ABSTRACT

Purpose: This study investigated whether providing Global Positioning Systems feedback to players in between bouts of small-sided games (SSGs) can alter locomotor, physiological, and perceptual responses.

Methods: Using a reverse counterbalanced design, twenty male university rugby players received either feedback or no-feedback during 'off-side' touch rugby SSGs. Eight 5v5, 6 x 4 minute SSGs were played over four days. Teams were assigned to a feedback or no feedback condition (control) each day, with feedback provided during the 2 minute between bout rest interval. Locomotor, heart rate, and differential rating of perceived exertion (dRPE) of breathlessness and leg muscle exertion were measured and analysed using a linear mixed model. Outcomes were reported using effect sizes (ES) and 90% confidence intervals, and then interpreted via magnitude-based decisions.

Results: Very likely trivial to unclear differences at all time points were observed in heart rate and dRPE measures. Possibly to very likely trivial effects were observed between-conditions, including total distance (ES= 0.15 [-0.03, 0.34]), high-speed distance (ES= -0.07 [-0.27, 0.13]), and maximal sprint speed (ES= 0.11 [-0.11, 0.34]). All within-bout comparisons showed very likely to unclear differences, apart from possible increases in low-speed distance in bout 2 (ES= 0.23 [0.01, 0.46]) and maximal sprint speed in bout 4 (ES= 0.21 [-0.04, 0.45]).

Conclusions: In this study, verbal feedback did not alter locomotor, physiological, or perceptual responses in rugby players during SSGs. This may be due to contextual factors (e.g., opposition) or due to the type (i.e., distance) or low frequency of feedback provided.

***Keywords**:*

Feedback, GPS, Heart rate, Small sided games, Rugby

Introduction

Small-sided games (SSGs) are commonly used as a tool for training team sport athletes.[1] Amateur and professional athletes[2] across a wide range of football codes (e.g., soccer[3], rugby union[4], and rugby league[5]) utilise SSGs as they can develop multiple facets (e.g. physical, technical, and tactical) of performance at the same time. Small-sided games contain multiple bouts of intermittent exercise that typically last between 2-5 minutes and can assist in the development of maximal oxygen uptake (VO_{2max})[6], with previous research demonstrating that 70% of SSG playing time is spent at VO_{2max}.[7] Time spent at VO_{2max} is important for increasing aerobic fitness[6], but due to contextual factors that dictate SSGs, athletes may be working at varying intensities. Consequently, developing simple methods that can promote greater physical outputs and prevent substantial reductions in training intensity might be of value for practitioners. One method that has been postulated to increase the physical intensity of SSGs has been through the provision of feedback.[8]

The use of augmented feedback has been well established as a method of promoting acute performance enhancement and mitigating the effects of fatigue during exercise.[9-12] For example, during resistance training it has been demonstrated that providing barbell velocity visually when exercising can enhance barbell speed by 7.7% compared to athletes who do not receive this feedback.[11] Furthermore, running performance and perceptions of effort can be improved when frequent positive encouragement is provided to athletes in maximal exercise tests.[12] It is thought that these improvements in physical performance are due to externalised focus which can mitigate feelings of fatigue [12] and improve motivation and competitiveness.[9] These acute enhancements in performance from regular feedback have also been shown to have accumulative effects, with athletes demonstrating greater physical adaptations over a training period.[13,14] Despite these findings, the use of terminal augmented feedback (i.e., providing feedback at the end of each bout) during SSGs has not been assessed.

Team sport athletes often wear microtechnology devices that contain Global Positioning Systems (GPS) and inertial sensors during training and match play.[15-17] These devices are commonly used to monitor training loads and intensities with information typically being available to practitioners and scientists after exercise. Additionally, these devices can also be used to provide 'live' feedback which can inform staff of internal and external load throughout a match or training session. Live information of locomotor metrics (e.g., total distance) has recently been shown to have excellent validity when compared to post-session data and might be a valuable tool for guiding training practices.[18,19] Alternatively, this information could be used as a tool for providing feedback during training (e.g., providing athletes the distance that they have covered throughout a training session) or promoting competition between athletes.[11] However, the effects of providing information of locomotor performance to athletes during training has not been investigated.

Small-sided games are regularly utilised by coaches as a training method. However, due to the various aspects (e.g., contextual factors and pacing strategies) that can influence physical outputs, training volumes and/or intensities might be lower than required for the desired physiological adaptation. This might be offset by the provision of augmented feedback, which has been shown to enhance acute physical performance.[9] Such information may assist with improved control over exercise prescription and external training loads. Thus, the purpose of this study was to investigate if providing GPS-based feedback to players in between bouts of SSGs altered the locomotor, physiological, and perceptual responses in rugby union players.

Methods

Participants

Twenty male university rugby union players were recruited from a British Universities and Colleges Sport (BUCS) squad that participated in the BUCS Super Rugby competition. The players had the following characteristics: mean (standard deviation (SD)); age: 19.8 (0.8) years; height: 1.81 (0.05) m and body mass: 96.8 (15.8) kg. University rugby is an open age competition, however ages in the current study ranged from 18-21 years. Ethics approval was granted by the Leeds Beckett University institutional ethics committee and adhered to throughout. Written informed consent was gained from all participants prior to commencement of the study.

Design

A reverse counterbalanced experimental design was used to assess the effect of verbal feedback on locomotor, physiological, and perceptual responses during SSGs. All participants completed testing on six separate occasions (refer to Figure 1 for study design). The first consisted of baseline physical testing (i.e., 40 m sprint and 30-15 intermittent fitness test[20]) and the second a familiarisation of the SSG that was completed throughout the study. For the SSGs, participants were divided into four position matched teams with each team consisting of three forwards (one front row, second row, and back row player) and two backs (one inside and outside back). During testing occasions three to six, each team completed two SSGs that were 6 x 4 minutes and were separated by 20 minutes of passive recovery. During each game, participants received either feedback of total distance covered in the previous bout, or no-feedback (i.e., control). Feedback was provided in a reverse counterbalanced design with teams receiving feedback on visits three and six or four and five. Each team played the same opposition on each occasion, with the same referee and rules applied. All testing was completed across a three-week period in September, which formed part of the preparation phase (pre-season) of the season. Two visits per week occurred on the same days (Monday and Thursday), at the same time each day (09:00 h) and were preceded by a period of 48 hours rest.

Insert Figure 1 here

Methodology

Baseline tests: In preparation for the baseline tests, players were asked to refrain from exercise for 48 hours before the testing session. Baseline tests were part of the pre-season testing battery and included a maximal 40 m linear sprint to assess maximal sprint speed (MSS)[21] and a 30-15 intermittent fitness test used to assess maximal heart rate.[20] The same grass pitches were used throughout the study.

Small-sided games: In total, each team took part in eight five-a-side 'off-side' touch rugby SSGs that were played across four days and had a 20 minute passive rest period between games on each day.[8] During each game, one team received feedback, while the other team did not. Each 24 minute SSG consisted of 6 x 4 minute bouts with a 2 minute passive rest period between bouts and were played on a 20 m (width) x 40 m (length) pitch.[8] Participants were informed of the rules but were not told that it was a competition between which team scored the greatest number of points or who travelled the furthest distance. Feedback was provided by the same sport scientist on all occasions, at a volume that was slightly louder than conversation level during the 2 minute passive rest period following each 4 minute bout. Together the team of five players were given verbal feedback on the distance (m) each member of their team had covered in the preceding 4 minute bout in a descending order while the opposition were asked to wait at the opposite end of the pitch. The feedback was provided from a real-time receiver (7.24 firmware, Catapult Sports, Melbourne, Australia) that was positioned at the side of the pitch, 10 m behind the playing field. The receiver was placed facing the players, so that at any time of the game the players were between 10-55 m from the receiver, which is within the manufacturer recommended distance of 250 m.

A standardised warm-up of light aerobic exercise, dynamic stretching and sprint efforts that included change of direction was undertaken prior to the games. Following this there were two pitches that ran simultaneously, with the same teams playing against each other in each game with the same referee and rules consistently applied.[8] When in possession, each team had 6 plays with the ball before handing it over. The first pass after a play the ball had to be made backwards, while all subsequent passes could be in any direction. When in possession of the ball and touched by the opposition, all players of the team in possession had to retreat back behind the play of the ball, while defenders had to return to an on-side position that was in front of the player that was touched. If the ball hit the ground from a misplaced pass or handling error, possession was turned over to the opposition. A try was scored when a player placed the ball down after the line of cones and resulted in a turnover of possession.

Data collection

During baseline testing, familiarisation and all trials, players wore a microtechnology device (S5 Optimeye, 7.24 firmware, Catapult Sports) and a heart rate monitor (T31 coded, Polar, Kempele, Finland). The microtechnology devices contained a 10 Hz GPS and a tri-axial accelerometer, gyroscope and magnetometer that sampled at 100 Hz. The devices were turned on outside to ensure they were connected to the satellites and were placed into a vest provided by the manufacturer. Players were assigned the same device for the entire study.

Microtechnology devices measuring at 10 Hz have been shown to be valid and reliable for assessing team sport movements.[22] The mean number of satellites connected and horizontal dilution of precision during data collection was 14.2 (0.8) and 0.69 (0.06), respectively. Any files where data were >10 $m \cdot s^{-1}$, <6 satellites, >2 horizontal dilution of precision, or >±6 $m \cdot s^{-2}$ were removed.[23]

All data from the microtechnology device and heart rate monitor were downloaded using the manufacturers software (v21.0, Openfield, Catapult Sports). The total distance covered (m) was analysed and also split into low-speed distance (m) and high-speed distance (m). Low-speed and high-speed categories were determined using a relative threshold of 61% from MSS testing.[24] The mean acceleration and deceleration ($m \cdot s^{-2}$) was determined using a rolling mean, that calculates the mean from absolute accelerations and decelerations over a given time duration.[25,26] Stagnos heart rate training impulse ($TRIMP_{mod}$) was used to provide a measure of internal load in relation to the participants' maximal heart rate as established in the baseline testing.[27] At the end of each 24 minute game, differential ratings of perceived exertion (dRPE) were recorded using the centi-max CR100® scale[28] for leg muscle exertion (RPE-L) and breathlessness (RPE-B).[29] The ratings were collected between 15 and 30 minutes following the end of each game.[30]

Statistical Analyses

Data are presented as mean (SD). Differences between feedback and no-feedback conditions were analysed using a linear mixed effects model in a statistical software package (v24 SPSS, IBM Corporation, New York, United States). It was determined that a linear mixed model approach was appropriate due to the repeated measurements of participants.[31] Assumptions of normality were checked using the Shapiro-Wilk test and visual inspection of the raw data via histograms and Q-Q plots. The raw data followed a normal distribution. Three comparative analyses were conducted between feedback and no-feedback during: a) one SSG (24 minutes), b) each 4 minute bout c) the first minute of each bout. The condition of feedback or no-feedback was the fixed-effect, while the ‘participant code’ was the random-effect. Data between conditions are presented as Cohen *d* effect size (ES), with uncertainty reported as 90% confidence intervals and interpreted using magnitude-based decisions.[30] Thresholds used for ES were: <0.2 = *trivial*; 0.20-0.59 = *small*; 0.60-1.19 = *moderate*; 1.20-1.99 = *large* and >2.0 = *very large*.[32] A smallest worthwhile change (SWC) of 0.2 of an effect was chosen. This was due to the lack of consensus regarding what constitutes a worthwhile change.[33] The probability of the effect being greater than the SWC was interpreted using the following scale: 25-74.9% = *possibly*; 75-94.9% = *likely*; 95-99.4% = *very likely* and ≥99.5% = *almost certainly*.[34]

Results

The data and differences between conditions for SSGs are presented in Table 1. Bout one of the SSG is not included in the analysis as feedback was first provided after the first bout.

*** Insert Table 1 near here ***

The within-bout data in each SSG are shown in Figure 2 and differences between conditions are presented in Table 2. Bout 1 of the SSG was not included in the analysis within Table 2 as feedback had not been provided.

*** Insert Figure 2 near here ***

*** Insert Table 2 near here ***

The differences between conditions for the first minute of each bout following feedback are presented in Figure 3. Bout 1 of the SSG was not included in the analysis.

*** Insert Figure 3 near here ***

Discussion

In this investigation providing GPS-based feedback of distance to players in between bouts of SSGs did not alter locomotor, physiological, and perceptual responses in rugby union players. It was found that between SSG conditions, all locomotor, heart rate, and dRPE outcomes were *possibly* to *very likely trivial* (apart from RPE-L which was unclear). Furthermore, for analysis of each independent bout, only *possibly* greater differences were observed in low-speed distance and MSS in the 2nd and 4th bout following feedback, respectively. To the best of our knowledge, this is the first study to investigate the effects of augmented feedback on intermittent team sports. These results might be due to the relatively low frequency of feedback provided (i.e., following each 4 minute bout) or due to contextual factors that can influence match play (e.g., game context and motivational factors related to performance). Consequently, these findings show that the provision of GPS-based feedback of distance every 4 minutes does not provide a substantial change in locomotor, physiological, or perceptual responses.

Findings from the current study show that across all locomotor, physiological, and perceptual measures assessed, there were no discernible differences between conditions. Furthermore, while differences in some outcome variables neared a small ES, these differences would be unlikely to cause substantial adaptations in a desired physiological capacity (e.g. between group difference in total distance was 23 metres (ES±90%CI: 0.15 [-0.03, 0.34]). While previous research has shown that feedback can be of benefit during fatiguing exercise,[9,11,35] these findings have primarily been demonstrated to occur in high force and power exercises (e.g. ballistic throws and singular sets of multi-joint resistance training exercise) that have a singular focus (e.g., push the bar explosively). Thus, the unique contextual factors related to game play might have mitigated any performance enhancing effects of feedback. This includes difficulty in being able to regulate individual performance due to reliance on teammates and opposition. Additionally, differences might have been obscured by intrinsic or extrinsic motivating factors related to the exercise (e.g., competitiveness, losing/winning, chasing/evading)[36] and the ability to utilise skill or tactics rather than increase locomotor outputs to improve the odds of scoring. Therefore, a disconnect between what the athletes' may perceive as their goal (e.g., winning the SSG), and the feedback of locomotor outcomes, may have occurred.

Across individual bouts following feedback (Figure 2 and Table 2), *possibly* to *very likely trivial* effects were observed in all variables, except low-speed distance (bout two) and MSS (bout four) that showed *possibly small* increases following feedback. This suggests that feedback does not have a substantial effect on locomotor and physiological responses from bout to bout and does not off-set fatigue as game play progresses. While speculative, it is thought that this lack of difference is due to the relatively infrequent feedback that was provided (i.e., every four minutes) during the study. Previous research by Nagata et al.[37] has demonstrated that frequency can moderate acute performance outcomes during resistance training, and that highly frequent feedback (e.g., following every repetition) might have greater effects on performance than at the end of each training set. This is further supported by research from Hubbard[38] who has stated that time delays in the provision of feedback reduces the usefulness of this information. Thus, future research should consider investigating the effects of feedback regularity during SSGs and whether changes in locomotor and physiological responses occur.

While SSGs are utilised to develop physical and physiological characteristics, they can also be used to develop technical and tactical elements of a sport.[6] Due to the lack of substantial changes in locomotor, physiological, and perceptual responses with terminal augmented feedback, practitioners may be better served by providing verbal encouragement, and small amounts of technical and tactical guidance to athletes.[12] However, this should be tempered by the knowledge that skill development can be enhanced by allowing athletes periods to problem solve during physical tasks with varying constraints.[39] Therefore, practitioners may wish to utilise live GPS during SSGs to assist with objective decision making (e.g., monitor athlete training loads, objectively observe outcomes of a training task) and strategically implement verbal feedback to guide technical or tactical elements of the sport.

While this study is the first to investigate the effects of terminal augmented feedback at regular intervals on locomotor, physiological, and perceptual responses, it is not without limitations. First, it is acknowledged that a range of factors including the field dimensions, SSG rules, and number of players on the field can alter external and internal responses when implementing these training methods.[1,40] Consequently, the effect of feedback with altered game variables cannot be dismissed. However, due to the near uniform responses observed in all variables and at all timepoints, it is thought to be unlikely that slight changes in game constraints would cause substantially different outcomes. Second, as previously stated, the frequency in which feedback was provided might have been too low to cause any substantial ergogenic effects. While previous research has suggested that increased feedback frequency can enhance acute performance and improve psychological factors that can influence physical outcomes,[9,11,37] due to the research question and ecological validity of the study design, it was not appropriate to continually interrupt the matches to provide feedback. Thus, future research should consider the effects of high frequency feedback in an ecologically valid manner. Third, it is feasible that feedback related to total distance did not resonate with the participants. If participants placed a greater emphasis on winning the SSG, the feedback of distance covered may not influence their movements throughout the match. Furthermore, it is acknowledged that the feedback of distance may be a metric that has varying relevance to each athlete. While some athletes may find this information as an important proxy for their effort and involvement, greater match specific feedback that is tactical or technical by nature may cause a differing response. Therefore, future research should consider investigating different forms of feedback and their effects on locomotor outcomes. Finally, the selection of a distribution-based SWC is a limitation. While anchor-based thresholds would have been preferable, at this current point in time, changes in each locomotor variable that equates to a 'worthwhile' change are still unknown.

Practical Applications

Augmented feedback is regularly used to enhance outcomes during training. This is completed within the gym and on the training field. However, findings from this study indicate that the provision of GPS-based feedback following each bout (4 minutes) of a SSG does not cause substantial changes in locomotor, physiological, or perceptual responses. Therefore, it is advised that live GPS be used as a tool to monitor training loads and provide feedback for informed decision making rather than as a method that might enhance acute training performance.

Conclusions

This study investigated if providing GPS-based feedback to players in between bouts of SSGs altered the locomotor, physiological, and perceptual responses in rugby union players. In this study, feedback did not demonstrate any ergogenic effects when supplied to athletes at 4 minute intervals during SSGs. Furthermore, this feedback did not demonstrate substantial improvements in locomotor, physiological, or perceptual responses. It is speculated that this lack of difference is due to contextual factors that can regulate gameplay, and the relatively low regularity in which feedback was provided. Alternatively, athletes may have perceived that the feedback provided did not relate to their on-field performance. Future research might wish to consider the effects of feedback regularity during SSGs and whether alternative methods of feedback (e.g., coach encouragement) can alter locomotor, physiological, or perceptual responses.

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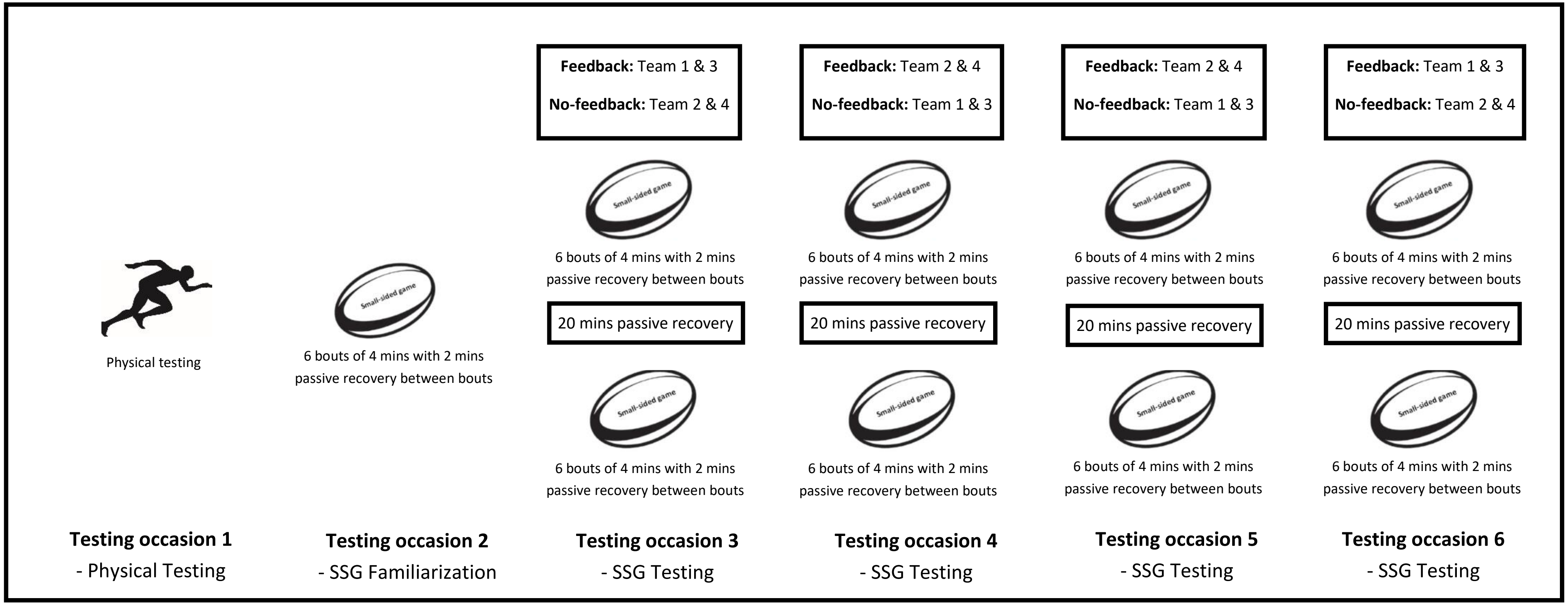

Figure 1. Outline of study design. SSG = Small-sided game.

Table 1. Locomotor, physiological and perceptual responses during touch rugby small-sided games following feedback or no-feedback

	Feedback	No-Feedback	Effect Size [90% CI lower, upper]	Magnitude-Based Inference
Total Distance (m)	2200 (156)	2177 (186)	0.15 [-0.03, 0.34]	0/66/34 – *Possibly trivial*
Low-Speed Distance (m)	2074 (152)	2046 (182)	0.18 [0.00, 0.37]	0/56/44 – *Possibly trivial*
High-Speed Distance (m)	126 (55)	131 (67)	-0.07 [-0.27, 0.13]	14/85/1 – *Likely trivial*
Maximal Sprint Speed ($m \cdot s^{-1}$)	6.8 (0.6)	6.8 (0.6)	0.11 [-0.11, 0.34]	1/74/25 – *Possibly trivial*
Mean Acc/Dec ($m \cdot s^{-2}$)	0.56 (0.06)	0.56 (0.05)	0.15 [0.02, 0.28]	0/68/32 – *Possibly trivial*
$TRIMP_{mod}$ (AU)	50 (19)	52 (20)	-0.05 [-0.17, 0.06]	2/98/0 – *Very likely trivial*
RPE-L (AU)	50 (13)	50 (11)	0.05 [-0.21, 0.32]	6/75/19 – *Unclear*
RPE-B (AU)	48 (12)	49 (12)	-0.09 [-0.32, 0.14]	22/76/2 – *Likely trivial*

NB: Bout 1 is excluded from this analysis as feedback was first provided after bout 1.

Data are presented as mean (standard deviation), Cohen's *d* effect size, [90% confidence intervals lower, upper], probabilistic chances of lower/similar/greater following feedback and a probabilistic term using magnitude-based inferences. CI = Confidence interval. Mean Acc/Dec = Mean acceleration and deceleration. $TRIMP_{mod}$ = Stagno heart rate training impulse. RPE-L = Ratings of perceived exertion for leg muscle exertion. RPE-B = Ratings of perceived exertion for breathlessness

Table 2. Between-condition differences following feedback or no-feedback in locomotor and physiological outcomes during each 4 minute bout of the small-sided games

	Bout 2	Bout 3	Bout 4	Bout 5	Bout 6
Total Distance (m)	0.14 [-0.09, 0.37] 0/67/33 *Possibly trivial*	-0.01 [-0.24, 0.22] 8/85/7 *Unclear*	0.08 [-0.15, 0.31] 2/78/20 *Likely trivial*	0.11 [-0.12, 0.35] 1/72/27 *Possibly trivial*	0.14 [-0.10, 0.37] 1/67/32 *Possibly trivial*
Low-Speed Distance (m)	0.23 [0.01, 0.46] 0/40/60 *Possibly greater*	-0.03 [-0.25, 0.20] 10/85/5 *Unclear*	0.06 [-0.16, 0.29] 3/81/16 *Likely trivial*	0.18 [-0.04, 0.41] 0/55/45 *Possibly trivial*	0.19 [-0.03, 0.43] 0/51/49 *Possibly trivial*
High-Speed Distance (m)	-0.19 [-0.46, 0.06] 48/51/1 *Possibly trivial*	0.04 [-0.21, 0.30] 6/79/15 *Unclear*	0.05 [-0.20, 0.30] 5/79/16 *Unclear*	-0.07 [-0.32, 0.19] 19/77/4 *Likely trivial*	-0.12 [-0.37, 0.13] 30/68/2 *Possibly trivial*
Maximal Sprint Speed ($m \cdot s^{-1}$)	-0.06 [-0.30, 0.19] 17/79/4 *Likely trivial*	0.06 [-0.18, 0.30] 4/79/17 *Likely trivial*	0.21 [-0.04, 0.45] 0/48/52 *Possibly greater*	-0.10 [-0.35, 0.14] 26/72/2 *Possibly trivial*	0.05 [-0.20, 0.29] 5/79/16 *Unclear*
Mean Acc/Dec($m \cdot s^{-2}$)	0.16 [-0.03, 0.34] 0/50/50 *Possibly trivial*	0.17 [-0.02, 0.34] 0/50/50 *Possibly trivial*	0.09 [-0.08, 0.28] 1/71/28 *Possibly trivial*	0.08 [-0.09, 0.26] 1/75/24 *Possibly trivial*	0.05 [-0.12, 0.23] 3/81/16 *Likely trivial*
$TRIMP_{mod}$ (AU)	0.00 [-0.14, 0.14] 1/98/1 *Very Likely trivial*	0.04 [-0.11, 0.18] 0/97/3 *Very Likely trivial*	-0.06 [-0.20, 0.09] 5/95/0 *Very Likely trivial*	-0.11 [-0.25, 0.04] 14/86/0 *Likely trivial*	-0.10 [-0.24, 0.05] 12/88/0 *Likely trivial*

NB: Bout 1 is excluded from this analysis as feedback was first provided after bout 1.

Data are presented as Cohen's *d* effect size, [90% confidence intervals lower, upper], probabilistic chances of lower/similar/greater following feedback and a probabilistic term using magnitude-based inferences. Mean Acc/Dec = Mean acceleration/deceleration. $TRIMP_{mod}$ = Stagno heart rate training impulse.

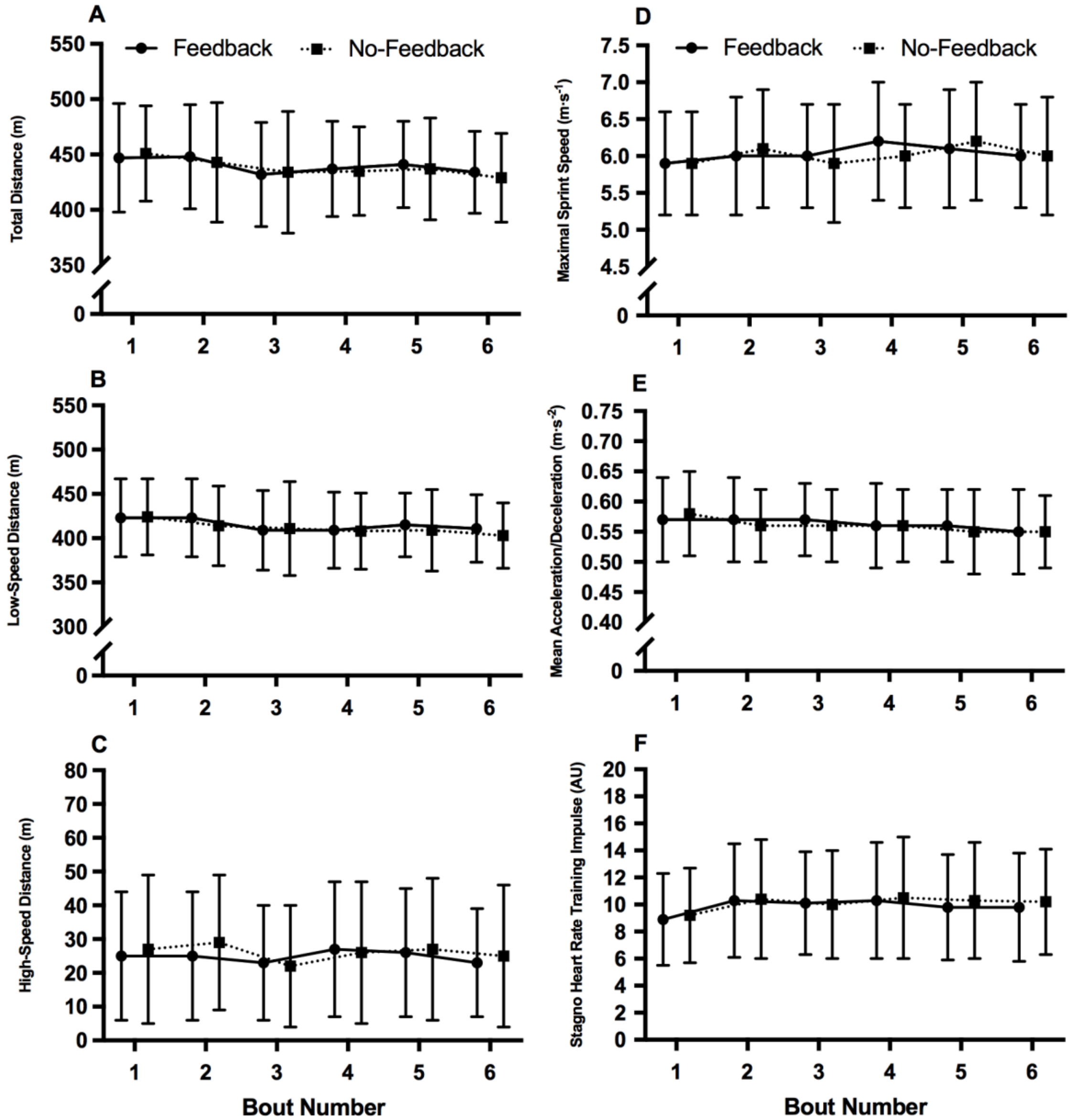

Figure 2. Data for 6 x 4 minute bouts of 'off-side' touch rugby small-sided games: Total distance (A), Low-speed distance (B), High-speed distance (C), Maximal sprint speed (D), Mean acceleration and deceleration (E) and Stagno heart rate training impulse (F).

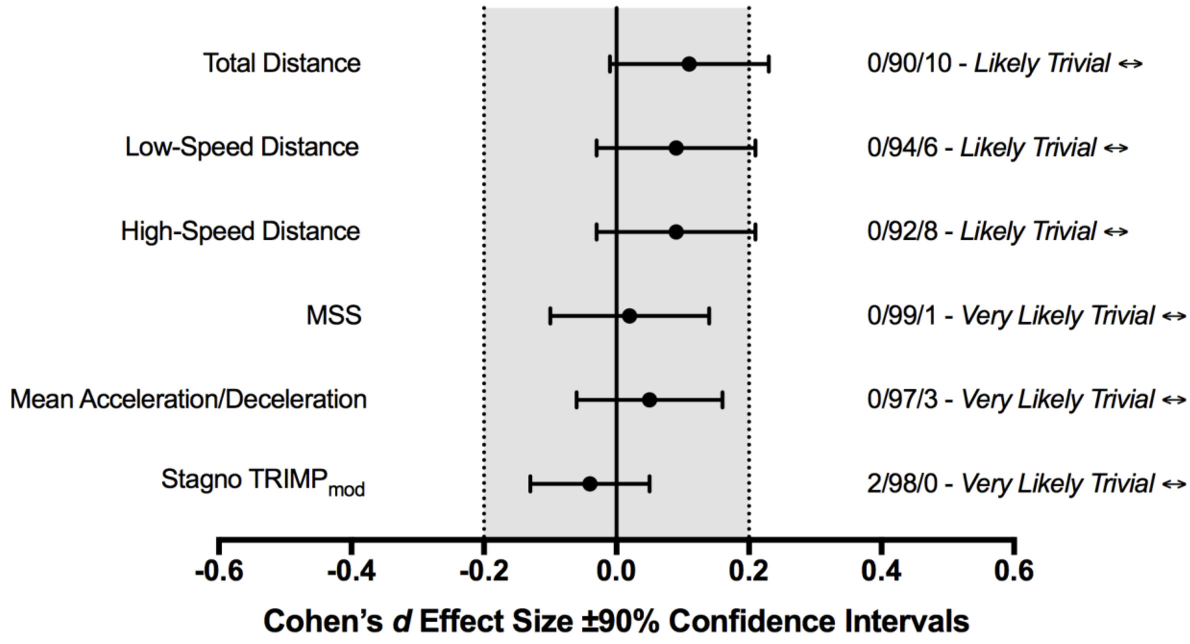

Figure 3. Locomotor and physiological comparisons between feedback and no-feedback conditions for the first minute of the small-sided game following feedback. Data are presented as Cohens d effect size, 90% confidence intervals and assessed via magnitude-based inferences. MSS = Maximal sprint speed. $TRIMP_{mod}$ = Stagno heart rate training impulse.