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Manipulating training activities to simulate physical match demands in rugby sevens

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ABSTRACT
Rugby sevens is a demanding sport that requires extensive physical preparation. Coaches often have limited contact time with players, but must ensure adequate physical, technical and tactical preparation. Playing form approaches (e.g., small-sided/conditioned games and phase of play activities) for training team sports are effective for improving tactical awareness and decision-making, but little information is available to guide the specific formats required to achieve adequate physical conditioning. To investigate what playing form approaches were able to meet and/or exceed physical match demands, microtechnology devices were used to measure total distance, high-speed distance, maximum velocity, acceleration load density, PlayerLoad and collisions in a group of international rugby sevens players (n = 22) during four tournaments and two training camps. Differences in the mean and duration specific demands of matches and different training session types (volume, quality, speed, collision) were determined using linear mixed models and effect sizes (ES) with 95% confidence intervals. Volume and quality training types simulated mean and peak match demands effectively. Speed training exceeded the peak high-speed running demands of matches over durations from 1 to 5 minutes (ES range 1.8 to 2.5). These results demonstrate that appropriately prescribed playing form activities are able to simulate the physical demands of rugby sevens competition.

1. Introduction

Rugby sevens is a physically demanding team sport that requires players to engage in large volumes of high-intensity running and frequent collisions (Ross, Gill, & Cronin, 2014). Rugby sevens is most frequently played in a tournament format, with five to six matches played over a two to three day period (Ross et al., 2014). The total workload accumulated by players over the course of a tournament typically exceeds that of a full 15-a-side rugby match and objective markers of fatigue remain elevated for up to six days following tournament participation (West et al., 2014). As such, adequate physical preparation for rugby sevens is essential (Schuster et al., 2017).

Research has shown that training sessions for both rugby sevens (Higham, Pyne, Anson, Hopkins, & Eddy, 2016) and rugby union (15 players) (Campbell, Peake, & Minett, 2018; Hartwig, Naughton, & Searl, 2011; Phibbs et al., 2018; Tee, Lambert, & Coopoo, 2016a) typically fail to emulate the physical intensity of match play. This suggests that training approaches can be improved and that research into improved training prescription is required. Playing form activities are a popular contemporary approach to training in team sports, and rugby in particular.

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Playing form activities are small-sided games, conditioned games and phase of play activities that are based on game scenarios and are specific to performance problems players are likely to encounter in competition. (Ford, Yates, & Williams, 2010). Evidence suggests that playing form activities effectively develop decision-making and tactical understanding (McKay & O'Connor, 2018; Miller et al., 2017).

Preparing players for international rugby sevens competition is subject to a number of logistical challenges that make the use of playing form activities advantageous. Sub-elite players typically play both sevens and fifteen man rugby (Ross et al., 2014), attending infrequent rugby sevens training camps in order to prepare for tournaments which take place three to six times per year. Full-time professional players on the World Rugby Sevens Series (WRSS) often live in different locations across their respective countries and cannot remain in camp continuously due to the long periods between competition events (Meir, 2012). This restricted access to players places unique demands on coaches who must quickly and efficiently impart their 'game model' and operationalize team tactics within limited timeframes (Richards, Collins, & Mascarenhas, 2012). As a result, training camps typically focus on developing player skill and team cohesion through a range of playing form activities (Meir, 2012).

This overt focus on tactical outcomes often limits the time that strength and conditioning (S&C) coaches have with players for physical preparation. Recently, it has been suggested that S&C coaches could collaborate with technical and tactical coaches to manipulate aspects of playing form training such as pitch size, work:rest intervals and player numbers to improve the quality of physical stimulus received in a process designated *tactical periodisation* (Tee, Ashford, & Piggott, 2018). While this approach is theoretically promising, little information is available regarding the specific manipulations that would elicit appropriate training intensity. Therefore, the primary aims of this study are to determine the whole and peak match demands of rugby sevens match play at an international, sub-elite level of competition, and subsequently to determine the parameters necessary to meet or exceed these demands through playing form activities. It is anticipated that this information will be useful to rugby coaches that make use of playing form activities in their own practice.

In addition to the primary aims, a further aim of this study it to provide important novel normative data for practitioners working in the field. Previous research in rugby sevens has described the described the peak running demands of competition over periods of 1 and 2 minutes (Furlan et al., 2015; Granatelli et al., 2014; Murray & Varley, 2015), however the mean ball in play time is 30.9 seconds (Ross et al., 2014). This study reports peak running, acceleration and collision demands over durations from 30 seconds to 5 minutes to support improved training prescription. Further to this, this study explores the use of acceleration load density (Delaney, Cummins, Thornton, & Duthie, 2018) and a novel collision algorithm (Hulin, Gabbett, Johnston, & Jenkins, 2017) to quantify the physical demands of rugby sevens.

2. Methods

2.1. Experimental approach to the problem

The action research concept informed the experimental approach to this study. Action research is a process through which an intervention or change program is implemented, and managed by, the participant(s) and situated in their practice (Carr & Kemmis, 1983). The coach and strength and conditioning coach of the team were the principal investigators in this project which aimed to devise more effective methods of training within the constraints of their environment. Microtechnology device (global positioning system (GPS) and accelerometer) data were collected during training camps and international tournaments to establish the specificity of playing form activities as a physical training stimulus.

2.2. Participants

Twenty-two male players representing an international rugby sevens team competing in the Rugby Europe Trophy competition between 2017 and 2019 were included in the study. The physical performance characteristics of these players are presented in Table 1. The Rugby Europe Trophy is the third tier of international rugby sevens competition (after the WRSS and Rugby Europe Grand Prix) and teams competing at this level are ranked between 13 and 26 in Europe. Players were informed of the study procedures and provided written informed consent. Ethical approval was granted by the Local Research Ethics Committee of Leeds Beckett University and the recommendations of the Declaration of Helsinki were respected. Procedures

2.2.1. Match and training exposures

Data were collected across four international rugby sevens tournaments (23 total matches) and two international training camps (10 individual training sessions). Tournaments were played under World Rugby laws and as such the data collected were purely observational. Training camp activities were designed by the coaches with the intention of maximising the development of tactical understanding, while simultaneously providing a highly specific physical training stimulus. Each training camp consisted of five training sessions over two days with each individual session organized around particular tactical themes (Table 2). Individual training sessions consisted of a warm up, followed by a skill development activity, followed by playing form activities, and a cool down comprised of an individual skill development task. The playing form activity blocks were structured to replicate the duration of a match half (7 mins), with 2-3 min recovery between each block. Activities within these blocks were organized around specific tactical '*moments of the game*' (Tee et al., 2018) (e.g., attack from midfield rucks, kick off defence, etc.).

Table 1: Physical performance characteristics of players representing an international rugby sevens team participating in the Rugby Europe Trophy competition.

	All players (n = 22)	**Forwards (n = 10)**	**Backs (n = 12)**	***p*-value**	**Effect size, ±95%CI**
Body mass (kg)	87.0 ± 7.2	91.6 ± 4.0*#	83.1 ± 7.1	0.002	1.1 ±0.7
1RM squat (kg)	141 ± 18	146 ± 20	137 ± 16	0.312	0.5 ±1.0
1RM bench press (kg)	108 ± 14	114 ± 16	104 ± 12	0.139	0.7 ±0.9
10m sprint (s)	1.82 ± 0.08	1.86 ± 0.09	1.80 ± 0.07	0.161	0.7 ±1.1
40m sprint (s)	5.45 ± 0.21	5.56 ± 0.16*	5.36 ± 0.20	0.046	0.9 ±0.9
Momentum ($kg.m^{-1}.s^{-1}$)	472 ± 40	486 ± 26	462 ± 47	0.217	0.5 ±0.8
Counter movement jump (CMJ) height (cm)	40.9 ± 4.8	38.8 ± 2.8	42.8 ± 5.5	0.121	0.7 ±0.9
CMJ peak power (Watt)	4394 ± 359	4419 ± 302	4373 ± 425	0.822	0.1 ±0.9
CMJ Relative peak power ($Watt.kg^{-1}$)	50.3 ± 3.9	48.5 ±1.8	52.2 ± 4.7	0.124	0.7 ±0.8
Bronco Run (s)	297 ± 11	300 ± 13	295 ± 9	0.406	0.4 ±1.0

Note: Testing procedures for all variables are detailed in the supplementary document. * indicates a significant difference between backs and forwards ($p < 0.05$) (independent samples t-test). # indicates that there is a greater that 75% likelihood that the differences observed were practically meaningful at an effect size threshold of 0.6 (moderate). Effect size represents the standardized mean difference between forwards and backs with 95% confidence intervals

Within these playing form activities, coaches attempted to manipulate the constraints of training to achieve particular physiological stimulus. Sessions were broadly categorized as either '*volume*' or '*quality*' type sessions. *Volume* sessions attempted to expose players to higher work rates than they would typically be exposed to during matches. The aim of *quality* sessions was to execute tactical movements successfully under physical demands similar to those experienced under match conditions. Quality sessions were utilized when new tactical approaches needed to be learned to allow time for brief periods of communication, feedback and reflection between playing bouts. In order to achieve these outcomes, work:rest ratios were manipulated to influence physical demands. *Volume* sessions were constructed with ball in play periods >45 seconds in duration and half as much rest provided (i.e work:rest ~ 2:1). *Quality* sessions were constructed with short ball in play periods <35 seconds in duration and longer rest periods up to 60 seconds in duration (work:rest ~ 1:2). This reflects the average ball in play time of 28-33 seconds during international competition (Ross et al., 2014).

In cases where play broke down before the required playing time interval had elapsed, coaches introduced another ball into the game and allow play to continue immediately from unstructured situations. Pitch dimensions were never altered and all sessions took place on a full size rugby pitch. Rugby sevens has one of the largest player to pitch area ratios of all team sports (at least 515 m^2/player), and as such pitch area is unlikely to be a limiting constraint on player movement patterns. Sample sessions are provided in Table 3 for clarity.

It was anticipated that even though session types could be manipulated to influence physical demands, it would be not be possible to manipulate game conditions sufficiently to provide consistent exposure to maximal velocity running or frequent high-intensity collisions, both of which are key determinants of performance (Ross et al., 2014). Therefore, specific game form drills were developed to emphasise either maximal velocity running or collision exposure and included in training sessions as skill development activities (Table 2). Due to the intensity of these activities each drill was typically only utilized once per training camp (Table 2).

2.2.2. *Quantification of match and training demands*

During training camps and tournaments players wore microtechnology devices (S5 Optimeye, Catapult Innovations, Melbourne, Australia) that sample GPS data at a frequency of 10Hz and contain a tri-axial accelerometer sampling at 100Hz. Players used the same microtechnology device for the duration of the data collection period. Devices were positioned between the shoulder blades, in a custom-designed undergarment provided by the manufacturer. The validity of these units for measuring team sports movements has been previously established (Johnston et al., 2012; Varley, Fairweather, & Aughey, 2012). Following the completion of each match or training session, data were downloaded to the manufacturer's software (OpenField 1.14, Catapult Innovations, Melbourne, Australia) and trimmed to only include playing time. Playing time was considered to be the beginning to the end of each half or playing block (inclusive of ball out of periods) for matches and training respectively. For training sessions, only playing form activities (volume, quality, collision or speed) were retained for analysis. Start and finish times of these activities were recorded by direct observation and then used to ensure that only relevant training periods were included in the data. Data were then exported as .csv files before

Table 2: Example training schedule from a two-day international rugby sevens training camp.

	TRAINING CAMP SCHEDULE			
	Day 1		**Day 2**	
07:00 to 08:00	STRENGTH AND POWER TESTING		-	
08:00	BREAKFAST		BREAKFAST	
08:30 to 09:30	TEAM MEETING		TEAM MEETING	
09:30 to 10:30	PREPARATION: Physio, taping, foam rolling and mobility work		PREPARATION: Physio, taping, foam rolling and mobility work	
10:30 to 12:00	TRAINING SESSION #1 Tactical Theme: Defence		TRAINING SESSION #4 Tactical Theme: Attack from broken play	
	Session type: Quality		**Session type: Volume**	
	Session content	Timing and detail	Session content	Timing and detail
	• Warm-up	10 minutes	• Warm-up	10 minutes
	Skill development • Collision – 2 vs 2 tackle drill	10 minutes Emphasis – repeat effort ~ 2-3 tackles/min	Aerobic capacity test • Bronco	10 minutes
	Tactical development • High D drill into game situation #1 • High D drill into game situation #2 • Game situation start from ruck#1 • Game situation start from ruck #2	4 x 7 minutes Work: up to 30s Rest:up to 60s Ratio ~ 1:2	Tactical development • Red zone attack #1 • Red zone attack #2 • Mid-field ruck attack #1 • Mid-field ruck attack #2	4 x 7 minutes Work: more than 45s Rest: less than 30s Ratio ~ 2:1
	Individual skills • Warm down Kick off skills	10 minutes	Individual skills • Warm down Passing skills	10 minutes
12:00 to 13:00	LUNCH		LUNCH	
13:00 to 14:00	PREPARATION: Physio, taping, foam rolling and mobility work		PREPARATION: Physio, taping, foam rolling and mobility work	
14:00 to 15:00	TRAINING SESSION #2 Tactical Theme: Kick off		TRAINING SESSION #5 Tactical Theme: Match simulation	
	Session type: Quality		**Session type: Quality**	
	Session content	Timing and detail	Session content	Timing and detail
	• Warm up	15 minutes	• Warm up (as per tournament)	10 minutes
	Skill development • Speed - testing OR speed games	15 minutes Emphasis – maximum velocity	Skill development • Wrestling and collision skills	15 minutes
	Tactical development • Game situation from kick off scenarios	3 x 7 minutes Work: up to 30s Rest:up to 60s	Tactical development • Full match simulation	3 x 7 minutes Work: up to 30s Rest:up to 60s
	Individual skills • Warm down Kick skill game	Ratio ~ 1:2 10 minutes	Individual skills • Warm down Penalty moves	Ratio ~ 1:2 10 minutes
15:00 to 16:00	RECOVERY: Snack, mobility, foam roller		TEAM MEETING	
16:00 to 17:00	TRAINING SESSION #3 Tactical Theme: Attack from set piece		ONE ON ONE MEETINGS AND CLEAN UP	
	Session type: Volume			
	Session content	Timing and detail		
	• Warm up	10 minutes		
	Skill development • Long passing	10 minutes		
	Tactical development • Attack from mid field scrums • Attack from wide scrums • Attack from lineouts • Warm down	3 x 7 minutes Work: more than 45s Rest: less than 30s Ratio ~ 2:1 10 minutes		

being further analysed in R (version R-3.1.3, R Foundation for Statistical Computing, Vienna, Austria). GPS files were excluded from the data set if the mean number of satellites connected was <10, or the horizontal dilution of precision was >2.0. In total, 378 match halves and 379 training bouts (221 quality, 125 volume, 20 collision, 13 speed) were analysed.

The variables of interest were total distance, high speed distance (distance >5m.s^{-1}), acceleration load density, PlayerLoad, maximal velocity and collision count. These variables were selected because they are representative of the various physical demands of the game and have been previously reported, providing a basis for comparison (Ross, Gill, & Cronin, 2015a, 2015b). Where appropriate, data were normalized to activity duration to account for differences in playing time (e.g., starters vs. substitute players) and thus total distance (m.min^{-1}), high speed distance (m.min^{-1} >5m.s^{-1}), PlayerLoad (AU.min^{-1}) and collisions (n.min^{-1}) are all presented as per minute values, while acceleration (m.s^{-2}) is presented as the mean value over the relevant time period and maximal velocity (m.s^{-1}) as the maximum value over the relevant time period.

PlayerLoad is a measure derived from the accumulation of data from all axes of the triaxial accelerometer, and is considered to be a representation of the mechanical load that athletes are exposed to (Barrett, Midgley, & Lovell, 2014). Collision count was determined using the 'tackle' algorithm provided by the manufacturer, which derives collision events from the interaction between accelerometer and gyroscope data. Collision data were exported and all collisions less than 1 PlayerLoad (AU) and or lasting less than 1 second were excluded from the analysis in order to improve the accuracy of the detection (Hulin et al., 2017). While it is acknowledged that this method has only been validated for use in rugby league, in the absence of a validated and commercially available application for determining collision counts in rugby sevens, this method was deemed to be representative of collision exposure.

Match and training exertions are described as both the overall mean (average exertion over the entire playing period) and duration specific (maximal mean exertion over specified time periods) values (Whitehead, Till, Weaving, & Jones, 2018). Specifically, time-series files detailing players instantaneous speed every 0.1s were exported from the proprietary software to RStudio. A custom algorithm was built using the *zoo* package (Zeileis & Grothendieck, 2005)to calculate the maximal mean of each player's instantaneous speed across different durations (30s, 1 min, 2 min, 3 min, 4 min, 5 min) using a shifting time window according to the methods of Delaney et al. (2015) (Delaney et al., 2015). The same time series files were used to derive acceleration load density by calculating the absolute value of all acceleration/deceleration data, before being averaged over the duration of the defined period. Acceleration load density provides a reliable assessment of the total acceleration and deceleration demands of an activity (Delaney et al., 2018; Delaney et al., 2019).

2.3. Statistical analysis

All data were log transformed prior to analysis to reduce non-uniformity of error. Differences in physical characteristics between backs and forwards were assessed using independent samples t-tests. Linear mixed models were constructed using the *lme4* package (Bates, Maechler, Bolker, & Walker, 2015) to assess the difference between match exertions and different training session types. Separate models were built for each measured variable and duration. Match or training session type were designated as fixed effects, while player identity, match or training session identity, player position (back or forward), period (half 1 or 2 for matches and interval 1 to 5 for training sessions) and season were all included as random effects. These random effects were included to address the non-independence of data (i.e., repeated measures on the same participants) and to account for differences in exertions that may occur as results of pacing and fatigue (Higham, Pyne, Anson, & Eddy, 2011; Tee, Lambert, & Coopoo, 2016b, 2019). Pairwise comparisons were made between training session types and match exertions using the least-squares mean test provided in the *emmeans* package (Lenth, 2019). Cohen's *d* effect sizes (ES) and 95% confidence intervals were then calculated for these pairwise comparisons using the *psych* package (Revelle, 2018). ES magnitudes were interpreted as 0.00-0.19, *trivial*; 0.20-0.59, *small*; 0.60-1.19, *moderate*; 1.20-1.99, *large*; and >2.0 *very large* (Hopkins, Marshall, Batterham, & Hanin, 2009).

Due to the applied nature of this study, it was important to assess whether differences were practically meaningful, rather than just significantly different. As such, percentage likelihood that observed effects exceeded a minimum threshold for practical importance were derived from the p-values of the least-squares mean tests (Hopkins et al., 2009). It has been previously demonstrated that mean running speed and acceleration are highly variable in team sports, and that as a result of this variability small effects may lie within the typical error of measurement of these metrics (Duthie, Thomas, Bahnisch, Thornton, & Ball, 2019). On this basis, an effect size of 0.6 was designated as the threshold for practical importance. Accordingly, differences were considered practically meaningful if there was a >75% likelihood of the effect being moderate (ES > 0.6).

3. Results

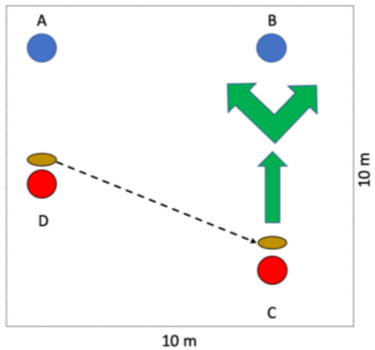
The mean movement demands of rugby sevens match play and the various playing form training structures are presented in Table 4. Figure 1 shows the magnitude of difference (ES ± 95%CI) from match-play of the various training structures for all of the movement variables.

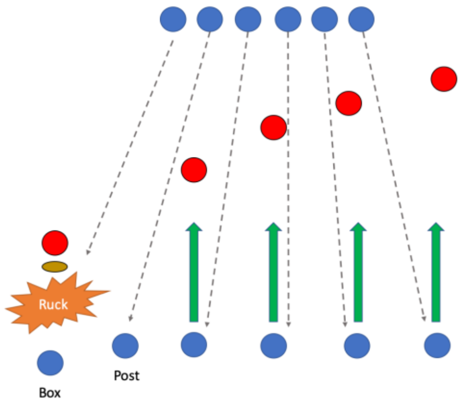
Both the *volume* and *quality* type training structures simulated the demands of match play well. There were no practically important differences between match play and *volume* type training for any of the performance parameters measured. The only meaningful difference between match play and *quality* type training was a *moderate* difference in PlayerLoad (ES -1.0, -1.1 to -0.8; $p < 0.001$; 85% likelihood).

The activities designed to emphasise either speed or collision exposure displayed some large differences from match activity. *Speed* type sessions resulted in less total distance being covered (ES -0.9, -1.5 to -0.2; $p = 0.001$; 91% likelihood) and less PlayerLoad (ES -2.3, -3.0 to -1.7; $p < 0.001$; 100% likelihood)

Table 3: Sample session plan focused on defensive organization, illustrating the incorporation of tactical periodization principles into session planning.

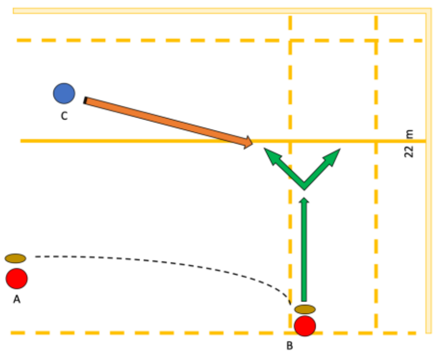
TRAINING SESSION #1		
Date: N/A	Phase: Pre-competition	Total time: 1 hour
Tactical Theme – Defence from rucks **Game moments**: Transition from first phase or turnover to 'high-D' structure **Tactical scenario:** Defending a ruck after slowing the ball down **Sub-principle:** Remove attack's time and space as quickly as possible **Sub-sub-principles:** Line speed depends on prior organization – get position + width quickly		
Technical: Organisation from box and post defenders when arriving at rucks. NB roles and responsibilities	**Physical:** - "Quality" emphasis – Work periods ~ 30 seconds/3-4 phases, with up to a minute between bouts. Work:rest 2:1 - Adequate rest ensure that learning occurs at game speed.	**Mental:** Quickly switch roles – transitions are normally preceded by an error – adjust quickly to new scenario

Activity	Duration	Structure	Key coaching points
Warm up	10 minutes	**Raise:** Passing grid with submaximal running **Activation and mobilization:** Running technique drills **Potentiate:** Wrestle in prep for contact exposure	- 'Rifles' – finish the pass - Control hips to dominate contact
<u>**Skill development**</u> 2 vs 2 tackle area drill	15 minutes	**2 vs 2 tackle area drill**  Player D pass to player C, Player C attempts to beat player B. Players D provide support and clean ruck. Player A make decision about whether to contest ruck or set defence.	Attackers - Agility before contact. Try to free arms for offload/long place. Support player 45 degrees on the inside and 2-3 m depth. Available for offload or clean. Defenders – Close space quickly! Settle prior to contact = feet ready to react to agility. Foot into contact zone. Wrap and leg drive after contact. Return to feet quickly. Catch up defender – Keep alignment. Awareness of offload. Identify opportunity for turnover or slow possession, or set defence quickly

Tactical development High D – work together to reduce attack time and space	4 x 7-minute blocks	**High D drill into game play** – 2 x 7 minutes  Attacking and defending players start 10 – 15m ahead of the ruck. Ruck contains 2 attacking and 1 defending player. On the signal, both groups of players advance to the ruck and set to play – this simulates game situation following a ruck especially if we manage to slow down the ball. Defensive players KPI's – 1. Set box, 2. Set post, 3. achieve width/alignment, 4. Work rate – achieve line speed, while maintaining connection. - Second block – defence two players in ruck = one less player in the line. **Game situations starting from ruck defence** – 2 x 7 minutes Defence starts flat, but from various ruck positions (left, right, middle). Principles of High D to be demonstrated in dynamic game play.	***Tactical:*** 1. Box and post most NB – must set to avoid blindside attack 2. Post must advance quickly to stop first attacker stepping back and attacking blind 3. Retreating defenders work hard to achieve with/alignment and be ready 4. Aggressive linespeed! Move fast when the ball is in the air, settle when ball is in hands. 5. Maintain alignment. ***Technical:*** 1. Shoulders remain square even if sliding to avoid being beaten on the weak shoulder. 2. Maintain connection with inside and outside defenders 3. Positioning – inside, inside shoulder ***Mental:*** 1. Agitated/angry coaching behaviours to increase pressure 2. Deliberately unfair refereeing during some bouts to develop resilience.
Warm down Kick off receipt skills	2 x 5 minute blocks	**Catching in the air** Players to pair off – one feeding, other catching. Feeder throws balls in the air requiring the catcher to move a few steps before jumping and catching overhead **Supported catches** As previous, but catchers now work as catching pods (1 lifter/1 catcher)	***Technical:*** 1. Move early, watch ball to the peak of its arc before settling 2. Hands above head and in the air to catch.

TRAINING SESSION #2

Date: N/A	Phase: Pre-competition	Total time: 50 minutes
Tactical Theme – Kick off recovery **Game moments**: Kick off to recovery possession or kick off to exert pressure **Tactical scenarios:** Leading/chasing game – One or two score differences **Sub-principle:** Pressure on catcher – no time to look/assess options – create a contact point **Sub-sub-principles:** Chase line – wide players ahead to cut of wider attack options.		
Technical: Kick quality – predictable height and positioning Kick chase – contestable = 1 competing player, 1 past the ball + organized line - Deep kick = 6 in a line, pressure into the corner	**Physical:** - Maximum velocity and high speed running volume - “Quality” emphasis – Work periods ~ 30 seconds/3-4 phases, with up to a minute between bouts. Work:rest 2:1 - Adequate rest ensure to ensure running intensity is maintained	**Mental:** Decision making regarding score line scenarios, and reacting to opposition strength/weaknesses.

Activity	Duration	Structure	Key coaching points
Warm up	10 minutes	**<u>Max velocity preparation</u>** **Raise:** Long passing grid with submaximal running **Activation and mobilization:** Running technique and plyometric drills **Potentiate:** Gradual acceleration into 10 – 15 VMax	- Stay straight – don’t run sideways to deliver long pass - Postures and shapes – accel vs Max V.
<u>Skill development</u> Speed weapons	15 minutes	**‘Finish in the corner’** drill ~ 5 attacks per player  Player A kick/pass to player B. Player C is the last defender and may start moving as soon as player A passes. Player C must receive the ball and use speed and agility skills to beat player C and score anywhere over the try line.	Attackers – Don’t allow defenders to close space before using your ‘weapons’. Vary speed and try to get defender to turn his shoulders. Defenders – Close space quickly! Shepard attacker, try to provide only one shoulder to attack and minimize the ability to use ‘weapons’.

Tactical development Kick offs	3 x 7-minute blocks	**Game play from kickoff starts** Block 1: Contestable kick – 1 x 7 minutes Block 2: Deep kick – 1 x 7 minutes Block 3: Variable (scenarios) – 1 x 7 minutes	***Tactical:*** 1. Contestable: Player in the air to compete with catcher – react to errors! 2. Deep kick: Pressure through high line speed and organized shape. Lock them in! ***Technical:*** 1. Kick quality 2. Timing arrival into jump zone ***Mental:*** 1. Decision making around kick type – when/why
Warm down Kick skills game	5 minutes	**Cover the field** Players kick to gain ground – if ball hits grass they receive another kick from where it landed. When close enough attempt drop goal.	***Technical:*** ***1.*** No pressure catch – set and execute 2. Kick skill – control fall of ball, head down.

Table 4: Mean movement demands of international rugby sevens matches and tactical periodisation training structures.

		Training type			
	Match	**Quality**	**Volume**	**Speed**	**Collision**
Total distance ($m.min^{-1}$)	107 ± 37	93 ± 17	102 ± 14	76 ± 7*	41 ± 5*$^{,§,\#,\%}$
High speed distance ($m.min^{-1}$)	16 ± 11	10 ± 5	10 ± 4	22 ± 3§	0.6 ± 0.4*$^{,§,\#,\%}$
Maximum velocity ($m.s^{-1}$)	7.2 ±1.0	6.9 ± 0.9	7.2 ± 0.8	7.8 ± 0.9	4.1 ± 0.4*$^{,§,\#,\%}$
Acceleration load density ($m.s^{-2}$)	0.35 ± 0.10	0.40 ± 0.07	0.41 ± 0.05	0.27 ± 0.09$^{§,\#}$	0.32 ± 0.06
PlayerLoad ($AU.min^{-1}$)	10.7 ± 1.3	9.0 ± 1.8*	10.2 ± 1.2	6.7 ± 0.8*$^{,§,\#}$	4.5 ± 0.5*$^{,§,\#,\%}$
Collisions ($N.min^{-1}$)	1.5 ± 2.4	1.0 ± 0.9	1.1 ± 0.9	-	1.4 ± 0.3

Note: *,§,$^{\#}$ and $^{\%}$ designate practically meaningful differences (> 75% likelihood of a moderate or greater effect) from match, quality, volume and speed type training respectively.

than matches. *Collision* training was the training type that was most similar to match play for collisions (ES -0.04, -0.6 to 0.5; *p* = 0.263; 100% likelihood of trivial effect), but was meaningfully lower for total distance, high speed distance, maximum velocity and PlayerLoad measures (*large* to *very large* effects, *p* < 0.001, 100% likelihood). Despite the intention to create overload, none of the training structures implemented lead to physical exertions that were meaningfully greater than match play.

When comparing between different training types, it is clear that *collision* type training is atypical, displaying practically important differences from all other training types for all measures except acceleration load density and collisions. *Speed* type training had meaningfully lower acceleration load density demands than both *volume* (ES -2.5, -3.3 to -1.7; *p* = 0.062; 89% likelihood) and *quality* (ES -2.2, -2.9 to -1.5; *p* = 0.079; 86% likelihood) type training. *Speed* training lead to more high speed running than *intensity* (ES 1.0, 0.3 to 1.6; *p* = 0.040; 87% likelihood) and *volume* (ES 1.2, 0.5 to 1.8; *p* = 0.381; 69% likelihood) type training, but only *intensity* presented a clear difference. No collisions occurred during *speed* training.

Based on the evidence of the previous analysis, *collision* training data was not carried forward to peak demands analysis due to being so clearly different. The averaged peak values for total distance, high speed distance and acceleration over time periods ranging from 30 seconds to 5 minutes are presented in Figure 2. There were no practically meaningful differences between matches and *quality* or *volume* training types over any duration. *Speed* sessions exceeded the average peak high speed running demands of matches over durations ranging from 1 to 5 minutes (*large* to *very large* effects, *p* < 0.05, > 89% likelihood).

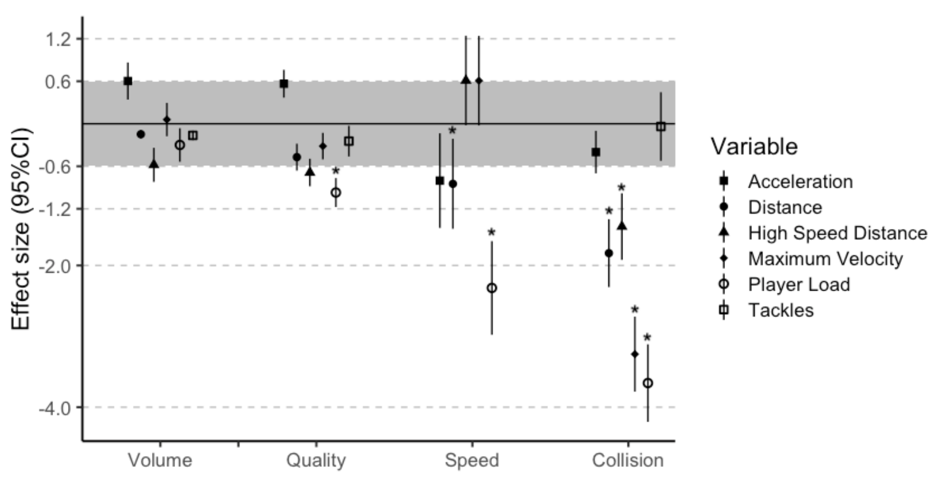


Figure 1: Comparison of standardized effect sizes with 95% confidence intervals of movement characteristics between international rugby sevens match-play and tactical periodization training activities. Positive values indicate outputs greater than match play.
Note: * designates a practically meaningful difference (> 75% likelihood of a moderate or greater effect) from matches.

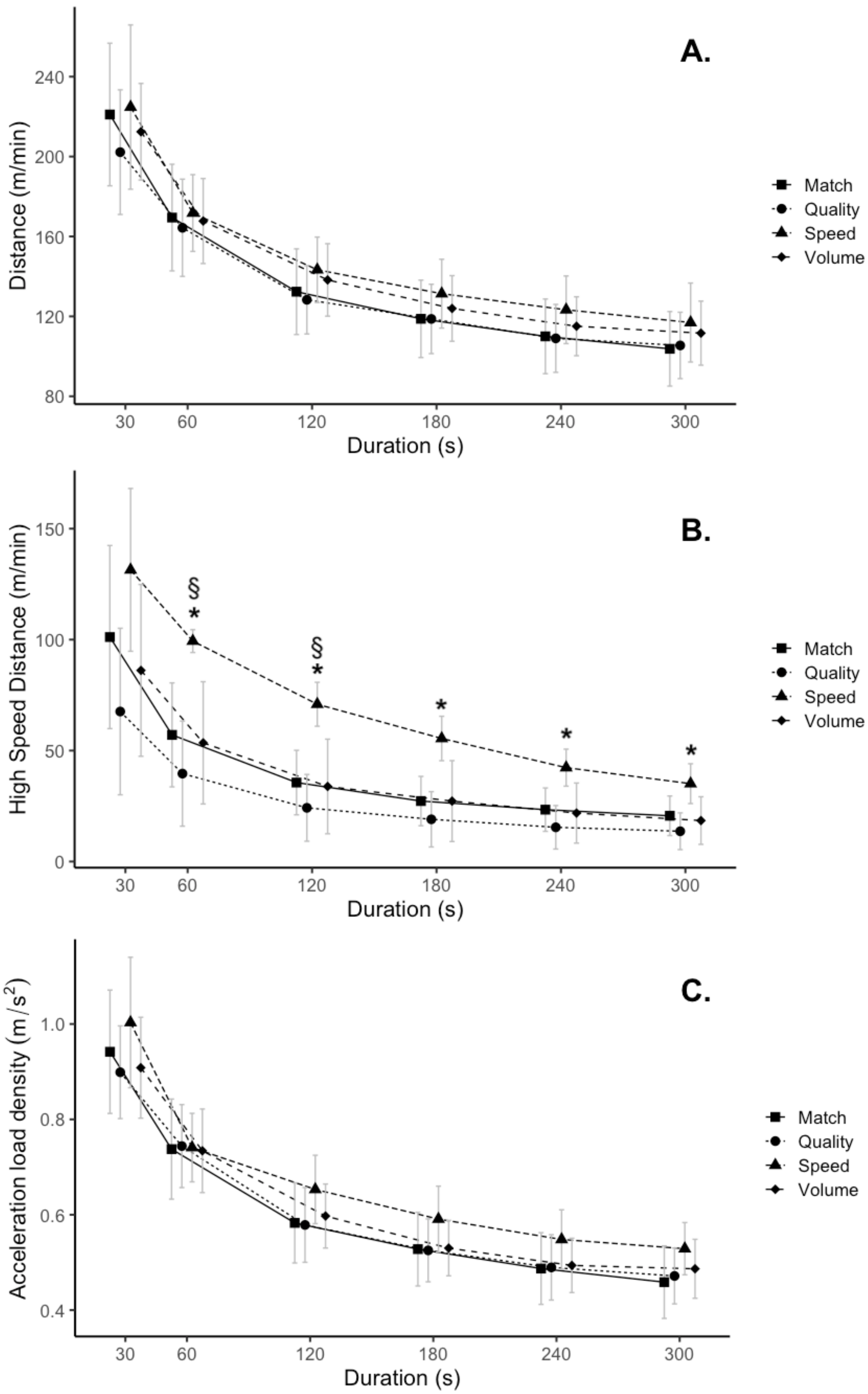


Figure 2: Peak (maximal mean) demands of international rugby sevens matches and tactical periodisation training types for A) total distance, B) high speed distance and C) acceleration load density over 30, 60, 120, 180, 240 and 300 second time periods. Data are presented as mean ± SD.

Note: * and § designate practically meaningful differences (> 75% likelihood of a moderate or greater effect) from matches from matches and *intensity* type training sessions. Positive values indicate outputs greater than match play. Absolute values are provided in the supplementary file.

Speed training was not practically different to matches for total distance or acceleration load density any time period. *Speed* training also exceeded the high speed running demands of *quality* training over durations of 1 and 2 minutes (*very large* effects, p = 0.013, > 87% likelihood). *Speed* training was also not practically different to *volume* training for any variable.

4. Discussion

The main finding of this study is that it was possible to provide a training stimulus similar to the physical demands of international rugby sevens match play through the use of playing form activities in training. These results contrast directly with previous examinations of rugby sevens training where training drills failed to reproduce the movement demands of matches (Higham et al., 2016). This study therefore presents novel findings, demonstrating that playing form activities can be highly specific to the physical demands of rugby sevens match play.

This study is also the first to provide a full range of peak duration specific demands for rugby sevens match play. Previous analysis of the peak demands of rugby sevens match play provided data over periods of 1 to 2 minutes (Furlan et al., 2015; Granatelli et al., 2014; Murray & Varley, 2015). The data provided here extend this analysis, considering both shorter (30 s) and longer periods of play (5 min). This is important because the mean ball in play time for international rugby sevens is approximately 30 seconds (Ross et al., 2014), thus the data provided here give a more accurate reflection of the ball in play demands. Understanding the peak intensities typical of longer game periods is essential for evaluating the effectiveness of training prescription (Delaney et al., 2017). There appears to be very little difference between rugby sevens, international rugby union (Delaney et al., 2017) and professional rugby league (Johnston et al., 2019; Weaving et al., 2019) when comparing the peak running intensities across all durations.

An interesting finding of this study was that the manipulation of work:rest ratios had relatively minor effects on the physical demands of training. Previous research demonstrates that following the highest intensity periods of play team sports players temporarily reduce their levels physical exertion (Bradley & Noakes, 2013; Peeters, Carling, Piscione, & Lacome, 2019).This suggests that players regulate their levels of exertion to ensure adequate reserves for future periods of play (Waldron & Highton, 2014). On this basis, the lack of differentiation between training structures may indicate that both types are sufficiently physically demanding that players are forced to regulate their efforts. Further consideration needs to be given to how to effectively differentiate training types to ensure variation in training stimulus.

In contrast, the manipulations applied within the playing form activities designed to maximise *speed* and *collision* exposures allowed for those particular movement challenges to be emphasised, but equally resulted in these activities becoming quite different from the generalised demands of match play. On this basis, it seems pragmatic to prescribe a combination of activity types to ensure that players are generally conditioned for match play, but are also regularly exposed to more intense sessions focused on developing particular physiological qualities. In this sense, the *speed* session was highly specific as a stimulus for maximal velocity and high speed running.

The match data provided here is the first to examine the physical demands in the third tier of international rugby sevens competition. In general, the total and high speed distance outputs were similar to those reported for tier 1 (sevens world series) players (Ball, Halaki, & Orr, 2019; Higham et al., 2016; Murray & Varley, 2015; Ross et al., 2015a, 2015b), with the exception of mean maximal velocity (tier 1 players (range 7.5 to 8.4 $m.s^{-1}$) (Higham et al., 2016; Ross et al., 2015b) vs. tier 3 players (7.2 ± 1.0 $m.s^{-1}$)). The peak running demands reported here and for tier 1 players were also similar (Furlan et al., 2015; Murray & Varley, 2015). Collectively these results suggest that there is very little difference in the movement demands between these distinct levels of competition. If the physical demands of play at different levels of competition are not meaningfully different, it is likely that the differences in performance ability lie in superior technical skills, effective tactical operationalisation and improved decision making. This observation underlines the value of playing form type training which maximise opportunities to develop these attributes.

This study presents a number of analyses that are novel in rugby sevens. Previous rugby sevens research has quantified the acceleration demands of the game using frequencies of entries into different acceleration thresholds (Ball et al., 2019). This approach is problematic because the discretization of time series data reduces the reliability of the measurement (Delaney et al., 2018). A more appropriate method is to report the acceleration load density for the period in question (Delaney et al., 2018). To the authors knowledge, this study is the first to apply this approach in mens rugby sevens. The peak acceleration load density of match play and training determined here are lower than those that have been previously reported for field hockey (Duthie et al., 2019), rugby union (Delaney et al., 2017), rugby league (Delaney et al., 2016) and women's international rugby sevens (Henderson, Chrismas, Stevens, Coutts, & Taylor, 2020). This may signify a difference in the physical performance of sub-elite vs elite team sport athletes, but further investigation is required.

A challenge for researchers working in the rugby codes is that although most microtechnology devices estimate collision exposure in some form, these estimations often don't correspond to actual collisions (McLellan, Lovell, & Gass, 2011). This study is the first to use the Hulin et al (2017) method to estimate collision exposure (Hulin et al., 2017). This measure has not been validated in rugby sevens, but unlike the majority of collision estimation metrics applied in rugby sevens, the measure was validated in professional rugby league against observable video criterion and displayed high levels of sensitivity (97.6%) and specificity (92.7%). Results showed that during matches players are exposed to 3 collisions every two minutes, which is similar to the peak collision frequency observed in professional rugby league players (Johnston et al., 2019).

A major limitation of this study is that no direct measures of technical or tactical skill were made and only physical performance was assessed. Anecdotally, the team in question performed well in the seasons studied, achieving their highest ever ranking in the European trophy competition in one of the seasons. Future studies should aim to assess technical and tactical outcomes alongside physical performance in matches and training.

In conclusion, this study has demonstrated that through use of appropriate manipulations of practice conditions, playing form activities can simulate the physical demands of match play in rugby sevens. This is useful because it confirms that highly specific physical preparation can be achieved while focusing on the development of technical, tactical and mental skills for competition. Playing form activities can be manipulated to emphasise particular aspects of conditioning (e.g., high speed running or collision exposure).

Conflict of Interest

The authors declare no conflict of interests.

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Supplementary Material 1

Mean peak movement demands of international rugby sevens matches and tactical periodisation training structures over time periods or 30 seconds to 5 minutes.

Session type	30 sec	1 min	2 min	3 min	4 min	5 min
Total distance ($m.min^{-1}$)						
Match	221 ± 36	169 ± 27	132 ± 21	119 ± 19	110 ± 19	104 ± 19
Intensity	202 ± 31	164 ± 24	128 ± 17	119 ± 17	109 ± 17	104 ± 17
Volume	212 ± 24	168 ± 21	138 ± 18	124 ± 16	115 ± 15	112 ± 16
Speed	225 ± 41	172 ± 19	143 ± 16	131 ± 17	123 ± 17	117 ± 20
High speed distance ($m.min^{-1}$)						
Match	101 ± 41	57 ± 23	36 ± 15	27 ± 11	23 ± 10	21 ± 9
Intensity	68 ± 38	40 ± 24	24 ± 15	19 ± 12	15 ± 10	14 ± 8
Volume	86 ± 39	53 ± 28	34 ± 21	27 ± 18	22 ± 14	18 ± 11
Speed	131 ± 37	99 ± 5*,#	71 ± 10*,#	55 ± 10*	42 ± 8*	35 ± 9*
Mean Acceleration ($m.s^{-2}$)						
Match	0.94 ± 0.13	0.74 ± 0.10	0.58 ± 0.08	0.53 ± 0.07	0.49 ± 0.08	0.46 ± 0.08
Intensity	0.90 ± 0.10	0.74 ± 0.09	0.58 ± 0.08	0.53 ± 0.07	0.49 ± 0.07	0.47 ± 0.06
Volume	0.91 ± 0.11	0.73 ± 0.09	0.60 ± 0.07	0.53 ± 0.06	0.49 ± 0.06	0.49 ± 0.06
Speed	1.00 ± 0.14	0.74 ± 0.07	0.65 ± 0.07	0.59 ± 0.07	0.55 ± 0.06	0.53 ± 0.05

Note: *, §, # and % designate practically meaningful differences (> 75% likelihood of a moderate or greater effect) from match, quality, volume and speed type training respectively.

Supplementary Material 2

Procedures for collection of data describing the physical performance characteristics of the participant group.

Participants

Twenty-two players representing an international rugby sevens team that competed in the Rugby Europe Trophy competition between 2017 and 2019 were included in the study. Players were informed of the study procedures and provided written informed consent. Ethical approval was granted by the Local Research Ethics Committee of Leeds Beckett University and the recommendations of the Declaration of Helsinki were respected. The physical attributes of players at this level of competition have not been previously reported and therefore a broad assessment of physical characteristics was conducted.

Testing procedure

Testing batteries were completed over the course of weekend training camps. Participants were instructed to rest for a full 24 hours before attending a training camp. Typically, jump testing followed by strength tests (1RM back squat and bench press) were completed on the first morning of the camp prior to any other training taking place. Following jump and strength testing, players completed an on field training session of 60 minutes in duration. Players then rested for at least 2 hours (during which time they ate lunch) before completing the sprint test protocol. Players then completed two more on field training sessions during the afternoon before resting over night. The bronco run was completed as the first activity on day two of the camp following a thorough warm up. Players then completed two further training sessions. As reflects the ecological nature of this testing battery adjustments to this protocol were necessitated by aspects such as weather, access to appropriate facilities and player fatigue. Despite this all players completed the test battery on multiple occasions. Supplementary Table 1 presents the mean of the best scores for all players across the three season observation period.

Strength

1 repetition maximum (1RM) strength for back squat and bench press were determined according to the National Strength and Conditioning Association's 1RM Testing Protocol (Haff & Triplett, 2015). Participants completed submaximal repetitions of each exercise at approximately 50–80% 1RM to serve as both warm-up and determination of 1RM load. With each exercise, subjects were then given 6 attempts, with progressively increasing load to achieve 1RM. 3 – 5 minutes rest was used in between each attempt. Both test protocols were completed using a 2.13m (7ft) Olympic bar and free weights. Participants were required to back squat until the top of the thigh was parallel with the ground, which was visually determined by the lead researcher. Players then had to return to a standing position with adequate technique to record a 1-RM score. For the bench press, athletes lowered the barbell to touch the chest and then pushed the barbell until elbows were locked out while keeping the head, upper back and buttocks on the bench and feet firmly planted on the floor. The largest successful weight achieved in each exercise was recorded.

Speed

10 meter and 40 meter sprint times were measured using a single beam photocell timing system (Brower timing systems, IR Emit, USA) on a grass rugby field with gates positioned at 10 & 40 meters. Players wore rugby boots during testing. Following a standardized warm-up consisting of light jogging, dynamic stretches, and submaximal sprint efforts, participants performed 2 maximal sprint efforts, from a start point of 0.5 m behind the first timing gate with 3 minutes passive rest between each attempt. The best split time over the two attempts was recorded for analysis. The reliability of this method has previously been determined as acceptable (CV for 10m and 40 = 3.1% and 1.3% respectively) (Darrall-Jones et al., 2015). Momentum was calculated by multiplying 10 meter sprint velocity by body mass.

Power

Counter movement jump (CMJ) height was assessed using the MyJump 2 (Version 1.0.11) smart device application, which measures jump height using flight time determined using the high-speed camera contained within the device (iPhone SE, iOS 12.4.1, camera resolution 1080p/60fps). The MyJump application has been shown to be appropriately valid (ICC = 0.997) and reliable (CV = 3.4%) for the determination of jump height (Balsalobre-Fernandez et al., 2015). CMJ tests were conducted as per the manufacturer instructions (Balsalobre-Fernandez et al., 2015). Players were given three opportunities to complete the test, with the best performance recorded. Attempts were separated by 60 seconds of passive rest. Peak power and relative peak power were calculated from jump height according to the methods of Sayers et al., (1999) (Sayers et al., 1999).

Aerobic Capacity

Aerobic capacity was assessed as the time to complete the 1 200 m shuttle run (Bronco) test (Kelly et al., 2014). The validity of this test for rugby athletes has been assessed against both the 30-15 intermittent fitness test (ICC = 0.73)(Kelly & Wood, 2013), and the yo-yo intermittent recovery level 1 test (ICC = 0.87) (Deuchrass et al., 2019). The test has appropriate reliability (TE = 2.4%) (7).

Supplementary Table 1: Physical performance characteristics of players representing an international rugby sevens team participating in the Rugby Europe trophy competition.

	All players (n = 22)	*Forwards (n = 10)*	*Backs (n = 12)*	*p-value*	*Effect size, ±95%CI*
Body mass (kg)	87.0 ± 7.2	91.6 ± 4.0*#	83.1 ± 7.1	0.002	1.07, ±0.65
1RM squat (kg)	141 ± 18	146 ± 20	137 ± 16	0.312	0.46, ±0.97
1RM bench press (kg)	108 ± 14	114 ± 16	104 ± 12	0.139	0.66, ±0.90
10m sprint (s)	1.82 ± 0.08	1.86 ± 0.09	1.80 ± 0.07	0.161	0.73, ±1.08
40m sprint (s)	5.45 ± 0.21	5.56 ± 0.16*	5.36 ± 0.20	0.046	0.87, ±0.86
Momentum ($kg.m^{-1}.s^{-1}$)	472 ± 40	486 ± 26	462 ± 47	0.217	0.47, ±0.76
Counter movement jump (cm)	40.9 ± 4.8	38.8 ± 2.8	42.8 ± 5.5	0.121	0.66, ±0.87
Peak power (Watt)	4394 ± 359	44.9 ± 302	4373 ± 425	0.822	0.11, ±0.93
Relative peak power ($Watt.kg^{-1}$)	50.3 ± 3.9	48.5 ±1.8	52.2 ± 4.7	0.124	0.69, ±0.84
Bronco Run (s)	297 ± 11	300 ± 13	295 ± 9	0.406	0.41, ±1.03

Note: * indicates a significant difference between backs and forwards ($p < 0.05$) (independent samples t-test). # indicates that there is a greater that 75% likelihood that the differences observed were practically meaningful at an effect size threshold of 0.6 (moderate). Effect size represents the standardized difference between forwards and backs with 95% confidence intervals.

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