would get another extra point for that.”	
	Impact of scoring system (10)	Conscious processing	“I always think when I’m making decisions but I think that in the decision I think the scores make you think more about the process and what you actually should do in certain situations to be successful.”	
		Staying relaxed	“But you do have to try and stay relaxed whilst making decisions as it’s just so fast.”	
		Plan of action	“Our preparation for the point scoring just highlights that if you use them we’ll score and play much better, it doesn’t over flood you because you already know how to do it, so you can plan for it.”	
		More reactive	“The ball was, their defence came up really quite quick, so I had to like think fast so all I thought was I had to take this in, didn’t have time to think.”	
	More options	“I think if someone says they’re going to run at the line, but then they’re equipped to say I’m going to run at the line put some footwork on, put the ball into my left hand and fend with my right. It’s just about how we do things.”		
	Team 3	Knowledge of scoring system (3)	Full description	“Footwork, fight, fend, forward.”
			Importance	“So really it’s just educating us on having better awareness to keep our eyes up and scan the field constantly for space to work to.”
		Impact of scoring system (10)	Conscious processing	“Obviously, it was always on my mind, but I don’t think that was a negative.”
Focussing on previous mistakes			“I’d say there’s a restriction in my head if I’m doing it again saying try not to mess it up as you did before.”	
Plan of action			“Yes footwork will have an influence on my go forward in future especially when I look back and reflect on my performance.”	

Note: Numbers in brackets denote number of times players from each team referred to the higher-order theme

In sum, player descriptions from Teams 1 and 3 indicate mixed feelings toward the player scoring system. Whilst players from Team 2, described feelings of confidence, focus and a clear understanding of why the scoring system was beneficial for their player development.

3.1.3. *Player Decision-making*

Knowledge of the scoring system. Irrespective of Team, all players could list the parameters of the player scoring system and recite what points would be awarded for. Players from Team 3 described that they had had to gain understanding of the scoring system by watching videos shown in the café that had been uploaded by the RFU. Instead, players from Team 2 built on their descriptions of the parameters of the scoring system and described why certain actions should be used depending on the game situation to receive a higher score.

Impact of the scoring system on decision-making. Seven out of the 9 players (2 Players from Team 1; 3 Players from Team 2; 2 Players from Team 3) described increases in conscious processing of task-specific information in relation to the scoring system. Players recalled moments of the game where they had consciously processed game information in relation to the scoring system which resulted in a positive outcome. For example, players identified how the language used in the scoring system triggered the conscious recall of an appropriate action. Furthermore, players identified examples where the scoring system influenced a change away from actions that had previously been deemed as ‘typical’ responses. Player 2 from Team 3 shared an example where increased conscious processing had resulted in a mistake by reference to the scoring system. He described feeling ‘restricted’ in future actions through worry of making similar mistakes. Whilst Player 2 from Team 1 recalled attempting to ignore the scoring system altogether.

All three players from Team 2 and Player 3 from Team 3 describe how they had used knowledge of the scoring system to shape plans of action that formed clear intentions for performance; for example, Player 2 (Team 2) recounted how he intended to use footwork before contact initially to create space. Players who described clear intentions for their performance recounted having

an increased number of options available to them as they carried the rugby ball, which they suggested allowed them to be more reactive. In addition, Player 2 from Team 2 highlights how the scoring system allowed him to stay relaxed in attempt to better respond to match information. However, Player 3 from Team 1 shared a contrasting experience. He highlighted that the scoring system exposed a weakness in his game, which then prevented him from attempting certain actions through worry of making mistakes.

In summary, all players had knowledge of the parameters of the scoring system, but only players from Team 2 expressed a deeper knowledge of why specific actions were more appropriate for certain game information. Seven of the nine players described increases in conscious processing of task-specific information in relation to the scoring system. Furthermore, players from Team 2 universally described that knowledge of the scoring system had led to the development of clear plans of action and an increase of options available to them whilst carrying the ball. However, increases in options did occasionally lead to negative outcomes when players had limited time to decide. The perceptions of players from Teams 1 and 3 regarding the impact of the scoring system on their decision-making were mixed, some described similar experiences to players from Team 2, whilst the remainder indicated that the scoring system increased focus on past mistakes or was ignored altogether.

3.2. *Quantitative Data Analysis*

Descriptive and statistical analysis of the performance analysis data are reported in Tables 4 and 5, respectively. Taken together the analyses of performance showed that Team 1 made significantly more total carries than Team 2, and marginally more total carries than Team 3. Total carries made by Team 2 were significantly less than those made by Team 3. Moreover, Team 1 had a higher total point score than both Team 2 and 3, who did not differ. The resultant points per carry for Team 1 were greater than for Team 3, but significantly less than for Team 2. Points per carry for Team 2 were also greater than those for Team 3.

Table 4: Performance analysis and Decision-Specific Reinvestment Scale data for the three participating teams (Mean represents average per player, per game).

	Team 1		Team 2		Team 3	
	Mean	SD	Mean	SD	Mean	SD
Total Carries	11.53	7.17	5.23	3.44	8.52	4.57
Total Points	24.73	19.94	12.19	8.13	11.16	5.52
Points Per Carry	1.86	.81	2.38	.70	1.37	.39
Reinvestment	12.97	4.11	16.23	2.39	15.74	3.43
Rumination	16.23	4.78	14.96	4.39	16.13	6.37

Table 5: Between-team comparisons of performance analysis and Decision-Specific Reinvestment Scale data.

	Team 1 vs Team 2		Team 2 vs Team 3		Team 1 vs Team 3	
	<i>p</i>	<i>d</i>	<i>p</i>	<i>d</i>	<i>p</i>	<i>d</i>
Total Carries	.001*	1.12*	.003*	.81	.05	.50
Total Points	.004*	.83*	.58	.15	.001*	.93*
Points Per Carry	.013*	.69	.001*	1.79	.004*	.76*
Reinvestment	.001*	.97*	.53	.17	.006*	.73*
Rumination	.30	.28	.43	.20	.94	.02

Note: * Denotes significant differences ($p < .014$) and large effect sizes ($d > .80$)

Tables 4 and 5 also present the descriptive and statistical analysis of Decision Specific Reinvestment Scale data. Taken together the analyses showed that Team 1 had significantly lower Reinvestment scores than both Team 2 and 3, which did not significantly differ. No between-team differences were shown for the Rumination factor.

4. Discussion

Carefully engineered rule modifications that re-shape a sport can cause desirable changes in player behaviour (Arias, Argudo, & Alonso, 2011; Ashford et al., 2020; Burton, Gillham, & Hammermeister, 2011). The primary aim of this study was to monitor the impact of an engineered scoring system on cognitive, affective and behavioural outcomes by exploring player perceptions. This aim was underpinned by the consideration of three research objectives; (i) to consider player’s perceptions of their Regional Academies approach to the player scoring system; (ii) the player’s approach to the scoring system; and (iii) the impact of the scoring system on player decision-making. A triangulation of methods were employed in data collection, using qualitative measures to garner the perspective of the players, psychometrics to capture decision-making thought processes and descriptive measures to monitor the impact of the scoring system on player effectiveness.

4.1. Player Perceptions of Their Regional Academies Approach to the Scoring System

Themes from the analysis of interview data demonstrate that each Regional Academy approached the introduction of the player scoring system differently. Players from Team 1 indicated that no formal preparation occurred for the scoring system outside of the original resources released by the RFU. Furthermore, one player recalled being told by coaches that their performance in the carry were at an acceptable level to be scored highly throughout the festival without preparation. Alternatively, players from Team 3 described that their first introduction to the scoring system was on arrival at the Wellington Festival. Conversely, players from Team 2 indicated they were given substantial amounts of support and

preparation for the scoring system by their coaches. Players described receiving on-field learning experiences through small-sided and/or conditioned games, and off-field learning through online video review opportunities in the six weeks leading into the festival. Research exploring the adoption of small-sided games (Bennett et al., 2018; Burgess & Naughton, 2010; Caso & van der Kamp, 2020; Fenner, Iga, & Unnithan, 2016; Ortega-Toro et al., 2018; Silva et al., 2016; Unnithan et al., 2012) and conditioned games (Caso & van der Kamp, 2020; Davids et al., 2013; Silva et al., 2014a; Silva et al., 2014b) have demonstrated improvements in tactical awareness and technical development, if the games are designed appropriately. Players recalled how coaches created multiple feedback opportunities within games that aided their development of task-specific knowledge, their application of knowledge and their technical ability to score highly. These experiences suggest that players were aware that their coaches manipulated the rules of training games, so consequences would emerge from the parameters of the game itself (i.e., not using footwork before contact) and provide specific corrective feedback relative to the scoring system (Chow, 2013; Cushion et al., 2011; Passos et al., 2008).

The type, frequency, and specificity of feedback have been identified as clear characteristics of a coach’s effectiveness in generating appropriate learning environments for player development (Cote et al., 2009; Horn, 2008; Erickson & Cote, 2016). Researchers have also suggested that reflective forms of off-field learning can positively shape and influence player knowledge, behaviour, effectiveness and decision-making (Bar-Eli, Plessner & Raab, 2011; Richards, Collins, & Mascarenhas, 2017; 2012). Players from Team 2 provided multiple examples where they had received specific praise and corrective feedback (Cushion et al., 2011) in relation to the scoring system online. Players recalled accessing clips of training footage where coaches had deliberately offered positive and negative examples of carries and scores for them to interact with. It is possible, that players from Team 2 had developed a collective understanding, shaped through a well-constructed shared mental model of performance because of these learning opportunities (Richards et al., 2012; 2017). Therefore, it is likely that the different learning experiences provided, or not provided, by each Regional

Academy have resulted in contrasting levels of task-specific knowledge.

Our findings demonstrate evidence of the relationship between preparation, task-specific knowledge and performance (Johnstone & Morrison, 2016; Lex et al., 2015; Mulligan, McCracken, & Hodges, 2011). Reinvestment scores indicate that the probability of players using knowledge to consciously process information in relation to the scoring system, was significantly higher for Team 2 (and for Team 3) than Team 1 (Kinrade, Jackson, & Ashford, 2010; 2015). This is reflective of the learning experiences provided by each Regional Academy extracted from interviews. At the same time, performance analysis indicated that the Points Per Carry for Team 2 was greater than the other teams.

Interestingly, Team 1 had the highest number of Total Points and Total Carries. Given the apparent lack of focus on the player scoring system and confidence from the coaches that their players 'would score well' it is probable that carrying was a prominent feature of their game plan coming into the festival. Of greater note to us, therefore, were the PPC scores. The points system was introduced to bring a focus to important perceptual-cognitive-motor elements of this crucial part of the game (Capranica & Millard-Stafford, 2011; Fenner, Iga, & Unnithan, 2016; Unnithan et al., 2012). Within a TID setting at this level one would expect a focus on developing the finer points of game awareness and skill. This requires players to try new actions to hone their skills for the future game. A combination of both qualitative data here suggests only one team, in this circumstance, focused on this process. Interpretation of the Regional Academies approach to the scoring system suggests that coaches within TID environments should not only use on-field and off-field strategies to develop the actions and intentions of their players, but go further to consider how they develop their understanding and task-specific knowledge of why intentions and actions are appropriate in given match situations (Anderson, 1982; Ashford, Abraham, & Poolton, 2021; Bar-Eli, Plessner, & Raab, 2011; Richards, Collins, & Mascarenhas, 2012; 2017).

4.2. Player Approach to the Scoring System – Affective Responses

Player descriptions of feelings towards the scoring system were both positive and negative and seemed to be partially dependent on their experiences in preparation for and at the festival. Some players from Team 1 expressed feelings of worry, nervousness and confusion. Similarly, players from Team 3 described feeling a lack of confidence of scoring well against the system, alongside feelings of worry. The worry described by players may have reduced self-efficacious beliefs (Bandura, 1989), self-confidence (Vealey et al., 1998) and could have led some to instances of ruminative behaviour (Kinrade, Jackson, & Ashford, 2010; 2015). Although no differences were found between the teams' Rumination scores, interpretation of individual player recollections suggest that ruminative behaviour may have occurred on an individual basis. Furthermore, this is likely to have been as a result of preparation for the scoring system being left to the autonomy of the individual in both teams. Analysis of interview responses provide evidence that when coaches disregard preparation for technical and tactical solutions when

modified rules are introduced, players may develop negative perceptions towards it (Taylor & Collins, 2019).

That said, Player 3 from Team 3 expressed feelings of increased confidence toward the scoring system after one of his carries from the warm-up festival was uploaded onto the highlights reel in the café as an exemplar. Furthermore, Player 1 from Team 1 harboured excitement, as he perceived ball-carrying to be a strength of his. Such descriptions suggest that those who believed they would score highly had an increased efficacy towards the scoring system (Bandura, 1989).

Players from Team 2 recounted feelings of focus, confidence and increased understanding of why the scoring system was beneficial for their long-term player development. The commonalities in the feelings shared by Players from Team 2 may demonstrate the development of psychological skills in reference to the scoring system. The feelings expressed demonstrate the players' ability to focus, be self-aware and self-evaluate, which have been defined as key psychological characteristics and skills essential for talent development (Dohme et al., 2019; MacNamara, Button, & Collins, 2010a; 2010b). Collins and MacNamara (2017) have suggested that psychological characteristics are transferable across domains and contexts. Therefore, it is plausible that players may also operationalise these characteristics and skills in areas of the game external to the scoring system.

4.3. Player Decision-making

All players were able to recite the parameters of the scoring system and how they would be scored. However, only players from Team 2 built on this. They described how information driven by the game situation would dictate why a decision to act was more appropriate than others. Anderson (1982) suggests that people not only require the development of procedural knowledge to perform (i.e., what to do and how to do it), but must also develop declarative knowledge to better understand why it is important/appropriate given the situation (Anderson, 1982; Ashford, Abraham, & Poolton, 2021; Johnstone & Morrison, 2016). Themes extracted from player interviews and Reinvestment scores offer the suggestion that increased declarative understanding developed in training could develop player's likelihood to consciously process game information (Kinrade, Jackson, & Ashford, 2010; 2015; Poolton et al., 2004).

Seven players described moments where conscious task-specific knowledge of the scoring system allowed them to retrieve effective memory representations during performance. A player from Team 2 recounted how terminology used within the scoring system triggered conscious processing of information when carrying the ball. Whilst taking contact he claimed to have realised that he was not making any ground, which stimulated a memory representation through the term 'fight'. This triggered a rapid selection of suitable actions to score effectively. Similarly, a player from Team 1 highlighted that before the festival he had always looked to use his size to 'bounce' defenders away whilst taking contact. Here, the player seems to recall the breaking of a well-established heuristic (Jackson et al., 2006; Raab & Laborde, 2011). Consequently, conscious processing of game information in reference to the scoring system may have allowed for a

diagnosis that resulted in the selection of an adaptive course of action of passing the ball to his teammate (Macquet, 2009; Macquet & Kragba, 2015). This indicates a relationship between improved task-specific knowledge of the game and the conscious processing of game information to make adaptive decisions (Ashford et al., 2021b; Collins, Collins, & Carson, 2021; Johnstone & Morrison, 2016).

Recent research has suggested that player learning capabilities and strategic thinking can be enhanced (Price et al., 2019; 2020). Player recollections from Team 2 frequently include instances of reflection and sense making of their decision-making process. These instances present evidence of deliberate strategic thinking, problem solving and metacognitive activity in reference to the scoring system, which are likely to have been a consequence of the learning experiences provided by their Regional Academy coaches (Price et al., 2019; 2020). Price and colleagues (2019; 2020) have suggested that coaching staff should aim to establish player development programmes that foster players' metacognitive ability. In this case study, the support provided by coaches in Team 2 may have promoted their players' metacognitive processes preceding, during and following performance.

Team 2's PPC scores and interview responses offers evidence that improved memory representations may facilitate their players to form suitable plans of action that enhanced their capability to effectively operate in dynamic game environments (Ashford et al., 2021b; McPherson & Vickers, 2004). McPherson and Vickers (2004) suggest that action-plan profiles support players to develop clear intentions for performance, such as intending to use footwork to find space between two defenders (Macquet & Fleurance, 2007). Furthermore, these players indicated that well-formed intentions created 'more options' for them to perceive before executing a ball carry. Subsequently, player descriptions imply that the scoring system has increased the landscape of information available for the player to act on (Ashford et al., 2020; Ashford, Abraham, & Poolton, 2021a).

Despite this, players from Team 2 also expressed that they became more reactive to game information whilst making decisions. Ashford, Abraham, and Poolton (2021b) suggested that Professional and University Rugby Union players are consistently required to make sense of in-game information in consultation with their knowledge of the game. So, if new information arises, such as an opposing player showing unexpected (or atypical) behaviour, their conscious knowledge will need to be updated (McPherson & Vickers, 2004). Using the communal language Ashford, Abraham and Poolton (2021a) recently developed for decision-making in team sports, players interviewed from Team 2 may be using knowledge of the game to update knowledge in the game where player's use game information to update memory representations to make effective decisions (Ashford et al., 2021b). However, players from Team 2 recounted both positive and negative experiences of this. Thematic analysis indicated that these experiences were dependent on the time available to process information with reference to the scoring system. When time was available, player's recall conscious processing of information resulting in successful outcomes. Whereas, when time was limited,

players describe attempts to consciously process information as impractical as the opportunity to decide had already passed.

Individual players from both Team 1 and 3 stated that they deliberately tried to remove the scoring system from their mind. Such an approach is common among humans making decisions in moments of uncertainty (Lipshitz & Strauss, 1997). However, when considered through the lens of TID, a tendency to suppress moments of uncertainty from consciousness may be a hindrance to a player's development. Evidence suggests that players being able to face uncertainty is essential in progressing along the rocky road to elite status (Collins & MacNamara, 2012; Taylor & Collins, 2019). Therefore, coaches should deliberately shape learning opportunities for players to face and develop appropriate responses to moments of uncertainty rather than an instinct to suppress.

5. Practical Implications and Conclusions

Our results suggest that the introduction of the player scoring system influenced player behaviour with regards to decision-making and actions, and the effectiveness of both whilst carrying the rugby ball into contact. However, the extent of the scoring system's impact appeared to be shaped by players perceptions of their Regional Academy's approach to its introduction to the 2019 Wellington Academy Rugby Festival. The triangulation of inductive and deductive thematic analysis alongside performance analysis measures suggest that the players' learning experiences shaped their decision-making and effectiveness whilst carrying the ball. According to the players interviewed from Team 2, they received substantial on-field and off-field support from their coaches, which seemed to affect their confidence and focus on the scoring system. Our interpretation of interview data is that these players developed their task-specific declarative knowledge (Anderson, 1982; Johnstone & Morrison, 2016); their capability to develop action-plan and current-event profiles, before and during performance (Ashford et al., 2021a; McPherson & Vickers, 2004), and showed an increased conscious awareness of the scoring system during performance (Macquet & Kragba, 2015; Raab, 2003). In contrast, players from the other two teams apparently received limited coaching support in relation to the scoring system. This seemed to manifest feelings of worry, concern, nervousness and confusion, which may have transcended into the performance of carrying the ball into contact (Kinrade, Jackson, & Ashford, 2010; Kinrade, Jackson, & Ashford, 2015; Kinrade et al., 2010) in some, but not all, of the players in these teams.

The findings highlight the role of the coach in supporting talented players to navigate rule modifications designed to influence learning and performance. This seems to be effective when coaches support players' understanding of the key performance indicators and why they have been developed. Furthermore, and building on this understanding, coaches should support players' development of declarative knowledge about what the requisite skills look and feel like in action, within an environment that offers opportunity for experimentation (Price et al., 2019; 2020). If players understand why specific actions are appropriate given a game situation it is likely to improve the

relationship between game information and their selection of an action (Anderson, 1982). Finally, interpretation of the findings imply that this understanding in such an environment seems to have helped players avoid feelings of worry, confusion, decision-rumination and task avoidance. In light of this, the findings of this study offer support for those presented in Ashford et al.'s (2021b) study exploring players decision making behaviour, as on multiple occasions players described the conscious processing of information for decision-making and shared examples of memory representations (Johnstone & Morrison, 2016; McMahon & McPherson, 2009). Additionally, players recognised that when time was limited, conscious processing of information led to undesirable results.

Some of the players in this study recalled deliberate attempts to suppress the uncertain proposition of the scoring system, and thereby, avoided adapting their behaviour accordingly. From a psychological point of view, players are confronted with feelings of uncertainty on a frequent basis in TID environments (Collins & MacNamara, 2012; Taylor & Collins, 2019). This would suggest they have not had the opportunity to develop skills, in this instance, in an environment that promoted experimentation with the rule changes. The sort of environment we are advocating here supports players to first acknowledge and then navigate their way through moments of uncertainty (Lipshitz & Strauss, 1997). Coaches can deliberately plan to coordinate moments of uncertainty for players in training, for instance, asking a defending team in a conditioned game to behave in a way that would be deemed atypical by the attacking players. Specific coach behaviours (e.g., instruction, questioning, feedback) could then be actioned to assist the player's acknowledgment of uncertainty and support the generation of an effective technical and tactical solution (Cushion et al., 2011; Muir et al., 2011).

This study was a first attempt to provide broad coverage of the impact of rule modifications on team player behaviour through a competition within TID environments (Tracey & Hinrichs, 2017). In exploring player perceptions, by use of interviews and psychometrics, alongside performance analysis measures, the approach taken in this study enabled the triangulation of descriptive and qualitative findings and deeper understanding of the subject (Clarke, Cushion, & Harwood, 2018; Messner & Musto, 2014; Piggott, 2010; Pitchford et al., 2004; Weissensteiner, 2015). Giving players a 'voice' (Piggott, 2010; Weissensteiner, 2015) exposed talent development academies influence on the cognitive, affective and behavioural outcomes realised by a player scoring system. Specifically, the learning experiences provided appeared to effect how prepared players felt to perform (affective); the acquisition and use of task-specific declarative knowledge (cognitive); and the effectiveness of players carrying the ball into contact (behavioural). That being said, the study did not give the players' coaches a 'voice' to explain their approach to preparing players for the rule modification specifically, and player decision-making in general. The study of how coaches coach decision-making in talent development environments may form part of a more holistic study of team player decision-making, which might also consider the influence of the variables of decision time and complexity (Gleeson & Kelly, 2019; Macquet & Kragba, 2015).

Conflict of Interest

Each author should reveal any conflict of interest. If there are no conflict of interests please state, "The authors declare no conflict of interests".

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Quantification of in-season training load in Division I male collegiate soccer players

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Periodization

ABSTRACT

The purpose of this study was to quantify any differences in training load (TL), as measured via Duration, Heart rate (HR) and Session-Rating of Perceived Exertion Load (S-RPE Load), in Division I male collegiate soccer players. Training sessions during the fall competitive season were categorized by the days away from the next competition [match day (MD) out] in 26 collegiate soccer players. All training sessions were monitored using HR transmitter technology. HR data was expressed as percent of total practice duration spent in zones (%HR_{Low} [$\leq 69\%$], %HR_{Mod} [70-89%] and %HR_{High} [$\geq 90\%$]). A significant, main effect finding was noted for Duration ($p < 0.01$), S-RPE Load ($p < 0.01$), %HR_{Low} ($p < 0.01$), %HR_{Mod} ($p < 0.01$), and %HR_{High} ($p < 0.01$) between MD out from competition. Post hoc analysis revealed MD-1 had the lowest TL across all MDs. Load on MD-3 was greatest for Duration (90.72 ± 23.78 min), S-RPE Load (1223.50 ± 393.60 au), and %HR_{High} (7.07 ± 9.87). The highest load for %HR_{Mod} was on MD-4 (35.52 ± 17.16 min), while %HR_{Low} was on MD-1 (74.45 ± 18.93 min). As MD approached, various trends, such as a bell-shaped curve (Duration, S-RPE Load, %HR_{High}) and a linear taper (%HR_{Mod}), were evident. Periodization trends in internal and external TL are evident within the microcycle lens where the focus of training is on recovery and preparation for the forthcoming match.

1. Introduction

In a team sport setting, daily training and weekly competitions result in variations in internal (physiological) and external (mechanical) training loads (TL) (Clarke et al., 2013; Malone et al., 2015; Manzi et al., 2010). During training, drills performed by the whole team require similar external load requirements, whereas the internal load response varies by individual (Azcarate et al., 2018; Foster, 2001; Impellizzeri et al., 2004). This indicates the importance in measuring both external and internal load placed on the individual athlete (Azcarate et al., 2018; Impellizzeri et al., 2004). Therefore, the measurement of TL is important for coaches, technical staff, strength and conditioning professionals, and medical personnel. This is particularly true as coaches and staff plan practices during the competitive season, to ensure that players are in peak physical condition to perform maximally during competition.

One of the most common, low-cost methods of estimating TL is session rating of perceived exertion (S-RPE). S-RPE provides a subjective measure following team training and competition (Foster et al., 2001). S-RPE Load, defined as training time multiplied by S-RPE, has been increasingly used to monitor training response and recovery across a variety of levels of competition, including professionally (Azcarate et al., 2018; Gaudino et al., 2015; Stevens et al., 2017). For example, S-RPE Load has been used in professional rugby to show a strong relationship to overall team injury. Importantly, the harder you train, based on S-RPE, the more likely you are to develop an injury (Gabbett et al., 2010). In a recent review on the relationship between internal and external training loads in team sports (i.e., football, Australian football, rugby & basketball), McLaren et al. (2018) found a large positive relationship between S-RPE and total distance ($r = 0.79$). Pustina et al. (2017) reported similar results in Division I male soccer players, between S-RPE Load

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and total distance ($r = 0.81$). S-RPE Load's popularity can be attributed to ease of use and low cost in quantifying individual player TL (Foster et al., 2001).

In addition to S-RPE, another common method to objectively quantify TL is the use of heart rate (HR) based methods. These methods have been studied across different sport domains including American football (Clarke et al., 2013), basketball (Manzi et al., 2010), and football (Impellizzeri et al., 2004; Stevens et al., 2017). Within American football ($r = 0.69-0.91$) and professional basketball ($r = 0.69-0.85$), similar relationships using various HR based methods and S-RPE Load have been reported (Clarke et al., 2013; Manzi et al., 2010). First developed by Banister (1991), training impulse is a method to quantify TL using HR and training duration. Variations have been formulated since then, providing additional versions to the original formula. In non-team sports such as running and swimming, strong links between HR methods and S-RPE were reported (Borresen et al., 2008; Wallace et al., 2009). Recently, HR based training protocols have been useful in determining the intensity of football matches. Sparks et al. (2017) showed moderate to large correlations between low intensity ($r = 0.46$) and moderate intensity ($r = 0.25-0.57$) velocity and HR zones in university level male soccer players. Verification of a relationship across these different sports with S-RPE Load has provided another reliable method for measuring TL.

Previous research has reported a variation in daily TL across different sport domains. Within American football (Canadian), where teams compete once a week, TL takes on a bell-shaped curve structure, representing a purposeful buildup and taper, with the highest TLs noted in the middle of the week and purposeful reductions in TLs the following days as the team prepares for the next match (Clarke et al., 2013). In professional basketball, a one match week saw clear tapering toward match day (MD). This trend of heavier TLs further out from competition was visible three days out from MD (656 ± 88 au) compared to one day out (222 ± 56 au). In a sport such as basketball, where multiple matches per week is common, weekly structure for training, recovery and days off commonly changes. While multi-match weeks present challenges for practice structure and player recovery, this study showed that total weekly TLs were less than 5% different than single-match weeks (Manzi et al., 2010). When solely looking at training days (i.e., excluding matches) the two-match week (1722 ± 229 au) had significantly less TL compared to a one-match week (2436 ± 233 au). Thus, indicating periodization strategies by the coaching staff, in order to provide proper training stimulus for the players. Therefore, quantifying TL can help structure more tailored training sessions to allow for proper recovery while ensuring adequate time is allotted for on-field strategy and skill acquisition in preparation for upcoming matches.

Like other team sports, football teams have shown similar tactical periodization on days out from competition. The current club season structure forces teams to compete in one to two-matches within a week due to domestic, league cup and continental competitions. As MD gets closer, findings of progressive tapering in TL have been reported (Kelly et al., 2020; Malone et al., 2015; Stevens et al., 2017). With only one match in a periodized microcycle, purposeful training stimuli can be

applied to the athletes. In professional Dutch football, a clear tapering of time spent in $> 90\%$ HR max from MD-4 to MD-1 has been reported (Stevens et al., 2017). Additionally, Kelly et al. (2019) reported that S-RPE Load was progressively reduced by 70-90 au per day in the three training days before a match. Another study focusing on a full week periodization plan (MD-4: off day), noted that only the practice prior to competition showed reductions in TL, with no differences in TL noted between the MD-5, MD-3 and MD-2 training sessions (Malone et al., 2015). These findings may be attributed to differing coaching styles, or periodization plans, but it appears that a consistent finding across elite level football teams show MD-1 resulting in the lowest TL, with varying degrees of taper or planned midweek spike in S-RPE Load or HR response in training during a one-match per week microcycle.

While internal (S-RPE Load, HR Based) and external (Duration) methods have been used previously to quantify and compare TL at the international and collegiate soccer level (Pustina et al., 2017; Sparks et al., 2017), there is limited knowledge on MD variability regarding TLs in United States Division I collegiate soccer. In collegiate level soccer where matches are played within a condensed semester time frame, with multiple matches occurring each week, S-RPE Load and HR-based TL analysis may be beneficial in monitoring training throughout the competitive season. Therefore, the intent of this study was to quantify any differences in TL, as measured via Duration, HR and S-RPE, by MD out from competition in Division I male collegiate soccer players.

2. Methods

2.1. Participants

Twenty-six Division I male soccer players (mean \pm SD: 20.4 ± 1.4 yr, 74.2 ± 6.7 kg, 180.7 ± 5.9 cm) were monitored across a 12 week Fall 2019 competitive regular season. The team competed in a total of 18 (13 non-conference, 5 conference) National Collegiate Athletic Association (NCAA) matches. Weekly training session quantity ranged from 4-6 sessions throughout the season with a range of zero to two matches in a seven-day microcycle.

All outfield players (9 Defenders, 9 Midfielders, 8 Forwards) were included for analysis. Players who were participating in individual, recovery, rehabilitation, or specific fitness sessions were excluded. Goalkeepers were excluded from analysis, due to the unique demands of their position and the increased potential of injury due to the monitor. The Institutional Review Board at Georgia Southern University approved the study, and all players consented to have their data analyzed for the study.

2.2. Apparatus

Each player was outfitted with an individualized HR monitor (Polar Team 2, Bethpage, NY) based on their demographics, and wore the same monitor throughout the season. Players were shown the RPE chart (Borg, 1962) prior to providing a value, and reported their value away from other players and coaches.

2.3. Procedure

All data collection was done on the field the team was participating on that day. Upon arrival to practice, players were provided their monitor ~15 minutes prior to training. All training sessions included warm-ups and coaching staff organized drills. The duration of training was measured from the point the team was organized by the coaching staff to initiate warm-up, until the final drill was concluded, and players were allowed to leave the training facility. Any player activity before or after these timepoints was excluded from the duration of each session. Within 15 minutes following the end of training, players returned the monitors and reported an RPE number on the intensity of the session.

HR monitors were used to measure practice time spent in three specific training zones (Low [$\leq 69\%$], Moderate [70-89%] and High [$\geq 90\%$]) determined based on the estimated HRmax of each player. The HR zones refer to the time spent in each zone divided by the total time of each training session. They are expressed as percent of total practice duration (%HR_{Low}, %HR_{Mod}, %HR_{High}). Training time spent in each zone was compared to total training time to ensure proper breakdown was provided. RPE Load was calculated as S-RPE multiplied by training duration (Foster et al., 2001) for each training session and used for analysis.

Training sessions were categorized based on their proximity away from matches (i.e., MD minus) (Malone et al., 2015; Stevens et al., 2017). The sessions were broken down into 4 days or more prior (MD-4), 3 days prior (MD-3), 2 days prior (MD-2), and 1 day prior (MD-1) to MD. Within microcycles where two matches took place (i.e., Tuesday & Saturday), the Monday session was categorized at MD-1, and Wednesday, Thursday and Friday sessions were categorized as MD-3, MD-2 and MD-1, respectively. Reasoning for this is to provide congruent proximity from competition between all 12 weeks of the season.

2.4. Statistical Approach

Data IBM SPSS Version 25.0 (SPSS, Inc., Chicago, IL) was used for all analysis. All data is reported as means \pm SD. Shapiro-Wilks test was used to assess normality of the distribution of data. A one-way ANOVA was used to compare MDs in proximity to competition. In the event of a significant main effect, post-hoc Bonferroni analysis was conducted on all findings. Significance was set at $p < 0.05$. Practical significance was assessed using Cohen's d effect size (ES) statistics with the Hopkins' scale of magnitude. The scale utilized for all practical significance was < 0.20 for trivial, $0.20 - < 0.60$ for small, $0.60 - < 1.20$ for moderate, $1.20 - < 2.00$ for large, and ≥ 2.00 for very large (Hopkins, 2009).

3. Results

Data was collected on 26 players over 42 practices during the season. Seventeen practices for MD-1, 11 for MD-2, 7 for MD-3, and 7 for MD-4 were included in analysis. One player was omitted from analysis due to a season ending injury during preseason. Descriptive data (mean \pm SD) for Duration, S-RPE load, %HR_{Low}, %HR_{Mod}, %HR_{High} for each MD out are presented, with a traditional bell-shaped curve reference, in Figure 1.

3.1. Duration

A significant, main effect finding was noted for Duration between MD out ($F(3,774) = 133.92, p < 0.01$). Post hoc analyses revealed that MD-1 was significantly shorter in Duration than MD-2 (-30.36 ± 1.83 min [mean difference \pm standard error], $p < 0.01, d = 1.64$), MD-3 (-33.66 ± 2.18 min, $p < 0.01, d = 1.63$), and MD-4 (-23.68 ± 2.02 min, $p < 0.01, d = 1.17$). Practice Duration on MD-4 was significantly less than MD-2 (-6.68 ± 2.17 min, $p < 0.05, d = 0.31$) and MD-3 (-9.98 ± 2.47 min, $p < 0.01, d = 0.43$). No differences were seen between MD-2 and MD-3 ($p = 0.93, d = 0.15$).

3.2. S-RPE Load

A significant, main effect finding was noted for S-RPE Load between MD out ($F(3,754) = 142.28, p < 0.01$). Post hoc analyses revealed that MD-1 was significantly lower in S-RPE Load than MD-2 (-475.53 ± 30.48 au, $p < 0.01, d = 1.73$), MD-3 (-632.04 ± 36.30 au, $p < 0.01, d = 1.99$), and MD-4 (-412.07 ± 34.22 au, $p < 0.01, d = 1.12$). S-RPE Load on MD-3 was significantly greater than MD-2 (156.51 ± 38.59 au, $p < 0.01, d = 0.44$) and MD-4 (219.98 ± 41.61 au, $p < 0.01, d = 0.51$). No differences were seen between MD-2 and MD-4 ($p = 0.50, d = 0.16$).

3.3. %HR_{Low}

A significant, main effect finding was noted for %HR_{Low} between MD out ($F(3,709) = 31.45, p < 0.01$). Post hoc analyses revealed that MD-1 spent significantly more time in %HR_{Low} than MD-2 ($9.04 \pm 1.87\%$, $p < 0.01, d = 0.46$), MD-3 ($16.43 \pm 2.17\%$, $p < 0.01, d = 0.87$), and MD-4 ($17.17 \pm 2.13\%$, $p < 0.01, d = 0.83$). %HR_{Low} on MD-2 was significantly higher than MD-3 ($7.40 \pm 2.32\%$, $p < 0.01, d = 0.38$) and MD-4 ($8.13 \pm 2.29\%$, $p < 0.01, d = 0.38$). No differences were seen between MD-3 and MD-4 ($p = 1.00, d = 0.04$).

3.4. %HR_{Mod}

A significant, main effect finding was noted for %HR_{Mod} between MD out ($F(3,709) = 30.88, p < 0.01$). Post hoc analyses revealed that MD-1 was significantly lower in %HR_{Mod} than MD-2 ($-5.67 \pm 1.42\%$, $p < 0.01, d = 0.38$), MD-3 ($-12.25 \pm 1.64\%$, $p < 0.01, d = 0.85$), and MD-4 ($-13.03 \pm 1.62\%$, $p < 0.01, d = 0.80$). %HR_{Mod} on MD-2 was significantly lower than MD-3 ($-6.58 \pm 1.76\%$, $p < 0.01, d = 0.47$) and MD-4 ($-7.36 \pm 1.73\%$, $p < 0.01, d = 0.47$). No differences were seen between MD-3 and MD-4 ($p = 1.00, d = 0.05$).

3.5. %HR_{High}

A significant, main effect finding was noted for %HR_{High} between MD out ($F(3,700) = 17.24, p < 0.01$). Post hoc analyses revealed that MD-1 was significantly lower in %HR_{High} than MD-2 ($-1.78 \pm 0.64\%$, $p < 0.01, d = 0.34$), MD-3 ($-5.02 \pm 0.73\%$, $p < 0.01, d = 0.65$), and MD-4 ($-3.02 \pm 0.72\%$, $p < 0.01, d = 0.47$). %HR_{High}

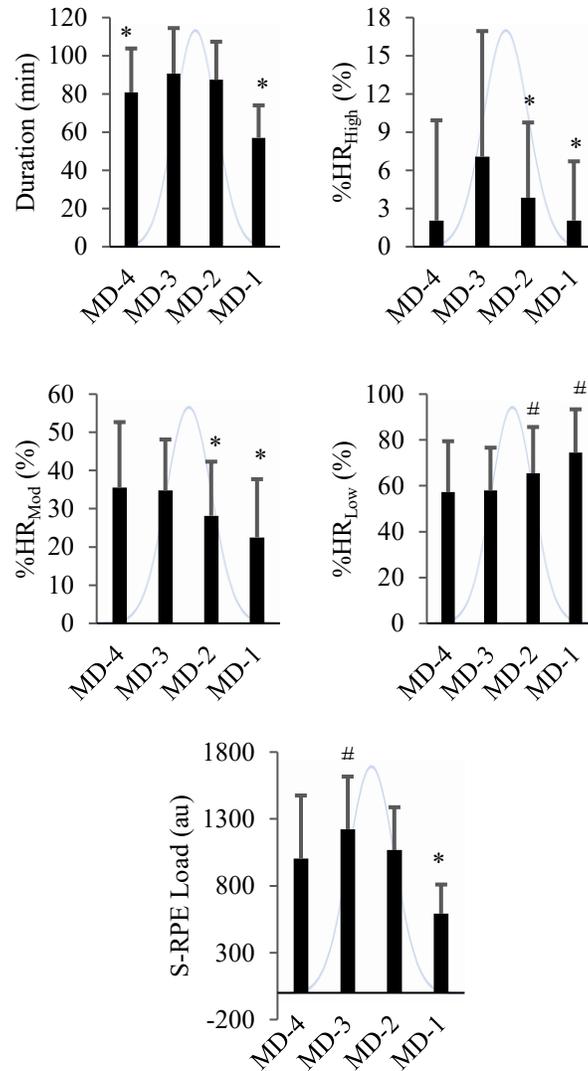


Figure 1: Means and standard deviations of total practice time (Duration), average percentage of time spent in each heart rate zone (%HR_{high}: $\geq 85\%$ HR_{max}, %HR_{mod}: 65-84% HR_{max}, %HR_{low}: $\leq 64\%$ HR_{max}), and Session rating of perceived exertion load (S-RPE Load), separated by days out from match (MD). Traditional bell-shaped curve is provided as visual reference to traditional models. Note: *Denotes day significantly ($p < 0.01$) lower than other days. #Denotes day significantly ($p < 0.01$) higher than other days.

on MD-2 was significantly lower than MD-3 ($-3.24 \pm 0.79\%$, $p < 0.01$, $d = 0.40$). No differences were seen in MD-4 compared to MD-2 ($p = 0.67$, $d = 0.18$) and MD-3 ($p = 0.13$, $d = 0.23$).

4. Discussion

The aim of the present study was to quantify internal and external indicators of TL in accordance with MD out from competition within a Division I male competitive soccer season. The findings of the present study provide a novel insight into the weekly training periodization of a high level American collegiate team. As previously seen, TL generally decreased as the match

approached (Akenhead & Nassis, 2016; Kelly et al., 2020; Stevens et al., 2017). The same trend was observed within the novel results. MD-1 recorded the lowest values for Duration, S-RPE Load, %HR_{High}, and %HR_{Mod}, while %HR_{Low} was greatest on this day. These findings provide insight into the coaching methodology with the emphasis on a lighter session on the last training day prior to competition, allowing players to have adequate recovery time.

In the current study, MD-3 (second day of training in each microcycle) was greatest for Duration, S-RPE Load, %HR_{High}. A common strategy among coaches is to place higher loads further away from competition. The current results showed an 18.00%

increase in S-RPE Load from MD-4 to MD-3, followed by an incremental reduction from MD-3 to MD-2 (12.87%) and MD-1 (47.57%). This coincides with results by Akenhead et al. (2016) that reported the highest S-RPE Load on the second day of the training week (MD-4) in elite level professional English football. Whereas Manzi et al. (2010) reported elite level European basketball athletes performed the highest S-RPE Load on the first training day of the week (MD-5). Malone et al. (2015) reported no differences in TL performed by athletes during the first three training sessions of the week in the English Premier League. The current study results resemble a bell-shaped curve which has been previously reported in various sport athletes where S-RPE Load increased after the first session of the week (Clarke et al., 2013; Los Arcos et al., 2017). This may be due to coaches being conscious of the proximity of the first session of the training week to the previous match and allowing for an initial lighter session to help build up to the planned hardest session of the week.

From MD-3 until MD, numerous studies across professional football and basketball all reported a gradual decline in S-RPE Load (Akenhead & Nassis, 2016; Kelly et al., 2020; Manzi et al., 2010) with a large drop in TL from MD-2 to MD-1. For example, Manzi et al. (2010) and Akenhead et al. (2016) observed a 51.84% and 27.81% reduction in S-RPE Load, respectively. Both representing the largest drop in load across the training week. The current study's 47.5% decrease in TL on the final training session before competition demonstrates the importance for recovery the 24 hours prior to competition. Additionally, Stevens et al. (2017) and Clemente et al. (2019) reported the same trend with total distance covered in a training session. This uniform reduction in player load indicates purposeful planning by coaches, and technical staff to prepare players for competition.

Training duration throughout the match week also portrayed similar trends as S-RPE Load. Conversely, in the Spanish La Liga and the Dutch Eredivisie leagues, Martin-Garcia et al. (2018) and Stevens et al. (2017) respectively, observed a progressive tapering from MD-4 (77 ± 9 min; 88 ± 11 min, respectively) toward MD-1 (61 ± 12 min; 59 ± 7 min, respectively). The findings of the current study portray closer trends based on duration with Martin-Garcia et al. (2018) due to the similar bell-shaped curve seen from an increase in duration from MD-4 to MD-3 (+10 min) followed by a progressive decrease toward MD. Additionally, these two European teams and the current study observed the largest drop in average training duration from MD-2 (La Liga: 80 ± 10 min, Dutch Eredivisie: 77 ± 12 min, Division I collegiate: 87.41 ± 19.95 min) to MD-1 (La Liga: 61 ± 12 min, Dutch Eredivisie: 59 ± 7 min, Division I collegiate: 57.06 ± 16.98 min). Interestingly, the collegiate team in the current study showed a similar large effect ($d = 1.64$) from MD-2 to MD-1 compared to the Professional La Liga ($d = 1.70$) and Dutch Eredivisie ($d = 1.83$) teams. Thus, as noted with S-RPE Load, this may be a result of the importance coaches' place in allowing players time to recover prior to a match.

%HR_{High} zone in the current study was reported to be the lowest for MD-1 (2.05%). Stevens et al. (2017) reported the lowest values for MD-1 for time spent in 90-100% of HR_{Max} (5.08%). Additionally, Akenhead and Nassis (2016) reported 5% of training on MD-1 at 90% or greater of HR_{Max}. In the present study, during their fall season the team played two matches in

seven out of 14 regular season weeks. With the intense nature of matches, along with their condensed schedule, the need for eliciting heart rate responses in the %HR_{High} zone may not be a priority for coaches. Therefore, the focus may shift to technical and tactical drills on MD-1, with an emphasis on allowing proper recovery.

%HR_{Mod} was lowest on MD-1 that followed a linear tapering in time spent in this zone from MD-4. Coutinho et al. (2015) observed a similar HR response in elite Portuguese football players of a similar age (u19) to the athletes in the current study. They found that time spent in the 85-89.5% HR_{max} zone was highest in the first session of the week followed by a slight decrease as MD approached. Interestingly, the average time spent in the 75-84.9% zone during the midweek training sessions increased after the first session of the week and then decreased in the pre match training session. In contrast to the present study, it is hard to compare the mid-week training sessions because they combined all sessions, except the first and last of the week, into one average time across the different HR zones. However, these findings do show similar trends in a slow taper towards MD in the moderate percentage zone (70-89.9%). As opposed to all other TL indicators, %HR_{Low} shows a progressive increase during the training week. MD-1 held the greatest amount of time followed by MD-2. Coutinho et al. (2015) reported the same trend with the pre match training sessions spending the most time in <75% of HR max compared to midweek and start of the week training sessions.

It should be noted that while this study reviewed the HR and S-RPE Load responses of an entire team during a competitive season, athletes were not separated by playing status for analyses. It is possible that as the season progresses, differentiation in TL would exist between starters and nonstarters, as coaches potentially provide starters with more rest throughout the training week. Future research should consider investigating the nature of playing status as a covariate to the MD out performance variables.

In summary, the present study quantified TL within a Division I male soccer team during the fall 2019 competitive season. MD-1 represented the lowest load throughout the training week, providing potential insight into the technical staff's emphasis on recovery one day preceding competition. For Duration, S-RPE Load, %HR_{High}, a bell-shaped trend in TL presented itself, which may signify the focus on recovery on MD-4 following the previous match. Whereas %HR_{Mod} showed a linear taper, while %HR_{Low} reported a linear trend of increased time as MD approached. Further research is still needed to better understand the TMs encountered by collegiate level soccer players and the different methodologies by coaching staffs to account for the short and condensed competitive schedule. The current findings provide insight into daily changes in TL leading up to competition during a competitive season to hopefully provide a deeper understanding into what is necessary to recover and prepare players for upcoming competition. The current results demonstrated a systematic reduction in daily TL in the days of training leading to the next competition with the lowest TL the day before competition. Due to the condensed nature of a collegiate season (17 matches in 91 total days), it is important for athletes to properly recover prior to the subsequent match. Additionally, with the goal to increase the athletic potential of the

student athletes, proper periodization of highly intense sessions needs to be carefully placed within a training cycle to avoid maladaptation.

Conflict of Interest

The authors declare no conflict of interests.

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