Manuscript title: Influence of game design, physical demands and skill involvement on the subjective task load associated with various small-sided games among elite junior rugby league players.

Abstract

Purpose: To determine if small-sided games (SSGs) could be designed to target specific task loads using the NASA task load index (NASA-TLX) as well as reporting the influence of the physical and technical demands. *Methods:* Using a within-session, repeated measures design, 26 junior rugby league players completed five SSGs focused on physical, technical, temporal, cognitive and frustration task loads. NASA-TLX responses were evaluated after each game; the physical demands were recorded using microtechnology; and skill involvement recorded using video analysis. ***Results:*** In each SSG, the task load emphasised (e.g. physical load/physical game) emerged with a higher score than the other loads and SSGs. The physical demands were lowest during the physical game (ES = -3.11 to 3.50) and elicited greater defensive involvements (ES = 0.12 to 3.19). The highest physical demands and attacking involvements were observed during the temporal game. Lower-intensity activities were generally negatively associated with physical, performance, temporal and total load (η^2 = -0.07 to -0.43) but positively associated with technical, effort, cognitive and frustration (η^2 = 0.01 to 0.33). Distance covered in total and at higher speeds were positively associated with physical, effort, performance, total load (η^2 = 0.18 to 0.65), and negatively associated with technical, frustration and cognitive load (η^2 = -0.10 to -0.36). Attacking and defensive involvements generally increased the respective task loads (η^2 = 0.03 to 0.41). ***Conclusion:*** Coaches and sport scientists can design SSGs specifically targeted at subjective task loads in a sport-specific manner and through manipulation of the physical and technical demands.

Key words: GPS, NASA-TLX, technical demands, mental demands, training, contact sports

Introduction

The demands of rugby league training and match-play are well-documented within the literature[1] and necessitate that rugby league players possess well-developed physical characteristics.[2] Rugby league players also require high levels of technical skill and decision-making capability in order to achieve the highest playing standards and may influence match-play statistics (i.e. tries scored and conceded).[3] As such, coaches are required to consider the most effective training methods to develop key sporting characteristics concurrently throughout a rugby league season.

The use of small-sided games (SSG) has emerged as a possible method for eliciting physiological adaptation in the context of a recognisable sport that contains movements and technical skills closely reflecting match-play.[4-6] One of the key benefits associated with SSGs is the ecological validity of training,[7] increased motivation[8] and they enable coaches to deliver technical and tactical advice whilst ensuring sufficient aerobic conditioning.[9] SSGs allow coaches and sport scientists to alter the constraints of the game (i.e. pitch size, player number, rules, recovery time etc.) to influence the internal (i.e. heart rate) or external (i.e. distance covered) responses.[8,9,10] For example, Foster et al.[11] compared the heart rate responses when altering the player numbers (4v4 *cf.* 6v6) and playing area (small *cf.* medium *cf.* large) in a junior rugby league players. Further, Gabbett et al.[12] observed no difference in all measures of skill performance during SSGs on a small and large field, or between junior and senior players, though when using an 'on and off-side' format, a greater number of involvement, effective passes, and total passes was observed in the ‘off-side’ condition.[13] Further research exploring the internal, external and technical responses to a wider range of game formats, including those specifically designed to focus on essential technical skills or task loads, could provide useful insight for coaches using and designing SSGs.

Whilst our understanding of the internal and external responses has increased, it is essential we seek to understand the multidimensional loads associated with SSGs. Mullen et al.[14] explored the influence of game-related and contextual factors on the task loads reported during rugby league match-play using the NASA task load index (NASA-TLX). The results of this study highlight the importance of considering the various demands experienced by players as a consequence of the task (i.e. tackling during a game), the environment (i.e. home/away) and players skills, behaviours and perceptions.[15] For example, Mullen et al.[14] reported how playing position can influence the temporal demands of match play. Further, an increase in cognitive load was associated with a greater number of technical errors, tackles, accelerations and time spent at high metabolic power.[14] Mullen et al.[14] also noted associations between the number of errors during a match and higher perceptions of frustration which may be interpreted in two ways.[14] As a result of fatigue experience during training and/or match-play, a greater number of errors may occur, so increasing distraction and frustration.[16] Equally, distraction may cause greater errors so increasing frustration and potentially fatigue. Either way, this observation is likely to have important implications on the outcome of a match and discriminate between playing standards.[17] Emphasis on task loads such as frustration during SSGs could support players management of distractions. To date, few studies have explored specific task load indices within the context of the SSGs. Gabbett et al.[13] reported greater cognitive load during an ‘on-side’ format of the game compared to ‘off-side’, whilst in soccer players, Badin, et al.[18] noted how mental fatigue impaired both offensive and defensive technical performance. Such findings raise important questions regarding the possibility of using SSGs to target specific task loads and develop player’s ability to tolerate them.

Accordingly, the aims of this study were to 1) determine if SSGs could be designed to target specific task load domains using the NASA-TLX, 2) quantify the subjective task loads across various SSGs and 3) determine the association between physical and technical demands with each task load.

Methods

Participants and study design

With institutional ethics approval, 26 male elite junior rugby league players were recruited from a single professional club (age 15.3 ± 0.5 y). All players completed five small-sided games during a single session using a repeated measure study design. All games were completed on a natural grass surface with players wearing their playing kit and boots. Players were split into two groups ($n = 12$ and $n = 14$) for feasibility purposes including management of the games and coach availability. Written informed consent was provided by all players (> 16 years) whilst assent from the player and parental consent was provided for those aged 14 to 16 years.

Methodology

With input from expert coaches and sport scientists, five individual SSGs were designed. Each was designed to target a task load on the NASA-TLX questionnaire, emphasising physical, cognitive, technical, temporal and frustration loads. Games were completed in a randomised order with group 1 completing them as physical, temporal, frustration, cognitive and technical, whilst group 2 completed them in the order of technical, physical, cognitive, frustration and temporal. To minimise the influence of fatigue, 5-minute games were interspersed with a 5-minute recovery period. All players were actively engaged in all SSGs with the pitch size adjusted for group size (mean = 72 m^2 per player).

Small-sided games

To emphasise physical load of the NASA-TLX, the game included full contact[19,20] and three 'plays' of the ball before turnover. The inclusion of 3 'plays' was thought to increase the physical load through encouragement to move play forward as much as possible, which increases the number of physical contacts in the 5-minute period. A 5 m retreat followed each tackle.

Emphasis on cognitive load from the NASA-TLX was achieve through the inclusion of two key rules that the players were not aware of, thus requiring a high level of cognition to detect, test and confirm the rule. The rules included were that only when two players simultaneously touched an attacker did the touch count advance and if the ball touched the chest of the catcher the ball was turned over to the defending team. Players completed 3 'plays' before the ball was turned over and a 5 m retreat was used. Contact in this game was limited to touch.

To emphasise frustration load on the NASA-TLX, we encouraged incorrect calls by the official, penalising players for forward passes, offside, ‘knock on’ as well as varying retreat distances and tackle counts. The players completed 4 ‘plays’ and a 5-m retreat were used with contact limited to touch. Incorrect calls by an official have been shown to increase frustration.[21]

Emphasis on temporal load on the NASA-TLX was achieved through an ‘off-side’ version of rugby where players were not permitted to move whilst in possession of the ball and only had 3-seconds to make a pass. Exceeding this 3-s period or dropping the ball resulted in a turnover.

Technical load on the NASA-TLX was emphasised using a game where players were required to ‘touch’ the opposition once in possession of the ball. Player were not able to move whilst in possession of the ball. This placed emphasis on the speed, accuracy and number of passes required between players.

External, technical perceptual loads

To quantify the external loads, a 10 Hz microtechnology device fitted with a 100 Hz triaxial accelerometer, gyroscope and magnetometer (Otimeye S5, Catapult Innovations, Melbourne, Australia) was worn by each player with the device positioned in a custom-made vest with the unit positioned between the participant's scapulae. To exclude intra-device variability, participants wore the same unit throughout all SSGs. Data were downloaded using Openfield (Catapult Sports, Melbourne, Australia) and analyzed for relative total and very low (0-1 $m \cdot s^{-1}$), low (1-3 $m \cdot s^{-1}$), moderate (3-5 $m \cdot s^{-1}$), high (5-7 $m \cdot s^{-1}$) and very-high (>7 $m \cdot s^{-1}$) intensity distance,[12] relative accelerations and decelerations (> 3 $m \cdot s^{-1}$), total PlayerLoad™, distance at high metabolic power (HMP; > 20 $W \cdot kg^{-1}$) and peak velocity.

The technical loads were determined using a 37-mm-digital video camera (Sony, DCR-TRV 950E, Nagaska, Japan). All games were analysed by a single researcher who has ~5 years' experience in performance analysis. A random selection of 5 players per game were re-examined by a second researcher (2 years' experience) and the agreement between researchers checked (inter-class correlation = 0.96). Intra-rater reliability for the researcher who completed the initial analysis was determined by re-assessing 7 players across all games (intra-class correlation = 1.00) The variables of interest were total attacking involvement (i.e. catches, catching errors, passes, passing errors) and defensive involvements defined as any purposeful contact made with the aim of stopping any advancement of the carrying player.

The perceptual responses were assessed following each SSG and required players to complete the NASA TLX questionnaire.[22] In brief, this questionnaire is split into two sections; section 1 requires players to report the "most significant contributor to the workload" between two loads measures (i.e. physical load or cognitive load) where all possible combinations are presented. The second part requires participants to provide a rating on a 21-point scale for physical, cognitive, temporal, technical, frustration, effort and performance. The tally of responses and scale are then multiplied and summed for total load.[22] All players were familiarised to both pars of the NASA-TLX before the session which involved defining the specific loads and discussing the measurement scale to ensure the anchors were interpreted correctly. Any questions about the scale during the data collection were answered by one of two research present. The Cronbach's alpha for the NASA-TLX is reported to be 0.83[22] and the coefficient of variation between two half of simulated rugby league match-play to be 6.8%.[23]

Statistics analysis

Data are presented as mean and standard deviation. Between-SSGs comparison were analysed using effect sizes and 95% confidence limits (ESs ± 95% CLs), with threshold values of 0.00 to 0.20 (trivial), 0.20 to 0.60 (small), 0.60 to 1.20 (moderate), 1.20 to 2.00 (large), and >2.00 (very large) used.[24] To supplement these ESs and 95% CL, inferences on the magnitude of difference included: 25% to 75% (*possibly*), 75% to 95% (*likely*), 95% to 99% (*very likely*), and >99.5 (*most likely*).[25] Separate linear mixed models were constructed to determine the influence of physical and technical demands during the SSGs on the subscales of the NASA-TLX (Table 1). To account for the dependent observation for participants and groups, individuals were included as random factors nested within a group, who in turn, were nested within an SSG. Fixed factors where 0 (i.e. distance) was not possible were grand mean centred. The *t*-statistic from the final model were converted to ES correlations (η^2)[26] with 95% confidence limits (95% CI). Correlations were interpreted as < 0.1, *trivial*; 0.1-0.3, *small*; 0.3-0.5, *moderate*; 0.5-0.7, *large*; 0.7-0.9, *very large*; 0.90-0.99, *almost perfect*; 1.0, *perfect*.[24] The likelihood of the observed effect was determined using a pre-designed spreadsheet[27] and interpreted with the same descriptors as those above used.[25] Analysis was completed using SPSS for Mac (IBM SPSS Statistics, Version 26.0, Armonk, New York).

**** INSERT TABLE 1 ABOUT HERE ****

Results

The mean and standard deviation for each domain of the NASA-TLX across the five SSGs are presented in Figure 1, whilst the physical and technical demands are in Table 2. Results provide evidence that the task load for which the game was intended (i.e. physical load/physical game) was higher than all other task loads. There was minimal difference in measures of effort, performance and total load across the five SSGs (Figure 1).

**** INSERT TABLE 2 ABOUT HERE****

**** INSERT FIGURE 1 ABOUT HERE ****

Between-SSG comparisons indicated that physical load was greater (ES = -2.95 to -4.55, *likely* to *most likely*) than all other loads, whilst high rating of effort were also observed (ES = 1.57 to 3.82, *most likely*) (Figure 2) during the physical game. The cognitive game elicited greater cognitive load than frustration, temporal, technical and performance loads (ES = -0.32 to -1.14, *likely* to *most likely*) but not effort (ES = 0.46 ± 0.64) (Figure 2). Effort load was greater than all other loads during the cognitive game (ES = 0.46 to 1.59, *likely* to *most likely*) (Figure 2). Frustration load was higher than all other loads (ES -1.94 to 1.91, *most likely*) during the frustration game, whilst physical, temporal and technical load were greater than effort and performance (ES = 0.14 to 1.90). Temporal load was greater than all other measures of load (ES = -1.25 to 1.52, *very likely to most likely*) except effort (ES = 0.20, *unclear*) whilst measures of frustration were low, and cognitive load was variable (Figure 2). Results demonstrate technical load was emphasised during the technical game (ES = -2.35 to 6.85, *most likely*), physical load was lowest of all task loads, and high degree of cognitive load and effort were observed. Fewer meaningful differences were observed for effort, performance and total task load (Figure 2). Between-SSG comparisons for physical and technical demands are provided in Supplementary File 1 (available online).

INSERT FIGURE 2 ABOUT HERE *

Results suggested that attacking and defensive involvements generally increased the respective task loads with η^2 ranging from 0.03 to 0.41 and -0.14 to 0.36, respectively (Figure 3). Distance covered in total and at high and very high speeds were positively associated with physical load (η^2 = 0.18 to 0.39), effort (η^2 = 0.24 to 0.65), performance (η^2 = 0.24 to 0.36) and total (η^2 = 0.18-0.51) load. High-speed distance was negatively associated with technical, frustration and cognitive load (η^2 = -0.10 to -0.36), whilst very high speed was negative associated with technical load (η^2 = -0.13) and frustration (η^2 = -0.28) (Figure 3). Very-, low- and moderate-speed were largely negatively associated with measures of task load, though very low-speed distance was positively associated with effort (η^2 = 0.33). Low-speed distance was positively associated with technical and frustration load (η^2 = 0.12 to 0.16), and moderate-speed was positively associated with total load (η^2 = 0.16) (Figure 3). Peak velocity was positively associated with all measures of load (η^2 = 0.01 to 0.18) except effort (η^2 = -0.06), whilst distance accelerating was positively associated with all but temporal and cognitive load (η^2 = -0.13 to -0.05). Associations for relative deceleration distance, metabolic power and player load were variable across the games (η^2 = -0.33 to 0.46) (Figure 3). The full model outputs are presented in Supplementary File 2 (available online).

INSERT FIGURE 3 ABOUT HERE *

Discussion

This study is the first to design SSGs to elicit specific task loads using a multidimensional rating technique, whilst reporting the association between task loads, physical and technical demands. The results indicated that the task load for which the SSGs were designed was greater than all other task loads and highest within that SSG, suggesting the SSGs were sport- and task-specific. The association between physical and technical demands with ratings of task loads demonstrated that, for the most part, lower-intensities activities were negatively associated, whilst distance at higher speed, attacking involvements and defensive involvements were positively associated with task loads. Collectively, these findings provide evidence to support the development of task load-specific SSGs for rugby league players with consideration for how the physical and technical demands can be manipulated to increase or decrease the subjective task loads.

Over the last decade, considerable research has explored various factors that alter the demands of SSGs including pitch size, playing numbers, coach encouragement and the inclusion or removal of sport-specific actions (i.e. physical contact).[6,11,20,28] Whilst such factors are known to alter the internal and external responses, less consideration has been given the perceptual load, with no studies exploring this across multiple domains. In this study, we sought to determine if, and to what extent, coaches involved in rugby league could design SSGs with a view to emphasising a specific task-load. Our results clearly demonstrate that the inclusion of certain constraints can place emphasis on specific task loads. For example, Figure 1 shows that the inclusion of a tackle in the physical game placed emphasis on the physical task load and effort, thus reaffirming previous work such as Mullen et al.[19] who demonstrated that a greater number of tackles was associated with an increased subjective physical demands and overall higher task load across a Super League season. With a high degree of importance placed on the tackle during rugby league, due its association with match outcomes and the internal/external responses,[14,20] our results suggest that including tackling within SSGs might be an effective way to increase the physical load and elicit greater rating of effort compared to other game formats. Such a format might not be effective for increasing the technical, temporal, cognitive, performance and frustration load. However, it is important to note that whilst the inclusion of a tackle increases the specificity, players are likely to be at greater injury risk compared to other metabolically demanding, sport-specific actions such a starting sets in a prone position[30] and increases the recovery time required before subsequent sessions.[31]

The results in Figure 1 and 2 highlights that the inclusion of specific rules within a game can serve to alter the cognitive and frustration load associated with the SSGs. In this study, we increased the cognitive load through deception; that is, we included specific rules within the game that the players were unaware of. As players were unaware of the results, this required them to consider the rule, test it and then confirm the rule. Such a SSGs design appears an effective strategy for placing emphasis on the cognitive load and might have important implications in rugby league whereby previous research has reported cognitive fatigue can impair the technical execution of a skills.[18] With regards to frustration, the inclusion of incorrect calls by the on-field referee appears to be effective with this task load being *most likely* higher than physical, cognitive, temporal, technical and performance task loads. This finding could have important implications in rugby league. A myriad of factors can lead to frustration such as referee response (i.e. incorrect call, disciplinary decisions)[29] that creates a distraction, reducing the athletes focus. This may result in a deterioration of task-related performance.[16] Practitioners and coaches designing SSGs should consider implementing SSGs designed to elicit cognitive and/or frustration load in a periodised manner, exploring a variety of methods to increase the load. For example, we postulate that giving players complex ‘plays’ or memory tasks before or during a SSGs might increase cognitive load, whilst including a player who consistently makes errors or a defensive team advancing before the ‘play the ball’ might increase frustration that, over time, might reduce distractibility.

Results considering the temporal and technical demands suggest that reducing the time players can hold the ball and increasing the number of passes, respectively, were effective strategies and can be incorporated within SSGs to aid in technical development.[13,18] Given the importance placed on passing, catching and ball-handling skills as well as decision-making ability,[32] the use of SSGs are well-placed for developing rugby league players, particularly when combined with alterations in pitch size, player numbers and coach encouragement.[5,6,12] When interpreting the results of this study, it is important to consider the loads across all domains of the NASA-TLX. For example, Figure 1 demonstrated no difference in total load, but when considering the individual domains, clear differences exist such as those for temporal and technical load. The temporal game elicited higher physical, temporal, effort, performance and frustration load compared to the technical game, which elicited higher technical and cognitive loads. Further, all games elicited a similar degree of effort and performance load. These results agree with previous work[19] and suggest the need to consider each domain individually when evaluating, designing and implementing SSGs with rugby league athletes.

This study also sought to determine the influence of physical and technical demands across the SSGs whilst concurrently controlling for all other factors to provide coaches and sport scientists with insight on how these alter task loads. The result indicated that with the exception of frustration, attacking and defensive involvements increases task load indices during SSGs. For example, our model (Supplement 2) suggests that the addition of 5 attacking involvements (i.e. passes or catches) will increase the physical, technical, temporal, effort, cognitive, performance and total load by 5, 23, 23, 11, 158, 12 and 2 AU, respectively. Similarly, 5 additional defensive involvements would, based on the modelling, increase physical, technical, temporal, effort, cognitive, performance and total load by 143, 10, 1, 10, 23, 8 and 33 AU, respectively. These agree with those of Mullen et al.[19] and Johnston et al.[20] who indicated that to increase the physical and total load, emphasis can be placed on defensive involvements, whilst for increasing cognitive, technical and temporal load, attacking involvements be emphasised. When considering the movement demands, our results generally suggest that total distance increases the task load indices with the exception of temporal demand; lower-intensity distances has minimal association or reduces the task load; and that higher-speed distances increase the task loads, and that peak velocity was positively associated with all measures except effort. From the model, results demonstrated that for every meter covered at very high-speed, the physical, temporal, effort, performance and total load would increase by 2-4 AU. In accordance with Mullen et al.[19] who observed an association between total task load with accelerations and deceleration, we found that relative accelerations and deceleration above 3 $m \cdot s^{-1}$ and PlayerLoad™ were positively associated with physical and total task load, whilst relative acceleration was also associated with effort, performance and frustration. Such findings likely reflect the greater increases in muscle temperature, metabolic, and mechanical stress during SSGs that are reflected in the higher ratings of effort.[33] Interestingly, distance at HMP was negatively associated with physical, cognitive and performance loads, which might reflect the methods to elicit the loads in this study. For example, those designing games to elicit physical load through greater HMP, might require a larger pitch, reduced playing numbers or additional in-game task to promote accelerated running.

Whilst this study provides a novel insight into how SSGs can be designed to emphasise specific task-loads, there are some limitations that require acknowledgement. Firstly, due to only using two groups, we were unable to counterbalance our research design. As such, it is unknown if a previously completed SSG had any influence on the subsequent SSGs, and this warrants further investigation. The use of a single rugby league club with participants categorised as youth athletes means further research is required to determine the suitability of these games and the NASA-TLX with academy and senior rugby league players. Finally, several of our results indicated differences that were *unclear* or *possible* and we urge caution when interpreting these findings as the confidence limits cross both positive and negative effects and the effect size likely falls within the typical error of measurement.

Practical Applications

Collectively, the results of this study have several practical applications for coaches and sport scientists working in rugby league. Firstly, the use of the NASA-TLX questionnaire provides a useful tool for designing and evaluating the individual subjective task loads associated with SSGs. Secondly, our results support the notion that SSGs can be designed to elicit a specific task load. This finding has important implications for coaches and sport scientists tasked with designing SSGs, where we encourage the development of a 'catalogue' of SSGs that elicit greater specific task loads. For example, we have demonstrated that the inclusion of a tackle increases the physical load, though this could be achieved through numerous game modifications, thus warranting further consideration with respect to specific task load domains. Finally, the results from the modelling provides coaches and sport scientists with some factors that serve to increase or decrease specific task loads. Again, using physical load as an example, coaches and sport scientist should design a game that increases total, high, and very high-speed distance, accelerating and decelerating as well as attacking and defensive involvements. Future research should seek to test the reliability of these games before determining the trainability of these task loads in the short- medium- and long-term with regards to athlete development using a periodised approach; explore various other sport-specific actions within SSGs; and consider a more detailed evaluation of the technical skills in rugby league.

Conclusion

This study supports the notion that SSGs can be designed to target specific subjective task loads and these can be achieved by manipulating a range of constraints such as rules of the game, physical demands and attacking and defensive involvements. Furthermore, the NASA-TLX provides a useful tool for evaluating SSGs that, when combined with microtechnology, provides a detailed quantification on the internal and external responses, which can inform the development and assessment of SSGs used in rugby league.

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Table 1. Covariates included in the model specification.

Table 2. The technical and physical responses to each rugby-specific SSGs.

Figure 1. Responses to individual task loads measured using the NASA-TLX for each game.
Note: Data expressed as mean ± standard deviation.

Figure 2. Within-game differences in the perceived individual task loads measured using the NASA-TLX.
Note: Data expressed as a standardised effect size ± 95% confidence limits. *Possibly, **Likely, ***Very likely, *Most likely. Vertical dashed lines represent a trivial, small, moderate and large effect size.

Figure 3. Effect of physical and technical (fixed factors) on individual and total NATA-TLX scores. N_ote: Data expressed as effect size correlations with 95% confidence limits. HMP = high metabolic power._ Effects that cross 0 are non-significant but may demonstrate a clear likelihood effect: **_Likely_, ***_Very likely_ ****_most likely_.