GPS comparison of training activities and game demands of professional rugby union

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Abstract

Closely matching training session exertions with actual match play intensities ensures players are physically prepared for competition. The movement patterns of four typical rugby union training activities (traditional endurance, high-intensity interval, game based and skills training) were compared with match play using global positioning systems (GPS). The degree of difference from match play was determined by calculating Cohen's effect size statistic. Training activities for players in different positions (tight forward, loose forward, scrumhalf, inside back and outside back) were similarly assessed. Movement patterns were measured as relative distance, distance walking (0-2m.s^{-1}), jogging (2-4m.s^{-1}), striding (4-6m.s^{-1}) and sprinting (>6m.s^{-1}), and sprint and acceleration (>2.75m.s^{-2}) frequency. Overall, high-intensity interval training was the most similar to match play, and could be adopted as a primary training activity. Game based training failed to meet match intensity in all positions (Effect size (ES) = medium to large)). If game based training is used as the primary training activity, supplementary training is required to ensure players are adequately prepared for match demands.

Introduction

The principle of specificity of training states that maximum training benefits will be gained when the training stimulus closely matches the movement and physiological demands of the sport[1,2]. To this end, time motion analysis is of great value to sports scientists and conditioning coaches in the production of game specific training programmes[3].

Rugby union has benefitted from time motion analysis, with first video based[1,4-7] and then GPS technology[8-13] improving the understanding of the physical demands of the game. Rugby union is played primarily at low speeds (walking and jogging), but interspersed with high-intensity periods where players sprint and are involved in physical collisions[1,4-7,12,13]. There are significant differences in the physical requirements of different playing positions. For example scrumhalves cover the most total distance, and tight forwards the least, outside backs attain the highest speeds, but also spend the most time walking[12].

Based on this information, a number of researchers have called for increased specialization of rugby union training programmes to ensure that these adequately match positional demands[1,5,6].

Rugby union coaches typically utilize a combination of training methodologies to prepare players for competition. Common practices include the use of traditional endurance conditioning (TEC) training (high-intensity running without the ball), high-intensity interval training (HIIT) (short duration repeated high-intensity efforts interspersed with low-intensity recovery periods), game based training (GBT) and game skills training (match related drills that simulate game scenarios)[14]. However, the typical physical demands of these training practices, and how well they relate to actual in-match movement demands is largely undetermined.

Within rugby union, there has been a movement toward game based training as a method of player preparation, due to the ability to improve physical fitness and skill factors simultaneously[15,16]. Research in other team sports has indicated that game based training generally replicates the physical demands of elite competition[17], but may fall short of replicating the most high-intensity periods of match play[17,18]. Similarly, it is unclear how well other training activities (traditional endurance, high-intensity interval and skills training) prepare players for the demands of match play. Only one research study has previously compared the demands of rugby union training and matches[19], showing that rugby training did not meet the demands of match play in adolescent players. No research exists comparing training and match demands in senior professional players.

While specificity of training is desirable, it may be unrealistic to expect training sessions to regularly reproduce match intensities and loads[20]. Increased training loads have been associated with increased injury rates in other contact team sports[21]. As such, the need to balance training loads required to maintain or improve performance with injury risk requires careful consideration. In addition, the diversity of physical attributes[22] and movement patterns[1,6,12] among different positions in rugby union, will result in different physical loads experienced among players from different positions participating the same training session. A one-size fits all approach to training is unlikely to ellicit optimal adaptations from players across a range of positions.

The aim of this study was to determine the specificity of typical training activities in rugby union, by comparison with the demands of match play. The specificity of each training activity for players in different positional groups was assessed. Knowledge of the movement demands of various training activities, and an understanding of how these may differ from actual match demands for players in different positions will provide valuable information to coaches for prescribing position specific training plans.

Methods

Experimental approach to the problem

A prospective, observational, longitudinal study was conducted to determine the movement demands of typical training activities of a professional rugby union team. Players' movement patterns were observed during training sessions and then compared with the match-play demands of professional competition.

Subjects

Fifty-three male rugby union players (Age 25 ± 3 years, stature 186 ± 7 cm and body mass 101.5 ± 12.2 kg), representing a professional South African rugby team, volunteered to participate in this study between 2011 and 2013. All participants received a clear explanation of the study, including the risks and benefits of participation, and written consent was obtained. The ethical review board of the University of Johannesburg approved all experimental procedures, and the study was conducted in accordance with the Declaration of Helsinki[23]. Players were divided into positional groups; tight forwards (props and locks), loose forwards (hookers, flanks and eighth men), scrumhalves, inside backs (flyhalves and centres) and outside backs (wings and fullbacks); based on previously determined similarities in positional demands[1,6]. The descriptive characteristics of each of these positional groups are detailed in table 1. Results are only reported for players who were free of illness or injury during training and match participation.

Table 1 – Descriptive characteristics of the 5 positional groups of professional rugby union players

	N	Age (years)	Stature (m)	Body Mass (kg)	Observations	
					Training	**Match**
Tight forwards	15	25 ± 4	1.91 ± 0.07	114.6 ± 7.5	157	30
Loose forwards	16	24 ± 3	1.86 ± 0.05	101.4 ± 6.4	200	23
Scrumhalves	5	23 ± 2	1.77 ± 0.01	84.9 ± 1.3	53	8
Inside backs	11	23 ± 3	1.83 ± 0.05	93.4 ± 6.2	106	12
Outside backs	11	24 ± 4	1.84 ± 0.05	91.7 ± 4.6	114	29

Experimental procedure

Players were monitored during 96 training sessions over a 25-month period from September 2011 to October 2013 that included two pre-season and two in-season training phases. Training sessions were classified in consultation with the team strength and conditioning coach into one of four types of training activity, indicated in table 2. Preseason training phases included more traditional endurance conditioning and high-intensity interval type sessions, while in-season phases were dominated by skills training sessions. All training activities were performed in both pre-season and in-season phases, and the movement profile of these activities was similar in different phases of the season. Unit specific skill sessions such as lineouts and scrums, as well as captain’s run and recovery sessions were excluded from the analysis.

Training session activities were compared to data from 24 matches played by the same team during the 2013 rugby season. Match files were “cleaned“ to remove the half time break and any other time spent off the field from each observation. The results of these match play analyses have previously been reported in detail, describing the variations in movement, impact and sprint variables among different positions[13]. In the current research study these data will be used to make magnitude based inferences regarding the degree to which common training activities differ from match demands. Any training or match observation < 30 minutes in duration was excluded from the analysis.

Table 2 – Characteristics and number of observations of the four training activities examined in this study.

Training Activity	Activity Description	Observations (N)
Traditional endurance conditioning (TEC)	Maximal aerobic speed and interval running activity on a track without the ball. Individual activity bouts ranged between 3-15 minutes. Work to rest ratios ranged from 2:1 to 1:3	96 during 8 training sessions
High-intensity interval training (HIIT)	Short burst high speed activity bouts without the ball of between 20 sec and 2.5 minutes, generally including a number of changes of direction and acceleration and deceleration components. Work to rest ratios ranged from 1:1 to 1:10	125 during 13 training sessions
Game based training (GBT)	Training games designed to improve physical qualities, skills and decision making. Pitch size and player numbers were varied to effect training intensity.	86 during 8 training sessions
Skills training (ST)	Training sessions in which match specific skill components are practiced to develop proficiency under pressure and coordinated patterns of play.	324 during 67 training sessions

Training and game play movement patterns were assessed through the use of portable global positioning devices (SPI Pro, GPSports, Canberra), sampling at a rate of 5Hz. The validity and reliability of GPS is acceptable for use in team sports environments[24-26], although caution is advised when interpreting very high speed running (>5m.s^{-1}) as this is subject to greater variability than lower speed zones[24]. Despite this limitation, these GPS devices have been utilized in research similar to the present study in rugby sevens[27] and adolescent rugby union[19]. Players were familiarized with the use on the GPS devices in a training session before the start of the study. Devices were carried in an elasticized harness, worn beneath the training or match jersey, suspended between the players shoulder blades. The unit was switched on prior to the warm up for each session to ensure that a satellite link was established before the beginning of activity. Following each session, GPS data were downloaded to a personal computer and analysed using Team AMS software (Version 10, GPSports, Canberra, Australia).

Total distance, session duration and maximum speed attained were recorded for each training session and match. Movement data was categorized into movement speed bands corresponding to walking (0-2m.s^{-1}), jogging (2-4m.s^{-1}), striding (4-6m.s^{-1}) and sprinting (>6m.s^{-1}). Total distance and distance covered in each speed band was normalized to time spent training or in match play to account for variations in session length. Sprint and acceleration characteristics were assessed as the frequencies with which players performed sprints (>6m.s^{-1}) and maximal accelerations (>2.75m.s^{-2}) for a minimum duration of 1s. Because reports of the mean physical demands of match play are likely to underestimate the most intense matches or periods of competition[28], maximum values for all variables are reported, to allow practitioners to assess the upper range of match requirements and training activities.

Statistical Analysis

All statistical analyses were performed using SPSS analytics software (version 22, IBM.com). Descriptive statistics (Mean ± SD) are reported for most movement variables. Sprint and acceleration characteristics are reported as frequencies (1 every N ± SD minutes). Maximum values of all variables are reported to provide perspective on the most extreme demands. Differences in movement variables between training activities and match play were assessed using a one-way ANOVA. A Levene's test for homogeneity of the mean was utilised. The majority of cases were not normally distributed, and in these instances a Welch robust test of equality of means and Games-Howell *post hoc* test were applied. In the case of normally distributed data a Tukey's *post hoc* test was utilized. Statistical significance was set at $p < 0.05$. Practical significance of observed differences was determined by calculating Cohen's effect size statistic, these were calculated for each position group for all movement variables. Effect sizes were determined as the standarised mean difference from match play, meaning that negative and positive effect sizes indicate that variables or less or greater than match play variables respectively. Effect sizes of 0.2, 0.6, 1.2 and 2.0 were considered small, medium, large and very large respectively (29). 95% confidence intervals for effect sizes were calculated using a excel spreadsheet designed for this purpose (retrieved from www.cem.org/effect-size-calculator 23 Nov. 2014). Effect sizes >0.6 (medium) were considered practically meaningful in this analysis.

Results

Comparison between training activities and mean match exertion

The movement profiles of contemporary training activities, and professional match play are presented in table 3. Figure 1a and b shows the magnitude of difference from match play of the various training activities for all of the movement variables, for all players and when players are divided into their positional groups. The relative intensity (m.min^{-1}) of traditional endurance conditioning (ES = large) was higher than match play, while skills (ES = large) and game based training (ES = medium) was lower. The maximum speed attained during traditional aerobic conditioning (ES = large) was lower than in matches. There was no meaningful difference in maximal speed between matches and game based, high-intensity interval or skills training.

Players covered more distance walking during matches than during any training activity (ES = medium to very large). Traditional endurance conditioning training exceeded match requirements for jogging and striding distance (ES = medium), while skills training failed to meet match requirements in these movement bands (ES = medium to large). High-intensity interval training exceeded match requirement for striding (ES = medium), but not for any other movement category. Most training activities were able to match game intensity in the sprinting distance and sprint and acceleration frequency categories. Traditional endurance conditioning displayed meaningful differences below match play for sprint distance (ES = medium) and acceleration frequency (ES = large).

High-intensity interval training was the training activity that was most similar to match requirements overall. Only distance covered walking was significantly lower than match play (ES = very large), and striding distance exceeded match play (ES = medium). After high-intensity interval training, game based training was the next most specific activity with trivial to small differences in all movement categories except relative, walking and jogging distance (ES = medium). Traditional endurance conditioning was the training activity that was most different to match play, with medium to large differences in every movement variable, except sprint frequency. Skills training falls short of match intensity (ES = medium to large) for relative, walking, jogging, striding and sprinting distance.

Comparison between training activities and mean match exertion for different positional groups

Figure 1a and b presents comparisons of the standardized differences of movement variables from match play for each of the 5 positional groups. There are differences in the specificity of training activities to match play for each of the different positional groups. Figure 1a indicates that for tight forwards, high-intensity interval, game based training and traditional aerobic conditioning training sessions all meet or exceed match play requirements for striding, sprinting, sprint frequency and acceleration frequency. There were only small to medium differences in these parameters between match play and skills training. This indicates that the sprint and high speed running requirements of tight forwards would be satisfied during most training sessions. However, game based (ES = large) and skills (ES = very large) training did not meet match running requirements in the jogging speed zone.

Similarly, the sprint distance and sprint and acceleration frequency requirements of loose forwards (figure 1a) seem to be adequately met by all training activities. However, game based training does not reach match intensity for striding (ES = medium) and skills training falls short of match play jogging and striding distances (ES = large).

There are a number of large differences in movement patterns during training activities and match play for scrumhalves (figure 1b). Skills training does not meet match intensity in any movement category except acceleration frequency (ES = medium to very large). Game based training matched match play in maximum speed obtained for scrumhalves, but there are medium to large differences in relative, walking, striding and sprint distance and sprint and acceleration frequency. Traditional endurance conditioning exceeds match play requirement for scrumhalves in relative distance (ES = medium), jogging distance (ES = medium) and striding distance (ES = large), but falls short of the maximum speed (ES = large), sprint distance (ES = very large (4.6, not accommodated on graph)) and sprint (ES = large) and acceleration (ES = very large) frequency required. High-intensity interval training is the most specific training activity for scrumhalves with differences in most movement categories ranging from trivial to medium, but there is a very large difference in walking distance.

Table 3 – ANOVA of movement characteristics of common rugby union training activities and match play.

	Match Play	TEC	HIIT	GBT	ST
Session duration (min)	73 ± 24	53 ± 22* (Medium)	74 ± 25# (Trivial)	99 ± 19*#$ (Medium)	111 ± 28*#$% (Large)
Total distance (m)	5050 ± 1636	4479 ± 1804 (Small)	5204 ± 1805# (Trivial)	5787 ± 1212*#$ (Small)	5300 ± 1328#% (Trivial)
Relative distance ($m.min^{-1}$)	69 ± 8	92 ± 34* (Large)	71 ± 21# (Trivial)	59 ± 9*#$ (Medium)	49 ± 11*#$% (Large)
Maximum speed ($m.s^{-1}$)	8.2 ± 1.3	6.2 ± 1.8* (Large)	7.5 ± 1.6*# (Small)	8.4 ± 1.3#$ (Trivial)	7.9 ± 1.3#% (Small)
Walking distance ($m.min^{-1}$)	34 ± 5	22 ± 9* (Large)	22 ± 5* (Very large)	29 ± 5*#$ (Medium)	27 ± 5*#$ (Large)
Jogging distance ($m.min^{-1}$)	23 ± 6	44 ± 28* (Medium)	27 ± 16*# (Small)	19 ± 6*#$ (Medium)	14 ± 5*#$% (Large)
Striding distance ($m.min^{-1}$)	10 ± 4	25 ± 23* (Medium)	20 ± 14* (Medium)	9 ± 3#$ (Small)	6 ± 3*#$% (Medium)
Sprinting distance ($m.min^{-1}$)	2.4 ± 1.9	0.9 ± 2.3* (Medium)	2.4 ± 3.1# (Trivial)	2.6 ± 2.3# (Trivial)	1.4 ± 1.4*$% (Medium)
Sprint frequency	1 every 9 ± 13 min	1 every 22 ± 8 min* (Small)	1 every 12 ± 9 min (Small)	1 every 9 ± 11 min# (Trivial)	1 every 14 ± 14 min*% (Small)
Acceleration frequency	1 every 6 ± 10 min	1 every 23 ± 11 min* (Large)	1 every 7 ± 9 min# (Trivial)	1 every 6 ± 11 min# (Trivial)	1 every 7 ± 8 min# (Trivial)

TEC = traditional endurance conditioning, HIIT = high-intensity interval training, GBT = game based training and ST = skills training. Distances are reported relative to activity time due to differences in duration of match and training exposures. *,#,$ and % represent significant difference from match play, TEC, HIIT and GBT respectively ($p < 0.05$). Effect size (ES) is reported for all training activities and represents difference from match play. Relative ($m.min^{-1}$) rather than absolute distances are reported due to differences in duration of training and playing exposures.

For inside backs, game based training is a highly appropriate training activity, with only small differences from match play in every movement category except walking distance (ES = large) (Figure 1b). High-intensity interval and traditional aerobic conditioning exceed the match intensity requirements of inside backs by exceeding the amount of jogging (ES = medium) and striding (ES = medium to large) required. Traditional aerobic conditioning fails to meet maximum speed, sprint distance and sprint and acceleration frequency requirements for inside backs (ES = medium to large). Skills training falls short of match intensity (ES = medium to very large) in every parameter except acceleration frequency.

No training activity satisfies match demands of outside backs for maximum speed (figure 1b). Game based training is a largely specific activity for outside backs as it meets match play requirements in most movement categories, except relative and walking distance and maximum speed (ES = small). Skills training displays medium sizes deficits in all movement categories except sprint and acceleration frequency (ES = medium). High-intensity interval training exceeds match play requirements for outside backs in relative, jogging and striding (ES = medium to large) distance, but also demonstrates large to very large deficits in maximum speed and acceleration frequency.

<u>Comparison of maximum values for training activities and match play</u>

Table 4 presents the maximum observed value for each movement variable, and the percentage difference from average match performance for each position group. These values provide a perspective on what the extreme range of physical load experienced during match play might be. The detail presented in the table indicates that distance covered walking and jogging may be increase by a third in the most intense matches, but that high-intensity running distance (striding and sprinting) can be increased up to 75% and 280% respectively. The factor that showed the highest deviation from match averages was sprint and acceleration frequencies. These showed that in the most intense matches sprint and acceleration exposure can be up to 250% greater than the average.

Table 4 – Maximum observed values for movement variables during match play and percentage difference from average match play values for five positional groups. Values are reported as max. (% diff.) The maximum value overall is highlighted in bold.

	Tight Forwards	Loose Forwards	Scrum-halves	Inside Backs	Outside Backs
Relative distance ($m.min^{-1}$)	81 (15%)	86 (25%)	99 (23%)	86 (26%)	78 (17%)
Maximum speed ($m.s^{-1}$)	9.9 (36%)	10.8 (35%)	9.2 (15%)	9.4 (18%)	**11.3 (20%)**
Walking distance ($m.min^{-1}$)	**45 (33%)**	**45 (47%)**	41 (15%)	43 (17%)	**41** (16%)
Jogging distance ($m.min^{-1}$)	**39 (35%)**	33 (37%)	33 (31%)	28 (36%)	25 (41%)
Striding distance ($m.min^{-1}$)	11 (59%)	20 (75%)	**25 (53%)**	14 (56%)	15 (71%)
Sprinting distance ($m.min^{-1}$)	1.5 (198%)	4.8 (128%)	5.8 (85%)	**9.1 (276%)**	7.3 (87%)
Sprint frequency	1 every 10 minutes (246%)	1 every 4 minutes (175%)	1 every 4 minutes (69%)	**1 every 3 minutes (213%)**	1 every 4 minutes (73%)
Acceleration frequency	1 every 7 minutes (86%)	1 every 3 minutes (159%)	1 every 3 minutes (41%)	**1 every 2 minutes (185%)**	1 every 3 minutes (63%)

Distances are reported relative to playing time due to differences in duration of match exposures.

Table 5 presents the maximum observed values for all movement variables during training activities. These maximum values indicate that it is possible to simulate even the most extreme match intensities within the training environment. Traditional endurance conditioning was the training activity that produced the highest values in most movement variables, indicating that this training activity may have value in training players for matches with the highest intensity.

Discussion

The purpose of any sport specific physical training programme should be to optimally prepare players for the demands of competition. This is achieved by maximizing training specificity through the manipulation of training activities to simulate or exceed the skill and physical demands of competitive match play. This study is the first to compare the movement characteristics of contemporary training activities in professional rugby union with match play demands using GPS technology. Based on the widely acknowledged differences in movement patterns of players in different positions[1,5,6,12,13], this study also assessed the appropriateness of different training activities for players in different positions. A major finding of this study was the substantial differences in the typical movement patterns of players involved in match play and during training activities. The results of this study can be used by conditioning coaches to develop position specific training programmes for professional rugby union players.

Table 5 – Maximum observed values for movement variables during training activities and percentage difference from maximum match value.

	TEC	HIIT	GBT	ST
Relative distance (m.min^{-1})	**189 (91%)**	116 (17%)	87 (-12%)	80 (-19%)
Maximum speed (m.s^{-1})	11.6 (3%)	11.4 (1%)	11.3 (0%)	**12.1 (7%)**
Walking distance (m.min^{-1})	**50 (11%)**	45 (0%)	42 (-7%)	39 (-13%)
Jogging distance (m.min^{-1})	**106 (172%)**	80 (105%)	57 (46%)	34 (-13%)
Striding distance (m.min^{-1})	**91 (264%)**	69 (176%)	15 (-40%)	25 (0%)
Sprinting distance (m.min^{-1})	**16 (76%)**	13 (43%)	10 (10%)	8 (-12%)
Sprint frequency	**1 every 1.5 min (100%)**	1 every 2.5 min (20%)	1 every 2.5 min (20%)	1 every 2.5 min (20%)
Acceleration frequency	1 every 2 min (0%)	1 every 2 min (0%)	1 every 2.5 min (-20%)	**1 every 1 min (100%)**

TEC = traditional endurance conditioning, HIIT = high-intensity interval training, GBT = game based training and ST = skills training. Relative (m.min^{-1}) rather than absolute distances are reported due to differences in duration of training exposures. Percentage difference from match maximums are presented in brackets. The highest value in each movement category is highlighted in bold.

Players walked more during match play than during any training activity (ES = medium to very large) (Table 3). This finding likely reflects the intermittent nature of rugby union match play, with regular stoppages to contest first phase possession. During these stops in play, players typically walk to the following phase of play, allowing an opportunity for active recovery to take place. World Rugby game analysis reports suggest that the ball is only in play between 42 and 46% of the time during a rugby match[30]. It seems that players are afforded more opportunity to walk during match play than during training sessions, which may assist players in maintaining intensity throughout the game when the ball is in play. Coaches and trainers should be aware that reduced walking distance during training limits opportunities for active recovery, and may make it difficult for players to perform the most high-intensity activities optimally.

High-intensity interval training was shown to be the training activity that is most specific to match play, with differences only present in the walking (ES = very large) and striding (ES = medium) movement categories (Table 3). High intensity interval training met or exceeded match play requirements for tight and loose forwards in all movement categories except walking (ES = large to very large), and is highly specific for these positions (Figure 1a). High-intensity interval training is the most specific training activity for scrumhalves, with small to medium differences from match play in most movement categories (figure 1b), but didn't satisfy scrumhalves match requirements for walking and jogging distance (ES = large to very large). The maximum speed and sprint and acceleration frequency requirements of inside and outside backs are not met by high intensity interval training (ES = small to large) (figure 1b).

Game based training was specific to match requirements in terms of speed and acceleration variables (trivial to small differences in maximum speed, sprint distance, sprint and acceleration frequency) (Table 3). This result agrees with the findings of Gamble[15] and Kennett[16] which show that game based training is an effective method of training for rugby union. However, a medium sized difference in relative distance covered, which resulted from differences in walking and jogging distances, between game based training and match play, indicates that game based training does not replicate match intensities. Gabbett et al. (2010) has also previously shown that game based training does not replicate match intensities.

When compared with individual position requirements, game based training was shown to be appropriate in some positions, but fell short of replicating match intensity for others. Game based training does not meet the relative distance and jogging requirements of tight forwards, or the relative distance and striding requirements of loose forwards (Figure 1a). This indicates that if game based training were used and the only form of conditioning for these position groups, they would be under prepared for match play. Game based training is a non-specific activity for scrumhalves as it does not meet match requirements for any movement category except maximum speed (Figure 1b). Game based training is a highly appropriate form of training for outside backs as it meets match play requirements in all movement categories except relative distance, maximum speed and walking (ES = medium). For inside backs, game based training was mostly specific, but falls short of match requirements for relative, walking and jogging distance (ES = medium to very large). Coaches and trainers should therefore be wary of the one-size fits all approach. While game based training is an effective training strategy, particularly in light of the potential to improve skill components in conjunction with physical conditioning[15,16], coaches and trainers must be aware of the need to supplement game based training with other training activities that complement the specific needs of players in different positions. Alternatively, clever manipulation of training variables within game based training may make it possible to better simulate match demands for all positions[16], but these would need to be monitored carefully.

Options available to coaches to supplement game based training for position specific training are traditional endurance conditioning and high-intensity interval training. Traditional endurance conditioning exceeds match intensity in relative (ES = large), jogging (ES = medium) and striding (ES = medium) distance, but falls short for maximum speed (ES = large), sprint distance (ES = medium) and acceleration frequency (ES = large) (Table 3). High-intensity interval training is effective for achieving adequate jogging, striding and sprinting intensities during training. The use of traditional endurance conditioning or high-intensity interval in combination with game based training would ensure that players are able to sustain match running intensities (figure 1a).

Skills training sessions had the lowest mean intensity of all training activities, with large to very large differences from match play for all position groups. This reduction in relative distance covered can be explained by medium to very large differences in the jogging and striding speed zones (figure 1a and b). There were similarities between skills training and match play in maximum speed, sprint distance and sprint and acceleration frequency for forwards (tight forwards and loose forwards), but this was not apparent for back (scrumhalf, inside back, outside back) positions.

Skills training was the most regularly prescribed training activity over the course of this study, and players participated in skills training sessions at least twice every week. Coaches should note that participation in skills training only will not adequately prepare for the physical demands of match play. However, it is not desirable to reproduce match intensity in every training session[20], as this would interfere with the recovery process and could lead to over-training[21]. Training should be targeted to develop all of the physical characteristics associated with success in rugby union[31], not simply repetitively replicate game demands. The reduced intensity of skills training therefore serves a practical purpose in creating an environment where workloads can be sustained through training sessions to allow gains in other areas such as tactical awareness and skill development.

An additional finding of this study is that no training activity studied here managed to simulate the maximum speed requirements of outside backs during match play (ES = medium to very large) (figure 1b). This indicates that outside backs should be regularly exposed to maximum speed training to maintain and develop this important attribute for performance. In addition, none of the training activities studied here adequately prepare scrumhalves for match play. These findings once again illustrate the uniqueness of the scrumhalf position within rugby union[6]. Scrumhalves would be best served by training with a combination of game based training, traditional aerobic conditioning and high-intensity interval training, but more position specific training protocols should be developed.

A unique aspect of this study, is the reporting of maximum observed values during match play (Table 4) and during various training activities (Table 5). These values provide a perspective on what the extreme range of physical load experienced during match play might be. This analysis revealed that while relative total distance, and distance covered walking and jogging may be increase by approximately a third in the most intense matches, high-intensity running distance (striding and sprinting) can be increased up to 250% (Table 4). This indicates that players should regularly be exposed to high-intensity running training, to allow them to cope with the extreme demands of match play should the need arise.

The results of this research study indicate that it is possible to meet and even exceed the movement characteristics of professional rugby union match play during training (Table 5). This result is in contrast with previous research in adolescent rugby union[19], international rugby sevens[27], professional rugby league[28], Australian rules football[20] and elite women's field hockey[18], which all showed that contemporary training practices failed to replicate match demands. The low ball-in-play time of professional rugby union (42-46%)[30], presumably lowers overall match intensity making possible to achieve these intensities during training. Attention should be paid to the high-intensity periods of play that occur between stoppages and ensuring that players are conditioned to perform at an adequate level during these repeated high-intensity bouts.

Another important consideration is that peak values of movement characteristics measured during training were similar to or exceeded the most extreme match demands. This indicates that some training sessions could be as demanding, or more demanding than matches. Caution should be taken when prescribing training sessions to ensure that the training load is not too demanding. This is especially important in situations where players in different positions complete the same training session but may experience vastly different physical loads. Training sessions should be carefully monitored (with GPS or other methods) to ensure that the desired intensities and training objectives are achieved.

A limitation of this study is the inability to accurately measure contact demands of training with the GPS devices used[32]. Physical contact reduces both total running distance[33] and high-intensity running during game based activities[34]. Since rugby union players frequently engage in physical contact (tackling, rucking, scrumming etc.) during match play, the influence of these contact factors on fatigue cannot be ignored[6,35]. Research from rugby league indicates that exposure to contact training is an important factor for success during match play[36]. Players were regularly exposed to physical contact during skills training sessions in this study, but not during traditional endurance conditioning and high-intensity interval activities. During game based training players were occasionally exposed to light contact. No attempt was made to quantify the effects of contact on movement characteristics of the various training activities, but exposure to physical contact may have affected movement characteristics during skills training. Improvement in the ability of GPS devices to monitor contact involvements will further improve our understanding of the effects of contact on training load.

A further limitation of this study was that all data were collected from a single team. As such, the results may be influenced by the particular playing personnel, team style of training and match tactics and may not be generalizable to other teams. Further research on a more heterogeneous sample is required to verify these findings.

The findings of this study illustrate the potential to improve the efficacy of training practices among professional rugby union players. Results of training programmes can be improved by increasing the specificity of training practices for players in different positions, thereby improving "return on investment" for time spent training. High training volumes are associated with increased injury risk in contact sports[21] and may not confer any additional performance advantage[37]. Therefore improved training efficiency will maintain and possibly improve physical performance while reducing risks associated with high training volumes.

Conclusion

Game based training offers the most specific form of general conditioning for professional rugby union players, but does not satisfy all of the specific requirements of players in different positions. Particular attention should be paid to the specific physical requirements of players from different positions to ensure that they receive adequate training stimulus. A one-size fits all approach is unlikely to achieve optimum results. Training sessions should be carefully monitored to ensure that the desired training intensity or objective is achieved.

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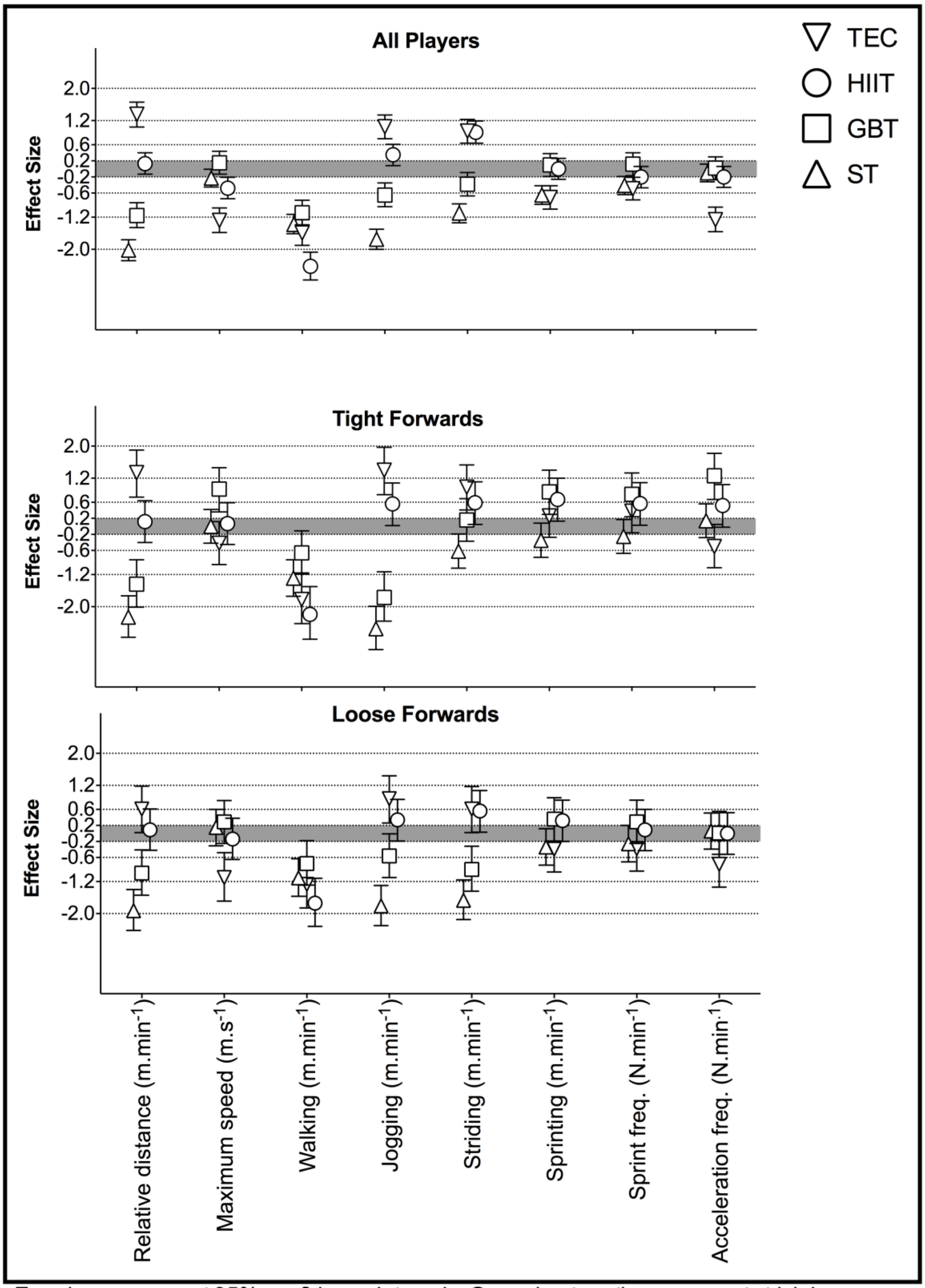
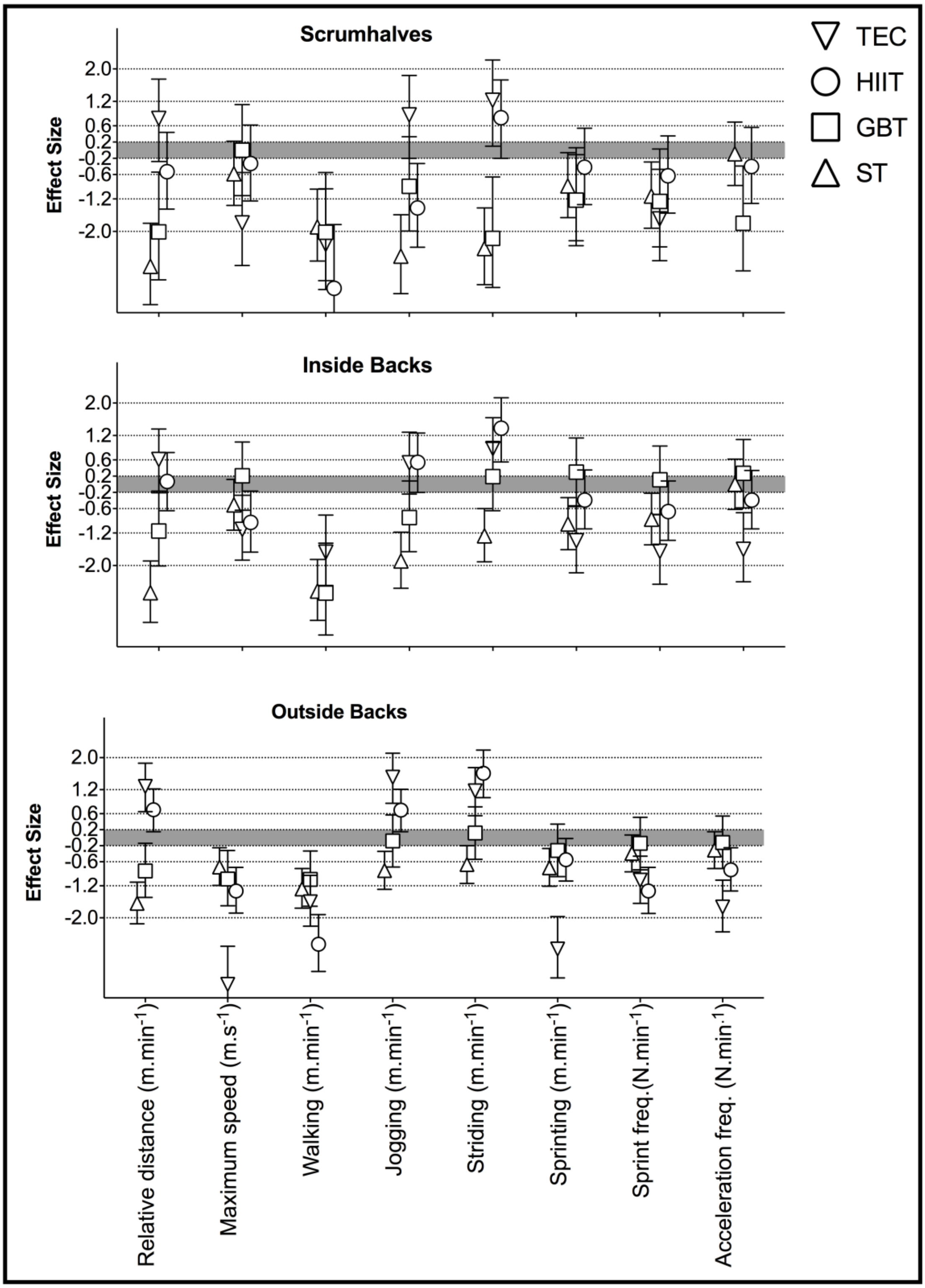


Error bars represent 95% confidence intervals. Greyed out section represents trivial differences. TEC = Traditional endurance conditioning, HIIT = high-intensity interval training, GBT = game based training and ST = skills training. Distances are reported relative to activity time due to differences in duration of match and training exposures.

Figure 1a – Comparison of standardized differences in movement characteristics between training activities and professional rugby union match play for all players, tight forwards and loose forwards.



Error bars represent 95% confidence intervals. Greyed out section represents trivial differences. TEC = Traditional endurance conditioning, HIIT = high-intensity interval training, GBT = game based training and ST = skills training. Distances are reported relative to activity time due to differences in duration of match and training exposures.

Figure 1b – Comparison of standardized differences in movement characteristics between training activities and professional rugby union match play for scrumhalves, inside backs and outside backs.