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The Effect of an Off-Feet Conditioning Protocol on Performance and Training Load Response to Intermittent Sprint Training Compared to an Equivalent Running Based Protocol

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ABSTRACT

Training for maximal intensity actions can lead to muscle damage, muscle soreness, and neuromuscular fatigue if not carefully managed. Due to this potential impact, coaches sometimes look to off-feet conditioning (OFC) as an alternative.
A training intervention compared an OFC protocol using cycle ergometer sprints with an equivalent running protocol. Seventeen (17) participants volunteered and completed the study. Following baseline testing participants were divided into a cycle (BIKE) or shuttle (RUN) group. Training intervention was 10-12 6 s sprint efforts with 80-seconds recovery.
Post testing showed significant time effect for absolute (p=0.045), and substantial change for Mean Power (p=0.0606) for BIKE. There was a significant time effect in the shuttle test (p=0.008) for RUN. Substantial, non-significant improvements in performance were found in 10 m (p=0.261) 20 m time (p=0.307) and Peak Power (p=0.160) for BIKE. RPE was significantly higher in BIKE (p<0.001). Next-day soreness was significantly higher for RUN (p<0.001).
Neither intervention negatively affected any measure. The cycle protocol may benefit sprint running performance. This form of training may mitigate the impact of high volumes of run-based training by decreasing eccentric loading thus reducing soreness. OFC may be useful for maintaining performance without adding mechanical stress on the lower body.

Keywords: Sport, conditioning, testing, training, cycling, open-skill

INTRODUCTION

Open skill sports such as team and combat sports are characterized by repeated, brief, high intensity activity, interspersed with lower intensity activities of mixed duration (47).These maximal intensity efforts tend to be less than 6 s in length with energy supplied predominately from phosphagen pathways (13). Recovery of the phosphagen energy system is dependent on the breakdown and resynthesis of Phosphocreatine (PCr) (23). Maximal intensity actions may be general in nature, such as sprinting or jumping (13), sports specific, such as dribbling the ball in Soccer (12), or have extreme levels of body contact in collision sports like Rugby (44) or combat sports such as Judo (17).

Although training to improve these maximal intensity moments in team sports is a necessary component of any physical preparation program, it can also lead to performance limiting responses such as muscle damage (2), delayed onset muscle soreness (25), negative changes to hormonal balances (29), and neuromuscular fatigue (40). Due to this potential cost of excessive maximal intensity training, coaches sometimes look to non-impact training modes, in an attempt to mitigate potential negative impact such as soreness (22). This is particularly important in sports that include a high number of collisions and sustained body contact that can add significantly to the physical toll of training (41). Cross-training, as it is commonly known, is defined as participating in alternative training, or combining alternative training with normal training methods (31). Cross-training may be used to develop physical, tactical, technical or physiological performance and may include involvement in alternative sports (50). Due to this broad definition of cross-training, the term Off-Feet Conditioning (OFC) is sometimes used to describe non-weight bearing training to specifically sustain or improve weight bearing physical performance (16).

Comparisons between different conditioning modes have generally shown training benefits will always be greater in the specific training activity; for example cycling training will improve cycling performance and running training will improve running performance (39). Whilst research is more common in relation to performance transfer between training modes in aerobic dependent sports such as triathlon (9, 14, 27), research into open skill sports with greater phosphagen energy requirements is less prevalent. Reduced post training soreness has been cited as a benefit of using OFC training methods to mitigate the impact of excess eccentric contractions (37). Controlling muscle soreness becomes more important as training volume increases (47). These findings have not been universal. Uphill running, another training tool to reduce impact on the lower body, had greater performance improvements when compared with sprint interval cycling (28). Another study found that sprint cycling resulted in a greater neuromuscular load on the knee extensors than running training with the same load (49).

Recently, maximal intensity training on cycle ergometers appears to have become more popular as a training and testing tool (38, 51). Existing research has shown some potential transfer benefits of maximal intensity OFC for maximal and ballistic performance. Improvements have been shown in jump performance (35), and sprint running performance (48). Interestingly improvements in endurance measures of performance from maximal intensity OFC, such as multi-stage shuttle test (21), VO2MAX (8), and intermittent running performance (26) have also been found.

One method of training that may be suitable for maximal intensity OFC is Intermittent Sprint Training (IST) (20). This form of training comprises short duration (≤10 s) maximal efforts with rest periods of greater than a minute. The primary goal of IST is to improve maximal intensity performance with minimal decrease in power output on each repetition (4). Therefore, the goal of this study was to analyse the effect of an IST protocol performed on a cycle ergometer with an equivalent volume running based training intervention, to determine the effect on various measures of performance. In addition, the study also looked at differences in perceived exertion and soreness between the two training modalities.

METHODS

Design

A training intervention study comparing an OFC program in the form of an IST protocol using maximal effort sprints on a cycle ergometer with a running protocol using identical volume, duration, and recovery was conducted. After baseline testing, participants were randomly divided into a cycle training (BIKE) group or shuttle run (RUN) group. The intervention involved 10 training sessions conducted over a four-week block.

Participants

Nineteen junior Rugby League players (17.6 ±1.5 y, 88.1 ±13.6 kg, 174.3 ±9.7 cm) volunteered for the study. Two participants failed to complete the required number of training sessions and were removed from the study cohort, leaving a total of seventeen participants. All players were members of a national level youth program aligned with a professional Rugby League club with an average of 2.2 (±0.7) years in the program.

The purpose and procedures were explained verbally to the participants by the researchers. Written copies of the procedures were provided for the participants to peruse, and time was allowed for questions. Informed written consent was obtained according to the Declaration of Helsinki after gaining approval from the University Human Research Ethics Committee (HREC(Health)#2019#05).

Testing

Baseline testing was conducted one week prior to the start of the intervention. Players were familiar with all testing protocols as part of normal training activities. Testing was conducted in two one-hour sessions. The 6 s cycle sprint (6sCS), and countermovement jump (CMJ), were conducted in a sports science laboratory during the first session. A 10-20 m sprint, six-second shuttle sprint (6sSS) and 1.2 km time trial running tests were completed at the players regular training ground, one hour after the completion of laboratory testing during the second session. Post testing was conducted 72 hours after the final training session using the exact same procedures at the same time of day as baseline testing.

Cycle Testing: A baseline 6sCS was performed on a cycle ergometer (WattBike Pro, Nottingham UK). After calibrating the bikes according to manufacturer recommendations and individualising bike set up, the athletes performed a standardized warm up consisting of 5 minutes of submaximal cycling, maintaining 80rev·min^{-1} at a resistance set according to manufacturer recommendations based on the subject's weight, age, and sex. Participants performed a 2 s maximal acceleration on the 3rd, 4th and 5th minute of the warm-up. This was followed by three-minutes of complete rest sitting quietly on the bike. Participants set up with the preferred leg forward at approximately 45 degrees below vertical and the hands on the lower racing handlebar position. After a 5 s countdown, the participants performed a maximal effort 6 s sprint from a stationary start, remaining in a seated position. A second maximal effort was completed after 90 s passive recovery. Encouragement was provided from the testers on each sprint effort. This protocol has been shown to be reliable and reproducible in male Rugby players (11). Peak power output (PPO), relative peak power output (rPPO), mean power output (MPO) and relative mean power output (relMPO) were recorded. A CV for PPO and MPO were calculated at 3.5%, and 3.0% respectively.

Jump Testing: Following ten-minutes of complete rest, participants completed the CMJ. Jump performance was assessed using a linear transducer (Gymaware, Kinetic Canberra Australia) attached to a dowel (weight ~200 grams) held across the shoulders, behind the neck. This apparatus has been shown to be a valid measurement tool for jump performance (36). The participants descended quickly to a self-selected point by bending at the hips and knees, then immediately jumped as high possible. Four warm up jumps were completed, followed by four test repetitions with 15 s between efforts. Jump height, and mean concentric velocity were recorded with the best results used for analysis. CV was calculated at 5.1% for mean velocity and 6.8% for jump height.

Sprint Testing: A standardised warmup was conducted before the 10 and 20 m sprint test. The warmup included six-minutes of jogging, lower body mobility exercises, skipping, sideways shuffle and marching drills over 10 m, practice starts over five-metres, and several 20 m runs at increasing speeds (i.e., 70%, 80%, 90%). Times were recorded using wireless, dual beam timing equipment (SmartSpeed, Fusion Sport, Sumner Park AUS). Timing gates were set up on the start line, 10 m, and 20 m marks. The participants started 50 cm behind the first gates to ensure the equipment was not tripped inadvertently (43). When ready, the subject sprinted as fast as possible between the three sets of timing gates. Three trials were performed with approximately 3 minutes recovery between efforts. CV was calculated at 2.5% for 10 m and 2.2% for 20 m.

Shuttle Tests: The 6 s shuttle sprint (6sSS) was carried out on a grass track. The 6sSS was based on a 10 m "out and back" sprint outlined in previous literature (52). Markers were placed at 1 m intervals from 0 to 10 metres. A full practice trial was completed at approximately 80% effort to ensure participants were comfortable with turning technique and athletes were given time to practice turning if required. Unlike the test on which it was based which used a single out and back sprint, the participants were required to run back and forth between the start line and the 10 m line for 6 s, aiming to cover the maximum distance possible. Participants were required to place one foot on or behind the line when changing direction. After 90 s passive recovery, a second repetition was performed. Distance covered in metres was recorded via a raised camera and viewed frame by frame (Nikon D5500, Nikon Tokyo Jap). CV for this test was calculated to be 2.7%.

1.2km Time Trial: The 1.2 km shuttle run time trial was conducted on a grass field. Markers were placed at the start, 20 m, 40 m and 60 m marks. The participants ran to the 20 m line and back to the start, to the 40 m line and back, then the 60 m and back. This was repeated five times non-stop as quickly as possible. Reliability for the 1.2 km time trial has been recorded elsewhere with an ICC of 0.99 and CV of 10.6% (7).

Training Intervention

An IST intervention comprising 10 training sessions over a four week period was completed. Participants were divided into two training groups via a selective process where the highest performing subject on the 6sCS was assigned to one group, the second highest to the other group, and so on. The BIKE group completed the 6sCS, whilst the RUN group completed repetitions of the 6sSS. The training session protocols were identical. Training was carried out simultaneously with each session performed at the same time of day to prevent any impact of diurnal changes. The training intervention used a ramped protocol. In the first three sessions ten repetitions of the 6sCS or 6sSS with 80 s recovery were completed, the 4-6th sessions 11 repetitions were completed and the 7-9th sessions 12 repetitions were completed. For the final session the number of repetitions returned to ten. Recovery duration of 80 s was based on recommendations in previous research (42). There was 48 hours between sessions. Participants were verbally encouraged to perform maximally on all efforts. No other conditioning or speed-based training was conducted during the intervention.

At the completion of each training session, Ratings of Perceived Exertion using the Borg scale (6), was recorded 15 min after the completion of the session. A Likert scale to express lower body muscle and joint soreness was recorded using a 0-10 scale, with 0 being no pain and 10 being extreme soreness which was been validated previously (15), 24 hours after the session.

Statistical Analysis

Mean, Standard Deviations, absolute change and % change in performance were recorded for each of the interventions. Smallest worthwhile change (SWC) was calculated as the standard deviation multiplied by 0.2. A 2x2 ANOVA [time (pre and post) and treatment (run and bike)] was used to determine differences between the two training interventions. Where significant differences were detected, a post-hoc T-Test was completed. A two sample T-Test assuming unequal variance was used to determine group differences for perceived exertion and soreness. Effect sizes and 95% confidence intervals were calculated. The level of significance was set at $p \leq 0.05$.

RESULTS

Pre and post means, standard deviation, percentage change in performance and SWC are outlined are outlined in Table 1. Effect sizes and 95% confidence intervals for all results are outlined in Figure 1 with all time and treatment effects labeled. Of note, there was a significant time by treatment effect for absolute MPO (ES = 1.07 [0.03, 2.12], p=0.045) with a difference of 83.6 W in favour of the Bike group. There was also a significant interaction effect for the 6sSS (ES = 1.9 [0.65, 3.15] p=0.002) with a difference of 1.71 m in favour of the RUN group. The interaction effect for relative MPO was p=0.061 (ES 1.05 [-0.05, 1.81]) whereby the BIKE group improved by 0.88 $W \cdot kg^{-1}$ more than the run group. There also was a substantial but not significant improvement in PPO (ES =0.72 [-0.32, 1.77] p=0.160). There were substantial non-significant improvements in 10 m (0.04 s, p=0.261) and 20 m (0.05 s, p=0.307) times. Changes in sprint performance are outlined in Figure 2. Details of RPE and next day soreness are outlines in Table 2. Post-exercise perceived exertion was significantly higher in the BIKE group compared to the RUN group. Next day perceived soreness was significantly higher for the RUN group compared to the BIKE group.

Table 1. Results following a 10 session 10-12 x 6-s effort training protocol comparing cycle sprints with sprint shuttle sprints.

Test	Pre (SD)	Post (SD)	% Change	SWC
Bike Group				
10 m (sec)	1.76(±0.06)	1.72(±0.11)	2.3	0.022
20 m (sec)	3.02(±0.11)	2.97(±0.11)	1.7	0.022
PPO (W)	1290.4(±158.4)	1436.1(±131.2)	11.3	26.24
MPO (W)	1117.6(±120.1)	1323.0(±136.9)	12.3	27.38
relPPO (W·kg^{-1})	14.4(±2.1)	16.0(±1.2)	11.1	0.24
relMPO (W·kg^{-1})	12.5(±1.8	13.9(±1.6)	11.2	0.32
CMJ height (cm)	44.2(±10.2)	46.7(±2.5)	5.7	0.5
CMJ vel (m·sec^{-1})	2.15(±0.38)	2.21(±0.25)	2.8	0.05
6 s Shuttle (sec)	23.1(±1.5	24.8(±1.5)	7.4	0.3
1.2km TT (sec)	320(±24.8)	312(±23.2)	2.5	4.64
Run Group				
10 m (sec)	1.73(±0.09)	1.74(±0.05)	0.6	0.012
20 m (sec)	2.96(±0.14)	2.96(±0.08)	0	0.016
PPO (W)	1249.9(±188.7)	1323.0(±276.4)	5.8	55.28
MPO (W)	1091.0(±190.2)	1144.6(±231.7)	4.9	46.34
relPPO (W·kg^{-1})	14.8(±1.6)	15.6(±1.9)	5.4	0.38
relMPO (W·kg^{-1})	12.9(±1.6)	13.5(±1.8)	4.6	0.36
CMJ height (cm)	46.8(±4.8)	48.6(±4.4)	3.8	0.88
CMJ vel (m·sec^{-1})	2.28(±0.2)	2.31(±0.11)	1.3	0.022
6 s Shuttle (sec)	22.0(1.5)	25.4(±1.6)	15.5	0.32
1.2km TT (sec)	323(±27.5)	315(±16.0)	2.5	3.20

PPO=Peak Power Output, MPO=Mean Power Output, relPPO=Relative peak Power Output, relMPO=Relative Mean Power Output, CMJ=Countermovement Jump, 1.2kmTT=1.2km time trial

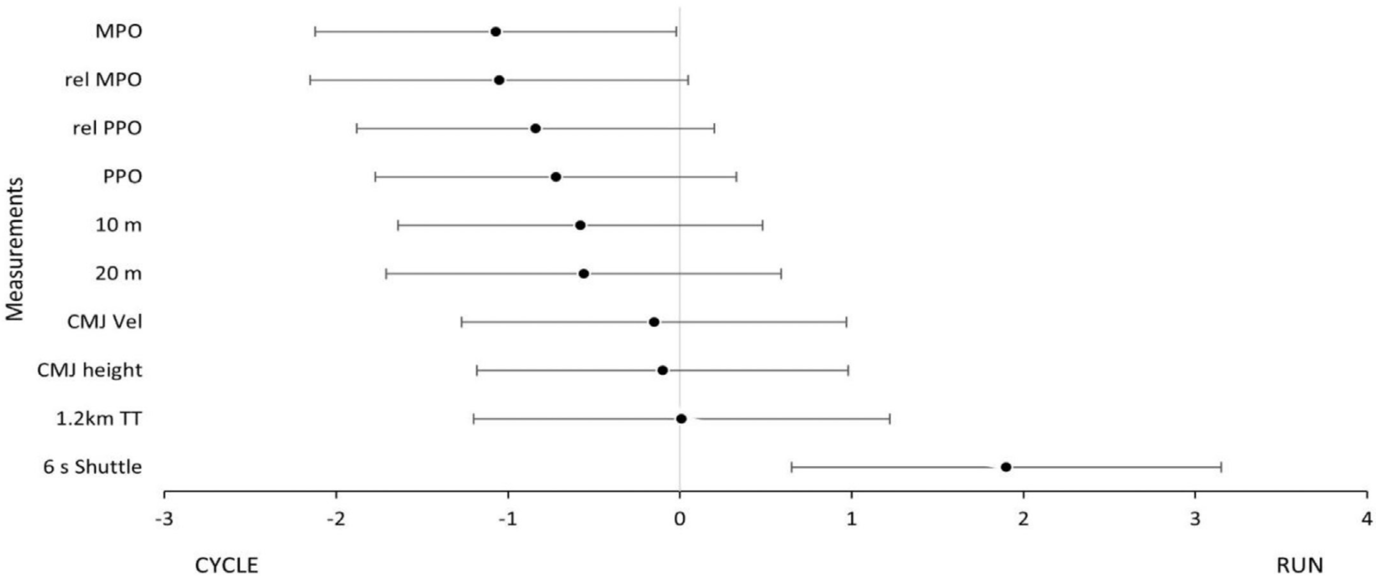

Figure 1. Effect Sizes and 95% Confidence Intervals for Post Testing Results.
PPO=Peak Power Output, MPO=Mean Power Output, rel PPO=Relative peak Power Output, relMPO=Relative Mean Power Output, CMJ=Countermovement Jump, CMJ vel=countermovement jump mean velocity 1.2kmTT=1.2km time trial

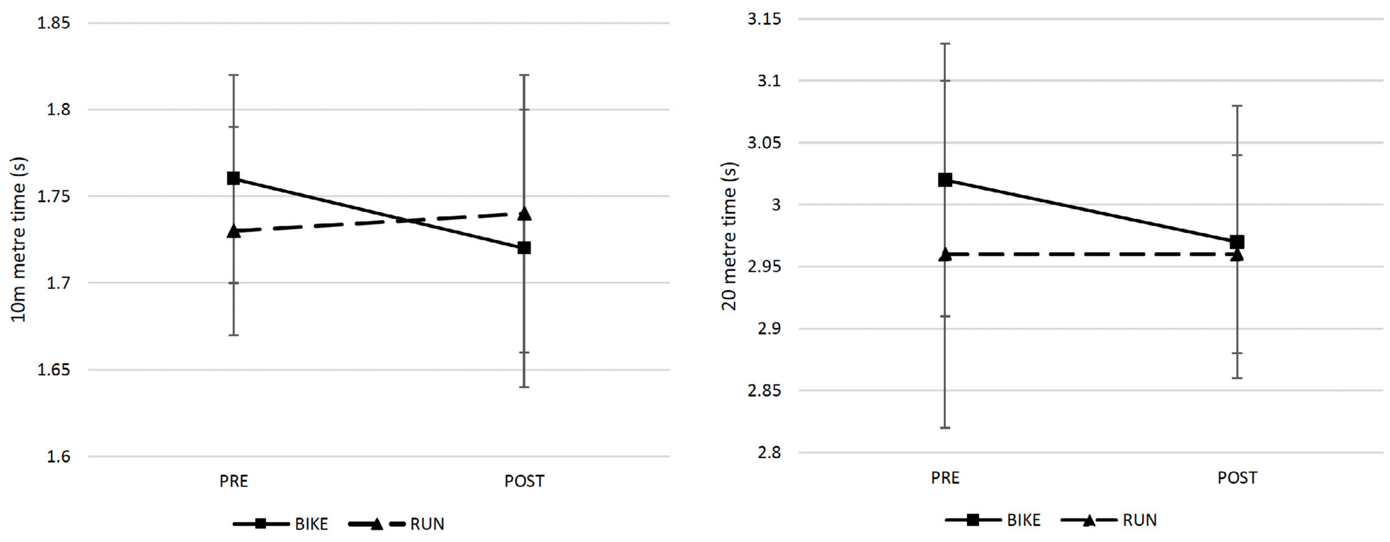

Figure 2. Mean pre and post results for 10m and 20m sprint tests

Table 2. Results of rating of perception exertion and post-training soreness.

Test	BIKE (SD)	RUN (SD)	ES (CI)	*P*
RPE	15.99 (1.3)	14.05 (2.3)	1.02 [0.7, 1.35]	<0.001
Soreness	1.69 (0.89)	4.71 (1.73)	2.19 [1.87, 2.52]	<0.001

RPE = Rating of Perceived Exertion

DISCUSSION

This study compared an IST protocol of OFC with an equivalent running protocol in youth Rugby League players. As expected, the RUN protocol led to a significant improvement in the 6sSS shuttle test whilst the BIKE protocol led to a significant improvement in MPO and substantial but non-significant relMPO as well as substantial improvement in PPO in the 6sCS. Task specificity may account for the level of improved by the two groups. The repeated high intensity sprints on the cycle ergometer is likely to have improved specific force production and efficiency of the quadriceps in the BIKE group (34). Conversely, the RUN group may have developed a more efficient deceleration and re-acceleration pattern after multiple trials of the 6sSS, with a minimum of two changes of direction on every repetition. Previous research has outlined the impact of specificity of training so this result was expected (39). The high number of repetitions, and the high volume of total repetitions; over 100 repetitions, may have led to specific improvement in technique of the two tests leading to a more efficient performance.

Whilst an improvement in task specific performance was to be expected. It is notable however, that a low volume of IST off-feet conditioning; lasting 14-16 min per session, did not create any negative transfer to any of the running tests or the CMJ for the BIKE group. Equally, the RUN protocol did not have a negative impact on any of the results for the 6sCS. High volumes of run training has been shown to have a negative impact on both run and cycle training performance (33). Other research, however, has also shown that cycling performance does not interfere with running technique in highly trained runners (5). The volume of training in this study may have been low enough to prevent any significant interference in cycling or running performance.

Perceived soreness recorded 24 hours post training was significantly higher for the RUN group. This may have occurred due to the higher eccentric load from accelerating and decelerating, as well as stress on the hip, knee and ankle when changing direction in the shuttle run. High volumes of eccentric loading has been previously reported as a cause of muscle soreness in activities with a high frequency of change of direction (47). Cycling, however, is a concentric dominant activity (3) with little to no eccentric loading or impact. Therefore cycling training would not exhibit the same type of stress on the lower body as running training. This may be an important finding for coaches hoping to mitigate the effect of high loads of sprinting, plyometrics and change of direction which are reliant on eccentric loading without a subsequent decrease in performance (46). Conversely, perceived exertion was significantly higher for the BIKE protocol than the RUN protocol. This finding was not surprising as it has been previously reported that RPE is higher in maximum intensity efforts on a cycle ergometer when compared to an equivalent run based protocols (30). Previous research has found similar results, where a cycling protocol using 15 s intervals resulted in greater neuromuscular fatigue of the knee extensors when compared to a work matched running protocol (49). In this particular cohort, a lower familiarity with cycling training compared to running may have contributed to the higher perceived exertion. Local muscular fatigue due to the more concentrated muscle mass involved, in particular the load on the quadriceps muscles, could have played a role in higher RPE reported in this study (8). In team sports, training is usually performed "on-feet" and based around running. The muscular load on the quadriceps in particular would have been unfamiliar for the participants compared to the typical muscular requirements in running which, has a greater contribution from the plantar flexors and hamstring muscles (3).

Although change in 10 m and 20 m sprint time was not significant, the substantial improvement (0.04 s and 0.05 s respectively), for the BIKE protocol compared to the RUN protocol may be of interest to coaches. These changes were higher than the smallest worthwhile change of 0.022 s for both the 10 m and 20 m times. Similar significant improvements have been found for 20 m and 30 m (35) and a 10-20 m split (48) following cycling based training interventions. This improvement could have been due to several factors. Energy system similarities; with the reliance on the phosphagen pathways to perform maximal intensity efforts may have contributed to this change (13). Cycling and running are also characterised by successive unilateral limb actions (24). The BIKE protocols used a stationary start which requires high concentric forces in the lower body to perform, similar to the first two or three strides of a sprint run (1). In line with this, the majority of improvement (~80%) by the BIKE group occurred in the first 10 m of the sprint where concentric force production would be more critical. In the second half of the 20 m sprint, contributions of the stretch shortening cycle will likely have increased (10) and therefore less impacted by a concentric dependent training methods such as the 6sCS. Chan, Ho and Yung (8) found no change in 30 m sprint time following a sprint interval intervention. A 30 m test would require greater contribution from the stretch short cycle. Conversely, improvement over 30 m, albeit with a less experienced group of participants have been observed following a training protocol using 5 s cycle sprints. (35). This protocol used a rolling start where resistance was added once a certain cadence was achieved, and therefore there was less resistance on the pedals (32). By contrast, the shuttle efforts used in the RUN protocol would have included deceleration and reacceleration at each of the turns and a much greater demand on the stretch shortening cycle (53). These actions would necessitate a higher eccentric demand on the lower body which may have lessened improvement in running speed in a straight line, especially over the distance of 10 metres.

The high physical cost of maximal intensity actions and collisions in a sport like Rugby League need to be taken into account when planning training (41). Goods, Dawson, Landers, Gore and Peeling (21)proposed that despite the specific nature of adaptation to training, excessive run training for Australian Rules football players may not always be a viable training option as it may lead to excessive fatigue. The addition of a low volume of non-specific, maximal intensity training has been shown to improve performance in speed (35) as well as skill performance (17). Although not measured in this study, it is possible the change in training mode may have added a level of variety and motivation to participants whose training is predominately running based without adding significantly to total training volume (19). The lower training volume in this study may be a consideration for remedying the level of fatigue that may result from excessive running without risking any interference in running form.

The current study used an exclusive training model, where participants performed either the BIKE or RUN protocol. In practice, OFC is more likely to be in addition to normal training, or a partial substitute to normal training activities, as opposed to a complete replacement (40). The addition of a small volume of maximal OFC in the form of cycling has previously been shown to positively impact physical performance when added to normal training activity (18). Tanaka (45) proposed that to impact running performance with an OFC tool like cycling, maximal training intensities would be required. The participants in this study may have benefited from the maximal intensity and longer recovery periods used in IST. The maximal intensity efforts in this study may have been helpful in maintaining performance despite being used as an exclusive training model. The lack of any negative transfer in an exclusive training model used in this study may support the use of OFC as part of an overall conditioning program for team sport athletes if total training volume and intensity becomes problematic. The role of OFC during the playing season in particular to maintain fitness without adding to training load may be worth consideration.

PRACTICAL APPLICATION

The present study found that a cycling IST training intervention did not negatively affect change of direction, running endurance and jump performance when compared to an equivalent intervention using the 6sSS. Additionally, the 6sSS run regimen did not negatively affect the 6sCS. The OFC protocol may also benefit 10 m and 20 m sprint performance. This form of training may mitigate the impact of high volumes of run based training by decreasing eccentric loading on the muscles and reducing soreness. Off-feet conditioning methods may be a valuable short-term alternate if recovery, fatigue, injury are limiting normal training activities. This method may also be useful during the season to maintain fitness without adding to total training stress or soreness to the lower body, however further investigation is required

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CONFLICTS OF INTEREST

The authors report there are no competing interests to declare.

FUNDING DETAILS

No funding was required for this study.

ETHICAL APPROVAL

Informed written consent was obtained according to the Declaration of Helsinki after gaining approval from the University Human Research Ethics Committee (HREC(Health)#2019#05).

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