Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology 11 (2018) 6–11

Contents lists available at ScienceDirect

Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology

journal homepage: www.ap-smart.com

Original Article

# Sprint cycling training improves intermittent run performance

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ARTICLE INFO

*Article history:*
Received 31 May 2017
Received in revised form
28 October 2017
Accepted 3 November 2017
Available online 1 December 2017

*Keywords:*
Physiology
Aerobic
Interval

ABSTRACT

*Background/Objective:* The aim of this study was to examine the effect of sprint cycling training on the intermittent run performance, sprinting speed, and change of direction (COD) ability of recreational intermittent sports athletes.
*Methods:* Sixteen participants participated in the study. The experimental group (EG, n = 8) received a total of 12 sessions of sprint cycling training in a 4-week period and the control group (CG, n = 8) received no training. Both EG and CG were instructed to maintain their daily activity during the 4-week period. Each sprint cycling session consisted of 4–7 sets of 30 s all-out sprint cycling.
*Results:* EG significantly improved in Yo Yo Intermittent Recovery Test (13.4% vs 2.4%,p = 0.006, Effect Size (ES): 0.31 vs 0.04), $VO_{2max}$ (7.8% vs −0.2%, p = 0.006, ES: 0.42 vs 0.00), and power output at $VO_{2max}$ (9.8% vs −4.8%, p = 0.002, ES: 0.91 vs 0.32) compared to CG while no significant changes were found in 30 m sprint times and pro-agility times in both EG and CG.
*Conclusions:* Sprint cycling significantly improved intermittent run performance, $VO_{2max}$ and peak power output at $VO_{2max}$. Sprint cycling training is suitable for intermittent sports athletes but separate speed and COD training should be included.


## Introduction

Intermittent endurance, i.e. the ability to repeatedly perform intense intermittent exercise,[1] is one of the most important fitness elements for intermittent sports, such as soccer, basketball and badminton.[2–4] Castagna et al.[3] found that the physical performance in soccer games is positively correlated to the intermittent endurance performance assessed via Yo-Yo Intermittent Recovery test distance covered. Castagna et al.[2] also found that Yo-Yo Intermittent Recovery test distance covered is negatively correlated to the decrement of agility performance after a simulated basketball game. This evidence describes the importance of intermittent endurance for intermittent sports. Such sports have high physical demands on intermittent endurance due to multiple brief intense activities such as jumps, turns, high-speed runs, and sprints.[5,6] Both aerobic and anaerobic capacity contribute to intermittent endurance performance.[1] Therefore, aerobic training (continuous running) as well as anaerobic training (strength, speed, and change of direction (COD) training) are traditionally adopted to develop the physical fitness of intermittent sports athletes.[7,8] In recent decades, both aerobic and anaerobic training were partly replaced by the intermittent run to build up their intermittent endurance as both aerobic and anaerobic component can be trained. Previous research found that multiple intermittent (i.e., 15–30 s) high speed runs improved the aerobic capacity and sprinting speed of athletes in intermittent sports.[9,10]

Indeed, intermittent running exercise may not be the best choice for athletes to develop their fitness under the rehabilitation process or during the preseason period. Running involves impact and eccentric muscle contraction during foot strike that may place unnecessary stress and shear force on the muscles and ligaments.[11,12] For a musculoskeletal injured (e.g. joint sprain, or leg muscle strain) athlete under a rehabilitation process, running is prohibited to avoid excess stress on the injured tissue. On the other hand, during the preseason period, the increase in training volume is adjusted by increasing the running distance which might cause undue muscle stress. Thus, there is a challenge for coaches to increase the training volume without further increasing the muscle stress of the athletes. To deal with these situations, cycling may be a

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https://doi.org/10.1016/j.asmart.2017.11.001
2214-6873/

good alternative training modality.

Cycling is a relatively low impact exercise with less eccentric muscle actions, which induces less muscle and soft tissue damage.[13,14] In endurance sports, such as distance running, continuous cycling exercise has been adopted as cross training which improved the aerobic capacity of athletes such as, $VO_{2max}$, muscle oxidative potential, lactate threshold, and running time trial performance.[15,16] Indeed, continuous cycling may not be the best protocol to adopt for intermittent sport athletes as only the aerobic component is likely to improve. Therefore, performing sprint cycling training might also be possible to improve intermittent running performance.

Sprint cycling training has been found to improve both aerobic and anaerobic performance during cycling tests. The majority of studies have used thirty-second Wingate cycling sprint as the training protocol to train different populations.[17–20] In the literature, multiple 30 s Wingate cycling sprints improved both aerobic performance ($VO_{2max}$, glycolytic & oxidative enzyme activity) and anaerobic performance (peak and mean power output) during a cycling test.[17,19] In addition, sprint cycling training is relatively efficient and saves time compared to continuous cycling training. Burgomaster et al.[19] and Gibala et al.[18] demonstrated in their studies that multiple sprints cycling protocol induces equal or greater magnitude of improvement in metabolic adaptations and exercise capacity compared to continuous cycling. In both studies, the total training volume (in terms of energy expenditure during exercise time) of the "multiple sprint" group is only 1/10th of the "continuous" group.[18,19]

As mentioned above, brief intense activities frequently occurs in intermittent sports. Sprinting and change of direction (COD) ability are the fitness elements that attributed to the performance of these activities. Previous literature showed that sprinting performance is associated with leg power.[21] As mentioned above, muscle power output was improved after sprint cycling training.[17,19] This is believed that such improvement in muscle power output should be able to transfer to the improvement in sprinting performance. On the other hand, the COD performance is composed of 3 major components according to Young's model[22]: 1) sprinting speed, 2) leg muscle strength, and 3) COD technique. With the improvement of sprinting speed, we speculated that the COD performance should be improved. Therefore, we hypothesized that sprint cycling training could improve the aerobic, speed, and COD performance in intermittent sports athlete.

To date, there has been no study showing the effect of sprint cycling on intermittent sport athletes. Therefore, the purpose of this study was to examine the effect of 4 weeks sprint cycling training on the intermittent running endurance and the anaerobic performance (speed and COD) in intermittent sports athletes. It was hypothesized that intermittent endurance, sprinting speed, and COD performance could be improved after sprint cycling training.

## Method

### *Participants*

Sixteen male recreational intermittent sports athletes (age: 29.8 ± 9.9 years old, height: 172.6 ± 2.7 cm, body mass: 66.2 ± 7.1 kg) participated in this study. The athletes participated in soccer, basketball, and badminton. Participants fulfilled the following inclusion criteria: (1) between 18 and 50 years of age; (2) recreationally active individuals who participate in regular exercise 4–6 times per week. Exclusion criteria were 1) ≥2 cardiovascular disease risk factors in accordance with the ACSM pre-participation health screening protocol,[23] or 2) participants suffered from lower extremity injuries before or during the experimental period.

The study protocol was conducted according to the Declaration of Helsinki and was approved by the Joint CUHK-NTEC Clinical Research Ethics Committee. All participants gave written informed consent after detailed explanation of the study. Participants were assigned to either experimental group (EG, n = 8) or control group (CG, n = 8). Matched-subject design was used in the study. Participants were matched in accordance with their height, body mass, training habit (training frequency) and $VO_{2max}$ data in the pre-test. No significant differences were found between participants in the EG and CG in height, body mass, body mass index, the habit of regular exercise, cardiovascular risk factors and $VO_{2max}$ data in pre-testing (Table 1 and Table 2). The average age of the participants was not matched because 4 participants (age over 40) in the CG were not available for the extra sprint cycling training and thus assigned to CG (as can be seen by the age differences in Table 1).

### *Design*

To examine the effects of sprint cycling training, all participants participated in pre-test, 4-week sprint cycling training for EG and no extra training for CG, and post-test. There were 2 sessions for both the pre-test and post-test. The sessions were separated by 4–7 days. Assessment of maximal oxygen consumption ($VO_{2max}$) was conducted in the first session. Thirty metres sprint test, pro-agility test and Yo-Yo Intermittent Recovery Test Level 1 (YYIRT1) were conducted in the second session. A familiarization test trial was provided on a separate day before the formal test session. After the pre-test, both EG and CG maintained their regular training while EG received a total of 12 extra sprint cycling training sessions in a 4 week period. The post-test was completed within 4–7 days after the training intervention period. The post-test procedure was the same as the pre-test. All tests and training were performed at approximately the same time of the day with indoor conditions (temperature: 23 °C, humidity: 60–70%).

Speed, COD, and aerobic endurance tests were used in the present study, which are important elements of intermittent sports. A 30 m sprint test and pro-agility test are commonly used to test athlete's maximum running speed and COD ability.[24] The YYIRT1 addresses both aerobic and anaerobic metabolism. Also, it is intermittent in nature which can represent athlete's intermittent endurance.[25] Maximal oxygen consumption assessment on cycling ergometer was used to determine the aerobic improvement from the effect of sprint cycling. This is to ensure that there is an improvement in aerobic capacity and the cross training effect can be tested.

### *Procedure*

#### *Weight and height*

Participants performed the measurement with minimal clothing and bare feet. Weight was measured with a BC-558 Digital weight scale (Tanita Corporation of America, Inc., Illinois, USA) to the nearest 0.1 kg. After that, height was measured with the HR-200 wall-mounted height rod (Tanita Corporation of America, Inc., Illinois, USA) to the nearest 0.5 cm.

#### *Maximal oxygen consumption assessment*

The participants performed an incremental test to exhaustion on a mechanically braked cycle ergometer (Monark Ergomedic 874E, Sweden) to determine the $VO_{2max}$ by using breath-by-breath gas analysis (Medgraphics Cardio 2, Italy) and heart rate by using heart rate monitor (Polar RS 400, Finland). For the initial three stages of the test, each stage consisted of a 2-min interval. The workload was set at 50 W, 100 W and 150 W. From the 4th stage, the workload was increased by 25 W on 1 min interval until

**Table 1**
Demographic characteristics of Experimental Group (EG) and Control Group (CG).

| Characteristics | Experimental Group ($n = 8$) | Control Group ($n = 8$) |
|---|---|---|
| Age (y) | 23.7 ± 4.3 | 35.1 ± 11.5* |
| Height (cm) | 172.2 ± 4.6 | 171.9 ± 1.9 |
| Weight (kg) | 67.5 ± 8.0 | 63.6 ± 5.9 |
| Body mass index ($kgm^{-2}$) | 22.7 ± 2.2 | 21.5 ± 1.8 |
| Habit of Regular Exercise (times per week) | 4.6 ± 1.8 | 5.0 ± 2.0 |

Values are represented as mean ± SD.
*significant difference between groups at $p < 0.05$.

**Table 2**
The effects of 4-week sprint cycling training program on physical performance measures.

| | Experimental Group ($n = 8$) | | Effect size (Cohen's d) | Control Group ($n = 8$) | | Effect size (Cohen's d) |
|---|---|---|---|---|---|---|
| | Pre | Post | | Pre | Post | |
| YYIRT1 distance covered (m) | 1490 ± 621 | 1690 ± 674* † | 0.31 | 1045 ± 595 | 1070 ± 640 | 0.04 |
| MHR during YYIRT1 (beat. $min^{-1}$) | 190 ± 7 | 191 ± 10 | 0.12 | 190 ± 10 | 195 ± 8 | 0.55 |
| $VO_{2max}$ (mL/kg/min) | 49.8 ± 8.6 | 53.7 ± 9.9* † | 0.42 | 45.1 ± 11.0 | 45.1 ± 9.8 | 0.00 |
| MHR during $VO_{2max}$ (beat.$min^{-1}$) | 184 ± 5 | 184 ± 5 | 0.00 | 183 ± 14 | 182 ± 11 | 0.08 |
| Power output at $VO_{2max}$ (W) | 255 ± 26 | 279 ± 27*† | 0.91 | 243 ± 38 | 231 ± 37 | 0.32 |
| 30 m sprint time (s) | 4.49 ± 0.15 | 4.56 ± 0.15 | 0.47 | 4.69 ± 0.22 | 4.78 ± 0.33 | 0.32 |
| Pro-agility time (s) | 5.22 ± 0.23 | 5.21 ± 0.11 | 0.06 | 5.27 ± 0.17 | 5.29 ± 0.19 | 0.11 |

Values are represented as mean ± SD.
*Significant difference between pre-test and post-test at $p < 0.05$.
† Significant difference between groups at $p < 0.05$.
YYIRT1 = Yo-Yo Intermittent Recovery Test Level 1; MHR = Maximum heart rate; $VO_{2max}$ = Maximal Oxygen Consumption.

exhaustion, and the average value achieved over a 1-min collection period determined the maximal oxygen consumption ($VO_{2absolute}$), maximal oxygen consumption expressed relative to body weight ($VO_{2max}$), the respective maximum heart rate (MHR) in minute average and the respective power output (Watts) in minute average.[20]

*Yo-Yo Intermittent Recovery Test Level 1*

The YYIRT1 consisted of repeated 2 × 20 m shuttle runs at an incremental speed instructed by audio bleeps from a tape recorder. Between each running bout, there was a 10s active recovery period to walk through 2 × 5 m of distance. The test ended when the participant could not keep up with the running speed in 2 consecutive runs. The total running distance covered by each participant was analysed.[26] Heart rate was recorded with a portable monitor (Polar RS 800, Finland). The data was recorded every 5 s throughout the test. The heart rate value of the last 15 s was averaged and used as the maximum heart rate (MHR).

*Linear sprint speed*

Thirty metres linear sprinting was evaluated with infra-red timing gate system (Smartspeed, Fusion sport, Finland) placed at the start line, and 30 m finish line. Participants started with standing position 0.5 m behind the start line. They were instructed to run at maximal speed throughout the 30 m distance. Three trials were performed with a 3-min recovery period between each trial. The fastest 30 m sprint time was used for data analysis.[24]

*Pro-agility test*

An infra-red timing gate system (Smartspeed, Fusion sport, Finland) was placed at the centre cone at the start/finish line. The test setup was shown in Fig. 1. The participant sprinted maximally from the starting line to the cone at one end and stepped on the line with one leg, then changed direction to sprint to the other end and stepped on the line with one foot, and made a final change of direction to sprint through the finish line at the centre cone (5 m). Three trials were performed with a 3 min recovery period between each trial. The fastest pro-agility time was used for data analysis.[24]

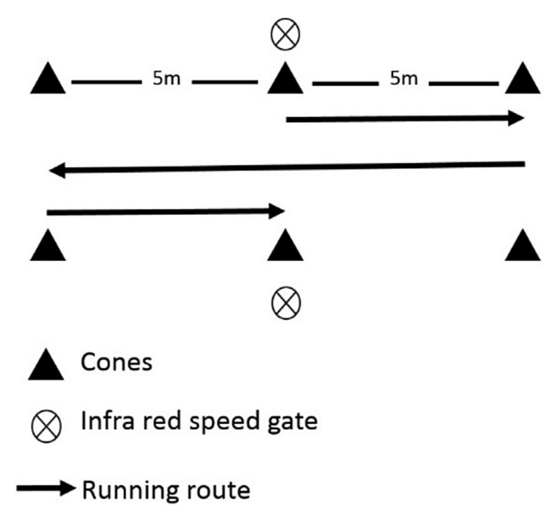


**Fig. 1.** Setup and running route of Pro-agility test.

*Training intervention protocol*

*Sprint cycling*

The training intervention consisted of a total of 12 sessions of sprint cycling training in 4 weeks. For EG, each training session consisted of repeated 30-s all-out sprints on a mechanically braked cycle ergometer (Monark Ergomedic 874E, Sweden) against a resistance equivalent to 7.5% of the participant's body mass. Participants were encouraged to continuously pedal as fast as possible throughout the 30 s period. During the 4 min recovery period between sprints, participants remained on the bike and pedaled at the lowest resistance and a low pedaling rate to prevent nausea. The number of sprints increased by one bout every week. The training volume in the first week was 4 sprints and the last week was 7 sprints.

*Statistical analysis*

All data are presented as mean and SD for each group in the pre-test and the post-test. Sharpio-Wilk test was used to test the data normality. Independent sample *t*-test was used to examine the baseline difference of all dependent variables between the EG and CG at pre-test. A two way (group x time) ANOVA was used to assess the effects of sprint cycling training. Follow-up independent t-tests were used when significant interactions were found. Effect size was measured using Cohen's d.[27] Threshold values for assessing magnitude of Cohen's d effect were 0.2, 0.5, 0.8 for small, moderate and large respectively. The significance level was set at $p \leq 0.05$.

## Results

*Training intensity during the intervention*

Each participant of EG has completed all 12 training sessions. The mean of the maximum power and the mean of the average power of each participant reached in each bout of 30-s sprint are 858 ± 115 W and 546 ± 73 W. Sample heart rate pattern is shown in Fig. 2. The mean of the maximum heart rate and the mean of the average heart rate of each participant reached in each bout of 30-s sprint are 173±6bpm and 165±8bpm.

*Yo-Yo Intermittent Recovery Test Level 1*

EG had significant improvements in the YYIRT1 distance covered (pre-post difference, pre-post difference %; p-value for significant difference for group × time interaction) (EG: +200 m, +13.4%; CG: +25 m, +2.4%, p = 0.006) compared to CG between pre-test and post-test (Table 2). No significant improvement was found in CG between pre-test and post-test. The effect size of EG is 0.31 (small to moderate) and CG is 0.04 (no effect).

*Maximal oxygen consumption assessment*

EG had a significant improvement in $VO_{2max}$ (EG: +3.9 ml/kg/min, +7.8%; CG: −0.1 ml/kg/min, −0.2%, p = 0.006), and power output at $VO_{2max}$ (EG: +24 W, +9.8%; CG: −12 W, −4.8%, p = 0.002) compared to CG between pre-test and post-test (Table 2). No significant improvement was found in CG between pre-test and post-test. For $VO_{2max}$, the effect size of EG is 0.42 (small to moderate) and CG is 0.00 (no effect). For power output at $VO_{2max}$, the effect size of EG is 0.91 (large) and CG is 0.32 (small to moderate).

*30 m sprint and pro-agility test*

There were no significant differences in 30 m sprint time (EG: +0.07 s, +1.5%; CG: +0.09 s, +1.9%, p = 0.829), and pro-agility time (EG: −0.01 s, - 0.3%; CG: +0.02 s, +0.3%, p = 0.773) when comparing EG and CG between pre-test and post-test. No significant changes were found in EG or CG. For 30 m sprint time, the effect size of EG is 0.47 (small to moderate) and CG is 0.32 (small to moderate). For pro-agility time, the effect size of EG is 0.06 (no effect) and CG is 0.11 (no effect).

## Discussion

This study demonstrated the physiological and performance adaptations following 4 weeks (12 sessions, 4–7 sets of 30 s) of sprint cycling in intermittent sport athletes. The result partly supports our hypotheses. Significant improvement were found in $VO_{2max}$, power output at $VO_{2max}$ and YYIRT1 distance covered, while no significant improvement were found in 30 m sprint time or pro-agility time. The current findings imply that the physiological adaptation from repeated sprint cycling improves the aerobic capacity and intermittent run performance but not sprinting speed and COD ability.

The magnitude of improvement of $VO_{2max}$ in the current study is similar to a previous study.[19] There was a 8.3% improvement after 4 weeks of sprint cycling training while Burgomaster's study had a 7.3% improvement after 3 weeks.[19] The improvement in $VO_{2max}$ was claimed to be contributed by the increase in oxygen utilization in muscle. Burgomaster et al.[20] showed 6 sessions of 4–7 bouts of 30-s all-out cycling sprint improved endurance capacity by 100% in a group of recreational subjects. Such improvement is likely mediated by the improvements in mitochondrial potential measured by citrate synthase maximal activity in resting muscle. i.e., increase endurance capacity by increasing the oxidative capacity of muscle.

The improvement in aerobic capacity was likely the main contributor to the improvement in intermittent run performance,

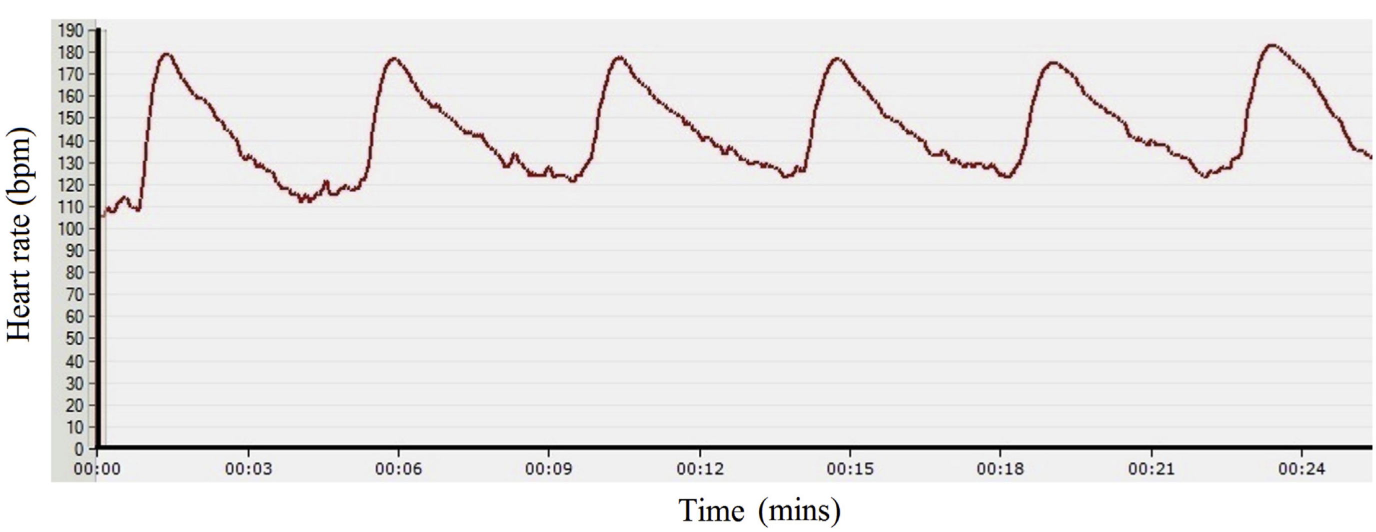


**Fig. 2.** Sample heart rate of the training session.

but further mechanistic evaluation is warranted. The aerobic improvement induced from cycling training should be able to transfer to the improvement in run performance regardless of exercise mode. Bangsbo et al.[25] and Castagna et al.[2] reported high correlations between $VO_{2max}$ and YYIRT1 distance covered ($r = 0.7$, $p < 0.05$ and $r = 0.77$, $p < 0.001$), which supported our findings. On the other hand, the YYIRT1 reflected the individual's ability to repeatedly perform intense running which led to a maximal activation of the aerobic system.[25,26] The improvement in YYIRT1 distance covered was also reported to be highly correlated with the improvement in high intensity running distance covered for soccer players during games.[25] Therefore, it is suggested that the physiological effect of sprint cycling may improve the game performance in intermittent sports, especially soccer.

Unexpectedly, thirty metres sprint performance was not improved after sprint cycling in the current study. Sprint cycling was shown to elicit specific physiological adaptations, which increased the cross-sectional area of type IIb in Vastus Lateralis,[28] and peak power output of muscle.[20] We expected that such anaerobic improvement can cause the improvement in explosive performance such as sprinting. Dupont et al.[9] confirmed this hypothesis that 10 weeks of 12–15 bouts of 15 s supramaximal run significantly improved both aerobic performance as well as the 40 m sprint performance. Therefore, we suspected that the difference in exercise mode (cycling vs running) may have inhibited the physiological adaptation of sprint cycling to running related explosive performance. The muscle recruitment of the lower limb muscles is considerably different in running and cycling. The vastus lateralis and gluteus maximus were shown to be the main power producers for cycling exercise while the hamstring especially the biceps femoris act as a co-contractor. In an EMG study, the vastus lateralis and gluteus maximus were fatigued after repeated sprint cycling. However, the biceps femoris was not fatigued after sprint cycling.[29] This indicated that the training stimulus on biceps femoris was relatively small during cycling training. Indeed, the hamstring is one of the important muscles which contributes to sprint performance.[30] Therefore, we speculated that sprinting performance was not improved after sprint cycling because insufficient training load was provided to hamstring muscles.

The pro-agility test time was not improved which implies that COD performance was not improved. There are 3 trainable parameters that contribute to the COD performance: 1) COD technique, 2) leg muscle strength, and 3) sprinting speed.[22,31] We hypothesized that sprinting speed was the only parameter to improve after sprint cycling while no improvement in the COD movement technique and leg muscle strength were speculated. i.e. after sprint cycling, the improvement of COD performance should be purely the result of the improvement in sprinting speed. Improvement in the COD movement technique was not anticipated. The movement of cycling is totally different from a COD movement. Good COD movement technique requires one to maintain a low centre of gravity and postural stability.[31] During the sprint cycling training, as the participants were sitting on the stationary bike and there was no change in the centre of gravity and posture. Therefore, sprint cycling should not be able to induce improvement in COD movement technique. In addition, no muscle strength improvement was anticipated. Muscle strength improvement relies on a heavy weight stimuli to induce neural and hypertrophic responses of muscles. It is possible to induce muscle strength gain during cycling only if the pedal force is heavy enough. One related study showed significant improvements in strength after 16 weeks of cycling training, in terms of 2 repetition maximum (RM) of pedal force, maximal isometric force in leg press and leg extension.[32] The cycling protocol in this previous study was in the format of “low repetitions and high pedal force” (40–80% of 2RM pedal force).[32] Indeed, the cycling protocol in the current study was a “high cadence and low pedal force” approach which should not be able to induce muscle strength improvement. Therefore, no significant improvement was found in COD performance due to no improvement in the 3 trainable parameters.

## Conclusions

This study demonstrated that intermittent sport athletes can enhance the intermittent run performance in the form of YYIRT1 by undertaking a 12 session (4–7, 30 s bouts) sprint cycling program. However, sprinting speed and COD performance were not improved. This study implies that sprint cycling training is feasible to be included in preseason training to provide certain aerobic improvements. Indeed, separate speed and COD training should be arranged to supplement the deficit of sprint cycling training. Such training programs may also be a good alternative training for injured athletes, who are prohibited from running exercise, to maintain their aerobic conditioning. Further randomized controlled trials using larger sample sizes should be conducted to strengthen the recommendation.

## Conflicts of interest

In the submission of “sprint cycling training improves intermittent run performance”, the author(s) have no conflicts of interest relevant to this article.

## Funding

Nil.

## Acknowledgements

This research project was made possible by equipment/resources donated by The Hong Kong Jockey Club Charities Trust.

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