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The acute effect of various feedback approaches on sprint performance, motivation and affective mood states in highly trained female athletes: a randomised crossover trial

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Abstract

Purpose: This crossover trial compared varying feedback approaches on sprint performance, motivation, and affective mood states in female athletes. **Methods:** Eligibility criteria was competitive female athletes, where participants completed sprint tests in four randomised feedback conditions on grass, including augmented feedback (sprint time; AUG-FB), technical feedback (cues; TECH-FB), a competition-driven drill sprinting against an opponent (CDD), and a control condition (no feedback; CON). Participants completed a 20m sprint (MS), 30m curved agility sprint (CAS), and a repeated-sprint ability (RSA) test, with sprint times, motivation level, and mood states recorded. The participants were blinded from the number of trials during the RSA test. **Results:** Twelve rugby league players completed all feedback conditions. The MS sprint times were faster for AUG-FB (3.54±0.16sec) and CDD (3.54±0.16sec) compared to TECH-FB (3.64±0.16sec), while there were no differences compared to CON (3.58±0.17sec). The CAS sprint times were faster for AUG-FB (5.42 ± 0.20sec) compared to TECH-FB (5.61±0.21sec) and CON (5.57±0.24sec), although CDD (5.38±0.26sec) produced faster sprint times than TECH-FB. Effort and value were higher with AUG-FB (6.31±0.68; 6.53±0.05) compared to CON (5.99±0.60; 4.75±2.07), while CON exhibited lower enjoyment ratings (4.68±0.95) compared to other feedback conditions (AUG-FB: 5.54±0.72; CDD: 5.56±0.67; TECH-FB: 5.60±0.56). **Conclusions:** Providing AUG-FB prior to sprint tasks enhances immediate performance outcomes than TECH-FB. Augmented feedback also benefited athlete enjoyment, task effort and coaching value. Female athletes should receive AUG-FB in testing and training environments, to improve immediate physical performance and motivation.

Introduction

The ability to sprint and maintain sprint speed, sometimes over multiple bouts, is a key component for successful performance in team sports [1]. The provision of augmented feedback is a common method for athletes to sustain a high level of exertion during sprint training to enhance training quality and maximise neuromuscular adaptations [2]. Augmented feedback, which is the provision of feedback from an external source, is generally categorised into knowledge of performance (KP), including information regarding the mechanics of the movement, and knowledge of results (KR), which refers to the success of the athlete's task with respect to an environmental goal [3].

During sprint training, coaches may verbally describe sprint technique to their athletes (i.e., KP), or provide feedback such as completion times following each sprint (i.e., KR). However, KP has been reported in some studies as having a detrimental performance effect on goal-oriented tasks, as learners may rely on task intrinsic cues and hinder automatic control processes that regulate movement [3]. Conversely, several studies have shown greater muscular power development and movement speed with the provision of KR, such as movement velocity, jump distance and sprint times, during 4-6 weeks of sprint training and resistance exercises [4-6]. It has been speculated that receiving KR can enhance athlete's performance during training, which optimises neuromuscular stimuli for training adaptation [4].

Indeed, instantaneous feedback on movement speed has been shown to acutely improve power and strength-oriented performances [4,7,8], although the acute effect of KR on sprint performance is still unclear. Improvement in sprint performance has been reported as a result of chronic physical training when supplemented with KR [5]. However, running demands in team sports are often non-linear, with sprints involving varying curvatures [9]. In addition, most studies that examined the acute effect of KR incorporated performance measures using single-effort, explosive movements [4,7,8]. Doma, Engel, Connor and Gahreman [10] recently examined the acute effect of KR via the provision of swim speed which resulted in faster completion times during a repeated sprint swim protocol amongst competitive swimmers. Whilst these findings provide insight on the implications of KR during repeated sprint training, swimming performance is not directly translatable to team sports. To date, studies have neither examined the acute effect of KR on curved sprint running performance nor running repeated sprint ability, which would provide much broader practical implications given that running is a common mode of exercise in field-based sports.

Although KR acutely enhances performance [4,7,8], providing the same type of augmented feedback repeatedly may also introduce boredom and increase athlete-coach dependency, which may impede the effort by the athlete [11]. Encouraging a competitive environment may improve the level of motivation, and is a key mechanism proposed for successful provision of augmented feedback [12]. However, the provision of KR, either as movement speed, or in competitive environments, may also increase anxiety and dejection when athletes receive negative feedback or fail to achieve a goal [13]. Therefore, examining psychological states may unearth additional mechanisms beyond current knowledge, although such an investigation is still limited.

Collectively, the provision of KR enhances both muscular power development and acute explosive performance measures, confirming the use of KR as an effective training strategy for athletes. However, most studies in this research area have either included male participants [2,4,5,14] or a combination of males and females [7,15,16], with even fewer studies on the effectiveness of KR in females athletes from team sports. Given the biological and sociocultural differences between male and female athletes [17], feedback approaches may have differential effects on motivation and affective states, and thus, motor performance of female athletes. Furthermore, female athletes remain significantly underrepresented in exercise science research [18], which disadvantages coaches to make evidence-informed decisions for female athletes and has become increasingly important with the recent rise of professional female athletes. Thus, the purpose of the current study was to examine whether various feedback approaches of KR, KP or competition-based sprinting drills, would influence the performance of female athletes during sprint-based conditioning tasks, and whether affective or motivational state is influenced by different feedback approaches. It was hypothesised that for all tests, any form of feedback will be beneficial to improve sprint performance in comparison to the control (CON) group, with competition-driven drills (CDD) and augmented KR feedback (AUG-FB) producing the fastest sprint time. It was also hypothesised that higher levels of anxiety and dejection will be reported in the AUG-FB and CDD conditions.

Methods

Participants

Fifteen participants were originally recruited for the study, although three participants did not complete the study. Thus, twelve female rugby league players completed the study (age = 19.6 ± 3.6years; mass = 74.9 ± 14.3kg; height = 168.3 ± 6.6cm). An *a priori* sample size calculation based on a previous study for intra-individual comparisons [4,5] indicated that twelve participants was sufficient with an anticipated effect size of 0.43, alpha level probability of 0.05, statistical power of 0.8, three numbers of measurements and correlation among the repeated measures of 0.5 (G*Power 3.1.9.2; Heinrich-Heine-Universitat Dusseldorf) to exhibit significant change in parameters. Participants were recruited via sporting organisations, ensuring that they at least played at a regional or state representative level as the inclusion criteria, although those with injuries sustained within the last six months were excluded. All participants met the inclusion criteria, with 50% playing semi-professionally during the previous or current Queensland-wide rugby league competition. To prevent any influence of biological factors, participants were requested to refrain from high-intensity activity 48 hours prior to testing; avoid caffeine or supplements 2 hours prior to testing; wear the same training boots and by conducting each testing session at the same time of day. All participants were provided with information sheets outlining the risks and benefits of the study and signed a written informed consent form. All experimental protocols and procedures were approved by the Institutional Human Research Ethics Committee.

Research Design

A randomized cross-over study, which was not prospectively registered, was conducted in Far North Queensland from April to December, 2021. A non-blinded, single sequence of randomisation was completed by the researchers from tossing a coin. The study was conducted across six sessions outside on a field with natural grass and avoided testing sessions in the rain to minimise the impact of weather on performance outcomes. This study was comprised of two familiarisations followed by four testing sessions with each 60-minute session separated by at least two days (median 7, range 2-21). The sessions were separated by two days to minimise potential carry-over effects of fatigue [10]. The familiarisation sessions enabled participants to be pre-screened and ensured they were accustomed to all testing procedures, feedback conditions and equipment. The subsequent four sessions consisted of testing under separate, randomised experimental conditions including: control condition (CON); AUG-FB; technical feedback condition (TECH-FB); and CDD. The four conditions were provided with feedback in the following ways: CON, where participants received no feedback on their immediate performance; AUG-FB, where participants received their sprint times immediately after performance and repeated again prior to the subsequent trial; TECH-FB, where participants received individualised technical feedback before each sprint and reminded again prior to the next sprint by a sprint coach, based on the athlete's running performance. Examples of technical feedback included: '*focus on making a 90-degree angle and driving through with your arms*' and '*focus on driving your knees and contacting the ground hard with your foot*'. The CDD condition involved participants completing the sprints against another athlete in a head-to-head race-like format. Athletes were matched based on their running speed recorded during the familiarisation to ensure competitiveness was maintained throughout each drill. At the beginning of each condition, a 1-10 visual analogue scale was used to assess muscle soreness (1 = "no soreness", 10 = "very, very sore") to monitor recovery between testing sessions [19]. The participants then completed a standardized warm-up, followed by maximum sprint (MS), curved agility sprint (CAS) and a repeated sprint ability (RSA) test. A countermovement jump test (Yard Stick, Swift Performance, Australia) was also conducted to monitor recovery between each type of sprint test, with participants required to reproduce their baseline jump performance, and further rest was provided if required. Following the final sprint test, intrinsic motivation inventory (IMI) and sports emotion questionnaire (SEQ) were undertaken to examine the participant's mood and motivation post-performance.

Sprint Tasks

The MS test was conducted using electronic timing gates (Speedlight Pro, SWIFT Performance Equipment, Lismore, Australia), with splits at 5m, 10m and 20m. This test was completed three times with 3 min rest between each trial with the best score for each time used for analysis. The CAS test required participants to run in a C-shaped curve around a middle marker as quick as possible. Timing gates were set at the start, middle (peak of curve, 15m forward and 5m out) and end of the 30m sprint, which was adapted from Filter, Olivares, Santalla, Nakamura, Loturco and Requena [20]. This test was completed four times in total, with two trials in one direction and the remaining two returning to the start enabling two trials alternating in the left and right directions. Between each trial, participants were also given 3 min rest with the best time (seconds) for each direction used for analysis. The repeated sprint ability (RSA) test consisted of 12x20m sprints with timing gates positioned at the start and finish lines, departing every 20-seconds, which was selected due to its representativeness of the distances and work-to-rest ratio experienced during team sport [21]. Participants were instructed that they would perform between 10-14 sprints to minimise the influence of pacing [22]. Average sprint time (seconds), performance decline (%) and accumulated scores of ratings of perceived exertion (RPE) using the 6-20 scale [23] were collected. In each sprint test, the participants were instructed to start from a standing position approximately 30 cm behind the start line, and to initiate their own sprint at maximum effort past the final gate.

Questionnaires

The IMI was undertaken to provide knowledge on participant's intrinsic motivation whilst completing each task and how they reflected on their performance. This questionnaire required participants to rate statements on a scale of 1-7 that related to their interest/enjoyment, perceived competence, effort/importance and pressure/tension [24]. The SEQ was completed at the end of every testing session and required participants to rate on a 1-4 Likert scale regarding how they felt following their performance in relation to the listed emotions (0 = "Not at all" to 4 = "Extremely") [13]. This questionnaire was completed to enable an understanding of the participant's emotions following the full testing session completed under a specific feedback condition.

Statistical Analysis

Descriptive statistics (mean ± standard deviation) for all feedback conditions and mean differences (95% confidence interval) between conditions were calculated. Data was assessed for normality via the Shapiro-Wilks test. For parameters that were normally distributed, a one-way analysis of variance (ANOVA) was used to compare between groups (CON, AUG-FB, TECH-FB and CDD) for all dependent variables. For parameters that were departed from the norm, a Friedman test was conducted. Post hoc analysis was conducted using the pairwise Bonferroni comparisons and alpha was set at 0.05. Data analysis was conducted using IBM SPSS Statistics Version 28 for Windows (IBM Inc, Chicago, IL, US).

Results

Sprinting Performance

No adverse events were reported during the sprint performance protocols. The completion times of MS in CDD (20m, $p = 0.014$; 10m, $p = 0.024$) and AUG-FB (20m, $p = 0.034$; 10m, $p = 0.04$) were significantly faster than TECH-FB (Table 1). Similarly, CDD was also faster than TECH-FB during the 5m splits ($p = 0.01$; Table 1). There were no other differences found between feedback conditions ($p>0.05$; Table 1).

With respect to CAS, both CDD (15m, $p = 0.005$; 30m, $p = 0.008$) and AUG-FB (15m, $p = 0.001$; 30m, $p = 0.006$) conditions were significantly faster than TECH-FB (Table 1). For 30m, AUG-FB ($p = 0.012$) was significantly faster than CON, whilst no other differences were found between the other conditions for 30m and 15m sprint times ($p>0.05$, Table 1).

The average RSA 20m sprint time ($p = 0.25$), percentage decrement ($p = 0.37$) and session sum of RPE ($p = 0.80$), revealed no significant differences between feedback approaches (Table 1).

Table 1 around here

Intrinsic Motivation Inventory

The CON condition resulted in significantly lower enjoyment scores compared with all other conditions (vs AUG-FB, $p = 0.001$; vs CDD, $p = 0.005$; vs TECH-FB, $p = 0.027$; Table 2). The AUG-FB condition demonstrated significantly higher scores for both effort ($p = 0.008$) and value ($p = 0.043$) when compared to the CON condition (Table 2). No other differences were found across conditions for effort, value, or perceived competence ($p > 0.05$; Table 2).

Table 2 around here

Sports Emotion Questionnaire

The measures of dejection and anger were not normally distributed, and thus a Friedman test was conducted for these outcome measures. There was a significant difference for anxiety (p

= 0.034) between the feedback conditions, however the post hoc test revealed no significant differences between conditions (Table 3). Similarly, no significant differences were found for dejection (p = 0.301), excitement (p = 0.383), anger (p = 0.791) or happiness (p = 0.692) across the various feedback conditions (Table 3).

Table 3 around here

Level of precision

Mean differences between conditions for all measures are reported in Table 4. The level of precision confirms the comparisons reported above, with narrower 95% confidence intervals for parameters exhibiting significant differences between conditions.

Table 4 around here

Discussion

The current study showed significantly faster sprint times in AUG-FB than TECH-FB. Additionally, CDD resulted in faster sprint times compared to TECH-FB and had a more profound effect on motivation states. Higher motivational states and enjoyment levels were evident in all feedback conditions when compared to the CON condition, while receiving some feedback induced greater effort and value scores in comparison. However, affective states (e.g., anxiety, dejection, excitement, anger, or happiness) of athletes were comparable between conditions. Together, these findings suggest that providing augmented feedback or incorporating CDD activities into conditioning tasks benefits both sprint performance and motivational states of highly trained female athletes.

Providing athletes with their sprint time (AUG-FB) or placing them in a competitive situation (CDD), resulted in faster sprint times compared TECH-FB. This finding is in line with previous studies, highlighting the acute benefit of instantaneous augmented KR feedback on athletic performance [4,7,8]. However, it is worth noting that most research examining the acute effect of augmented feedback examined jump performance, rather than sprinting, and in male participants [4,7,8]. Weakley, Till, Sampson, Banyard, Leduc, Wilson, Roe and Jones [5] reported that male rugby union players improved their sprint performance following the provision of sprint times after each trial (i.e., augmented KR feedback) during 4-weeks of training. Throughout the study, Weakley, Till, Sampson, Banyard, Leduc, Wilson, Roe and Jones [5] identified players within the feedback group frequently compared their sprint times and actively competed among each other, which may also explain improved sprint performance during CDD activities in the current study. In fact, CDD is a strategy often incorporated for athletes to maintain high motivation, mimic competitive gameplay, and optimize performance transfer to matches, which can enhance athletic performance [12]. Collectively, competition against oneself (e.g., previous sprint times; AUG-FB) or teammates (CDD) suggests higher levels of motivation in athletes, thereby partially explaining improvement in sprint time compared with technical feedback.

The AUG-FB and CDD promotes an externalized focus (EF) of attention [7], which may also explain improvement in sprint performance in our study. Inducing an EF of attention involves athletes' directing their attention to external factors of a desired outcome, such as the movement effects, task, or environment, thereby allowing for unconscious self-organization of motor patterns to regulate efficient movement [7]. During the feedback conditions of the current study, athletes' attention was likely directed towards either the outcome (i.e., time), or competitiveness (i.e., to beat their opponent) of their sprint task. Alternatively, technical feedback, given as technique-focused cues, is thought to have induced an internal focus of attention in this study by redirecting participant's attention to specific body segment movements within their sprint performances [7]. Thus, it is likely that the AUG-FB and CDD exhibited an EF of attention in our study, thereby enhancing sprint performance in female athletes.

Regarding motivational states, we found an increase in enjoyment during all feedback interventions compared with CON, with significant increases in ratings of effort and value also observed during AUG-FB condition. Whilst the novelty of our parameter selection makes comparison to previous studies difficult, proposed mechanisms such as improved motivation and competitiveness with feedback, provide sufficient evidence for these findings. Wälchli, Ruffieux, Bourquin, Keller and Taube [25] highlight that augmented feedback acts on motivation, whereby participants try to outperform their foregoing performance or the performance of an opponent. When participants succeed, or they receive positive feedback, enjoyment is increased. Furthermore, competitiveness is also increased which allows athletes to maintain high motivation and effort toward greater exercise intensity [12], substantiated in the current study, within highly trained female athletes.

Previous research has shown that non-elite athletes have reported increased anxiety and dejection when they receive negative feedback or fail to achieve their outcome goal [13]. Therefore, we initially hypothesized that athletes may feel higher levels of anxiety and dejection if they were unable to improve on their prior sprint time or outperform an opponent. However, the current findings did not support our hypothesis, with similar affective states reported between feedback conditions. One explanation may be due to the professionalism of participants who are training and playing at a highly trained or national level. Fishbach, Eyal and Finkelstein [26] proposed that experts tend to seek more negative feedback on their performance to motivate themselves, while novice athletes may experience feedback-induced anxiety and dejection. Additionally, professional athletes are likely more familiar with receiving constructive or negative feedback (either from a coach or in-game situations) and may have developed a resistance to the emotional effects of negative performance results (i.e., anxiety and dejection; [27]. Additionally, no differences were seen across positive emotions (i.e., happiness and excitement), although these affective states are not inherent for successful performance [28]. It is recommended that further research investigates the motivational and affective mood states of female athletes during both testing and training environments.

Finally, the RSA showed no significant differences between feedback conditions, which contrasts prior research that highlighted the beneficial effects of KR feedback for attenuating the swimming performance during an RSA protocol [10]. Research has shown that in fatiguing exercises (e.g., multiple cycle sprints), power output is adjusted to limit the development of peripheral fatigue beyond a constant threshold [29], possibly due to pacing effects evident during repeated sprint ability tasks [22]. Thus, it is possible that the athletes in our study may have paced themselves during the RSA protocol, exhibiting comparable measures between conditions. However, more research is necessary to better understand the influence of augmented feedback on maximal effort performance whilst fatigued.

While this study is the first to examine the influence of feedback on sprint performance and motivational states in highly trained female athletes', it is important to note the limitations. Firstly, the homogeneity of highly trained female athletes may limit the generalisability to male athletes, and those with different skill levels. Secondly, a pacing effect may have been present during the repeated sprint task, impacting the level of fatigue experienced by athletes. However, effort was made to control pacing by recording RPE, and blinding athletes to the number of sprints. Third, athletic performance may have been affected by hormonal fluctuations in female athletes [30]. Nonetheless, we attempted to control for this effect by randomising feedback conditions irrespective of the stage of the menstrual cycle. Fourth, we did not collect data on ethnicity. Thus, it is recommended that future research examine the acute effect of augmented feedback across different stages of the menstrual cycle, or irregular cycles and the impact by contraceptives, between various ethnicities. Finally, randomisation was completed by the researcher and allocation was not concealed, and future research in this area should consider rigorous randomisation procedures to minimise bias.

Practical applications

Augmented feedback in the form of KR or CDD instantaneously enhanced sprint performance in highly trained female athletes than TECH-FB. Thus, coaches should consider incorporating augmented feedback and drills that promote competitiveness in testing and training environments to improve immediate sprint performance by enhancing the motivation of in this population of athletes.

Conclusion

In conclusion, this study showed sprint performance was improved when female athletes were provided with augmented KR feedback or placing them in a CDD task when compared to technical feedback. Additionally, augmented feedback (either technical or terminal) was shown to have beneficial effects on athletes' motivational states.

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Table 1. Mean and standard deviation results of maximum linear speed, curved agility sprint and repeated sprint ability tests for the control (CON), augmented (AUG-FB), technical feedback (TECH-FB) and competition-driven drill (CDD) feedback conditions

	AUG-FB	CDD	TECH-FB	CON
Maximum linear speed				
20m (s)	3.54 ± 0.16*	3.54 ± 0.16*	3.64 ± 0.16	3.58 ± 0.17
10m (s)	2.02 ± 0.09*	2.03 ± 0.09*	2.09 ± 0.09	2.04 ± 0.10
5m (s)	1.17 ± 0.07	1.18 ± 0.05*	1.22 ± 0.06	1.18 ± 0.07
Curved agility sprint				
30m (s)	5.42 ± 0.20*^	5.38 ± 0.26*	5.61 ± 0.21	5.57 ± 0.24
15m (s)	2.94 ± 0.11*	2.92 ± 0.14*	3.02 ± 0.14	3.00 ± 0.14
Repeated sprint ability				
Average time	4.00 ± 0.24	4.06 ± 0.31	4.07 ± 0.17	4.11 ± 0.27
PD (s)	10.58 ± 4.74	13.04 ± 5.36	12.56 ± 5.53	11.15 ± 3.70
Total RPE	136.6 ± 29.6	130.4 ± 34.1	131.7 ± 23.5	135.4 ± 35.7

PD – performance decrement; RPE – Rating of Perceived Exertion.

**p<0.05 compared to TECH-FB; and ^p<0.05 compared to CON.*

Table 2. Mean and standard deviation of Intrinsic Motivation Inventory (IMI) results for the control (CON), augmented (AUG-FB), technical feedback (TECH-FB) and competition-driven drill (CDD) feedback conditions

	AUG-FB	CDD	TECH-FB	CON
Enjoyment	5.5 ± 0.7*	5.6 ± 0.7*	5.6 ± 0.6*	4.7 ± 1.0
Effort	6.3 ± 0.7*	6.3 ± 0.4	6.2 ± 0.7	6.0 ± 0.6
Value	6.5 ± 0.5*	6.5 ± 0.5	6.5 ± 0.7	4.8 ± 2.1
Perceived competence	4.3 ± 1.5	4.1 ± 1.4	4.4 ± 1.0	3.8 ± 1.1

**$p < 0.05$ compared to CON condition*

Table 3. Mean and standard deviation of Sports Emotion Questionnaire (SEQ) results for the control (CON), augmented (AUG-FB), technical feedback (TECH-FB) and competition-driven drill (CDD) feedback conditions

	AUG-FB	CDD	TECH-FB	CON
Anxiety	0.7 ± 0.5	0.9 ± 0.7	1.1 ± 0.6	0.8 ± 0.5
Dejection	0.2 ± 0.2	0.3 ± 0.4	0.3 ± 0.3	0.3 ± 0.5
Excitement	1.5 ± 1.3	1.8 ± 1.1	1.6 ± 1.0	1.4 ± 1.1
Anger	0.1 ± 0.2	0.1 ± 0.2	0.2 ± 0.2	0.2 ± 0.3
Happiness	1.8 ± 1.1	1.8 ± 1.1	1.6 ± 1.0	1.6 ± 1.1

Table 4. Mean differences (95% confidence interval) between the control (CON), augmented (AUG-FB) and competition-driven drill (CDD) feedback conditions for all physical performance and affective mood states

	CDD vs CON	AUG-FB vs CG	TECH-FB vs CG	CDD vs AUG-FB	CDD vs TECH-FB	AUG-FB vs TECH-FB
Maximum linear sprint						
20m (s)	-0.04 (-0.08, 0.01)	-0.04 (-0.09, -0.002)	0.07 (-0.02, 0.16)	0.01 (-0.04, 0.57)	-0.11 (-0.17, -0.04)	-0.11 (-0.19, -0.04)
10m (s)	-0.01 (-0.05, 0.20)	-0.02 (-0.06, 0.01)	0.05 (-0.01, 0.10)	0.01 (-0.03, 0.05)	-0.06 (-0.10, -0.02)	-0.07 (-0.12, -0.02)
5m (s)	-0.01 (-0.04, 0.03)	-0.02 (-0.05, 0.01)	0.04 (-0.01, 0.08)	0.01 (-0.02, 0.04)	-0.04 (-0.07, -0.02)	-0.05 (-0.09, -0.01)
Curved agility sprint						
30m (s)	-0.19 (-0.32, -0.06)	-0.15 (-0.23, -0.07)	0.04 (-0.11, 0.18)	-0.04 (-0.14, 0.06)	-0.23 (-0.33, -0.12)	-0.19 (-0.26, -0.11)
15m (s)	-0.07 (-0.14, -0.01)	-0.06 (-0.12, -0.01)	0.02 (-0.06, 0.11)	-0.01 (-0.05, 0.03)	-0.10 (-0.14, -0.05)	-0.09 (-0.13, -0.04)
Repeated sprint ability						
Average time (s)	-0.05 (-0.14, 0.05)	-0.10 (-0.17, -0.04)	-0.03 (-0.16, 0.09)	0.06 (-0.04, 0.16)	-0.01 (-0.16, 0.13)	-0.07 (-0.20, 0.05)
PD (s)	1.89 (-1.45, 5.22)	-0.57 (-1.91, 0.77)	1.41 (-2.15, 4.97)	2.47 (-1.63, 6.56)	0.48 (-3.81, 4.77)	-1.98 (-5.56, 1.59)
Total RPE	-5.00 (-22.28, 12.28)	1.17 (-11.26, 13.60)	-3.72 (-17.80, -10.37)	-6.17 (-17.60, 5.27)	-1.28 (-22.11, 1.95)	4.88 (-10.92, 20.68)
IMI						
Enjoyment	0.92 (0.50, 1.34)	0.85 (0.50, 1.19)	0.91 (0.33, 1.48)	0.08 (-0.14, 0.29)	0.02 (-0.44, 0.47)	-0.06 (-0.46, 0.34)
Effort	0.40 (0.18, 0.62)	0.35 (0.16, 0.53)	0.23 (-0.07, 0.54)	0.06 (-0.18, 0.29)	0.17 (-0.09, 0.43)	0.11 (-0.18, 0.40)
Value	1.79 (0.49, 3.08)	1.78 (0.59, 2.97)	1.74 (0.36, 3.13)	0.01 (-0.25, 0.27)	0.04 (-0.30, 0.38)	0.03 (-0.32, 0.39)
PC	0.35 (-0.13, 0.83)	0.43 (-0.08, 0.95)	0.58 (0.08, 1.09)	-0.08 (-0.62, 0.46)	-0.23 (-0.99, 0.52)	-0.15 (-0.84, 0.54)
SEQ						
Anxiety	0.05 (-0.21, 0.30)	-0.06 (-0.28, 0.15)	0.30 (-0.01, 0.61)	0.11 (-0.12, 0.34)	-0.25 (-0.57, 0.07)	-0.36 (-0.66, -0.06)
Dejection	-0.05 (-0.26, 0.16)	-0.11 (-0.29, 0.07)	-0.003 (-0.28, 0.28)	0.06 (-0.07, 0.20)	-0.05 (-0.23, 0.14)	-0.11 (-0.29, 0.07)
Excitement	0.52 (0.18, 0.86)	0.16 (-0.30, 0.62)	0.20 (-0.29, 0.69)	0.36 (0.05, 0.67)	0.32 (-0.32, 0.96)	-0.04 (-0.73, 0.66)
Anger	-0.11 (-0.27, 0.05)	-0.11 (-0.28, 0.06)	-0.02 (-0.26, 0.23)	<0.01 (-0.06, 0.06)	-0.10 (-0.29, 0.10)	-0.10 (-0.28, 0.09)
Happiness	0.17 (-0.09, 0.42)	0.14 (-0.30, -0.57)	-0.03 (-0.49, 0.42)	0.03 (-0.48, 0.55)	0.20 (-0.29, 0.69)	0.17 (-0.45, 0.78)

IMI – Intrinsic Motivation Inventory; SEQ – Sports Emotion Questionnaire; PD – percentage decrement; PC – perceived competence

Table 1 | CONSORT checklist of information to include when reporting randomised crossover trials

Section/topic	Item No	Description	Page No*
Title†	1a	Identification as a randomised crossover trial in the title	1
Abstract†	1b	Specify a crossover design and report all information outlined in table 2	2
Introduction:			
Background‡	2a	Scientific background and explanation of rationale	3, 4
Objectives‡	2b	Specific objectives or hypotheses	4
Methods:			
Trial design†	3a	Rationale for a crossover design. Description of the design features including allocation ratio, especially the number and duration of periods, duration of washout period, and consideration of carry over effect	4
Change from protocol‡	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	NA
Participants‡	4a	Eligibility criteria for participants	4
Settings and location‡	4b	Settings and locations where the data were collected	4
Interventions†	5	The interventions with sufficient details to allow replication, including how and when they were actually administered	4, 5
Outcomes‡	6a	Completely defined prespecified primary and secondary outcome measures, including how and when they were assessed	5, 6
Changes to outcomes‡	6b	Any changes to trial outcomes after the trial commenced, with reasons	NA
Sample size†	7a	How sample size was determined, accounting for within participant variability	4
Interim analyses and stopping guidelines‡	7b	When applicable, explanation of any interim analyses and stopping guidelines	NA
Randomisation:			
Sequence generation‡	8a	Method used to generate the random allocation sequence	4
Sequence generation‡	8b	Type of randomisation; details of any restriction (such as blocking and block size)	4
Allocation concealment mechanism‡	9	Mechanism used to implement the random allocation sequence§ (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	4
Implementation†	10	Who generated the random allocation sequence,§ who enrolled participants, and who assigned participants to the sequence of interventions	4
Blinding‡	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those assessing outcomes) and how	4
Similarity of interventions‡	11b	If relevant, description of the similarity of interventions	NA
Statistical methods†	12a	Statistical methods used to compare groups for primary and secondary outcomes which are appropriate for crossover design (that is, based on within participant comparison)	6
Additional analyses‡	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	6
Results			
Participant flow (a diagram is strongly recommended)†	13a	The numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome, separately for each sequence and period	4
Losses and exclusions†	13b	No of participants excluded at each stage, with reasons, separately for each sequence and period	
Recruitment‡	14a	Dates defining the periods of recruitment and follow-up	4
Trial end‡	14b	Why the trial ended or was stopped	NA
Baseline data†	15	A table showing baseline demographic and clinical characteristics by sequence and period	4
Numbers analysed†	16	Number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	4
Outcomes and estimation†	17a	For each primary and secondary outcome, results including estimated effect size and its precision (such as 95% confidence interval) should be based on within participant comparisons.¶ In addition, results for each intervention in each period are recommended	7
Binary outcomes‡	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	NA
Ancillary analyses‡	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing prespecified from exploratory	NA
Harms†	19	Describe all important harms or untended effects in a way that accounts for the design (for specific guidance, see CONSORT for harms[32])	6
Discussion:			
Limitations†	20	Trial limitations, addressing sources of potential bias, imprecision, and if relevant, multiplicity of analyses. Consider potential carry over effects	8, 9
Generalisability‡	21	Generalisability (external validity, applicability) of the trial findings	9
Interpretation‡	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	7, 8 and 9
Other information:			
Registration‡	23	Registration number and name of trial registry	4
Protocol‡	24	Where the full trial protocol can be accessed, if available	NA
Funding‡	25	Sources of funding and other support (such as supply of drugs), role of funders	NA

CONSORT=Consolidated Standards of Reporting Trials.
*Note: page numbers are optional depending on journal requirements.
†Modified original CONSORT item.
‡Unmodified CONSORT item.
§Random sequence here refers to a list of random orders, typically generated through a computer program. This should not be confused with the sequence of interventions in a randomised crossover trial, for example receiving intervention A before B for an individual trial participant.
¶A within participant comparison takes into account the correlation between measurements for each participant because they act as their own control, therefore measurements are not independent.