Baltic Journal of Health and Physical Activity

Volume 16 | Issue 1 Article 5

2024

How does rest Interval duration affect performance? An experiment on high-intensity sprint exercises

İbrahim Orkun Akcan
Sport Science Faculty, Erzincan Binali Yıldırım University, Erzincan, Turkey, orkunakcan24@gmail.com

Cengiz Ölmez
Sport Science Faculty, Ordu University, Ordu, Turkey, cengizolmez@odu.edu.tr

Recommended Citation
Akcan IO, Olmez C. How does rest interval duration affect performance? An experiment on high-intensity sprint exercises. Balt J Health Phys Act. 2024;16(1):Article5. https://doi.org/10.29359/BJHPA.16.1.05

How does rest Interval duration affect performance? An experiment on high-intensity sprint exercises

Abstract

Introduction: The purpose of this study was to examine the effects of interval and high-intensity sprint training (RST) with different rest intervals on the respiratory function, aerobic and anaerobic power. (2) Materials and Methods: The study involved the voluntary participation of 20 male participants. The participants were divided into two groups: 2IRG (2-minute rest between repeated sprints) and 4IRG (4-minute rest between repeated sprints). The changes in the respiratory function, aerobic, and anaerobic power parameters were examined in the 2IRG and 4IRG athletes who performed two training sessions per week for 4 weeks. (3) Results: The findings indicated that there was no improvement in the respiratory function among the athletes, but there was a significant improvement in aerobic and anaerobic power parameters. However, this improvement was similar in both the 2IRG and 4IRG groups. (4) Conclusions: A 4-week high-intensity interval training program with two RST sessions per week was insufficient to elicit improvements in the respiratory function. However, RST protocols with 2-minute and 4-minute rest intervals provided similar aerobic and anaerobic benefits.

Keywords

HIIT, repeated sprint training, respiratory function, aerobic power, anaerobic power, rest interval

Baltic Journal
of Health and Physical Activity
e-ISSN 2080-9999

Article

How does rest interval duration affect performance? An experiment on high-intensity sprint exercises

İbrahim Orkun AKCAN[1], **Cengiz ÖLMEZ**[2]*

[1] Sport Science Faculty, Erzincan Binali Yıldırım University, Erzincan, Turkey; ORCID 0000-0001-6983-2145
[2] Sport Science Faculty, Ordu University, Ordu, Turkey; ORCID 0000-0001-8584-6272

* Correspondence: Dr. Cengiz ÖLMEZ, Cumhuriyet Campus 52200 Altınordu – Ordu / TÜRKİYE; e-mail: cengizolmez@odu.edu.tr; phone no : +90 (452) 226 52 00

Abstract: Introduction: The purpose of this study was to examine the effects of interval and high-intensity sprint training (RST) with different rest intervals on the respiratory function, aerobic and anaerobic power. (2) Materials and Methods: The study involved the voluntary participation of 20 male participants. The participants were divided into two groups: 2IRG (2-minute rest between repeated sprints) and 4IRG (4-minute rest between repeated sprints). The changes in the respiratory function, aerobic, and anaerobic power parameters were examined in the 2IRG and 4IRG athletes who performed two training sessions per week for 4 weeks. (3) Results: The findings indicated that there was no improvement in the respiratory function among the athletes, but there was a significant improvement in aerobic and anaerobic power parameters. However, this improvement was similar in both the 2IRG and 4IRG groups. (4) Conclusions: A 4-week high-intensity interval training program with two RST sessions per week was insufficient to elicit improvements in the respiratory function. However, RST protocols with 2-minute and 4-minute rest intervals provided similar aerobic and anaerobic benefits.

Keywords: HIIT; repeated sprint training; respiratory function; aerobic power; anaerobic power; rest interval.

Citation: Akcan IO, Olmez C. How does rest interval duration affect performance? An experiment on high-intensity sprint exercises. Balt J Health Phys Act. 2024;16(1):Article5. https://doi.org/10.29359/BJHPA.16.1.05

Academic Editor:
Agnieszka Maciejewska-Skrendo

Received: May 2023
Accepted: September 2023
Published: March 2024

Publisher's Note: BJHPA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

High-intensity interval training (HIIT) is a frequently used training method to enhance athletes' performance [1]. However, there is a confusion in the literature regarding how long rest between intervals would provide maximum benefits. The existing research presents varying results on the optimal rest interval during HIIT exercises [2–6].

Another source of confusion regarding HIIT training and rest intervals between intervals appears to be related to physical and physiological adaptations. Some studies have focused on the anaerobic outcomes of HIIT training and found that sprint training with short rest intervals enhances anaerobic capacity [4, 6]. After HIIT training sessions consisting of repeated sprints, parasympathetic reactivation occurs more rapidly, supporting the increase in anaerobic capacity [2].

Other studies have focused on the aerobic outcomes of HIIT training [3, 5]. These studies report that high-intensity endurance training increases aerobic capacity and improves performance [3, 5]. These findings highlight the physical and physiological benefits of HIIT training. However, the duration of HIIT sessions and the rest intervals between exercises remain subjects of debate. In a previous study, despite an increase in plasma noradrenaline levels following four weeks of intensive training, no change was reported in VO_2max levels [7]. However, in general, HIIT training has been reported to enhance skeletal muscle oxidative capacity, making it a time-efficient strategy to induce metabolic adaptations compared to traditional aerobic endurance training [8].

This article aims to examine the aerobic and anaerobic effects of high-intensity sprint training with different rest intervals in more detail and gain a clearer understanding of which rest interval provides maximum benefits. The hypothesis of this study is that athlete groups designed with all-out efforts but with different rest durations (2 minutes or 4 minutes) will achieve similar gains after 4 weeks. Therefore, the objective of this research is to investigate the effects of high-intensity interval training designed with different rest intervals on the respiratory function, aerobic, and anaerobic power performance parameters and to determine the optimal strategy for maximum benefits. This study will assist athletes in determining the most appropriate rest interval when designing their training programs. Additionally, it will significantly contribute to a better understanding of the impact of high-intensity exercises.

2. Materials and methods

2.1. Participants

This study was conducted with voluntary participation of 20 elite-level healthy males. The participants performed high intensity sessions with 2 min and 4 min rest intervals with Repetitive Sprint Training (RST); 10 athletes formed the 2 min rest interval group (2IRG) (age: 19.9 ± 0.9 years; height: 177.6±6.5 cm; weight: 71.15 ± 8.6 kg; BMI: 22.61 ± 2.95 kg/m^2), and 10 athletes formed the 4 min rest interval group (4IRG) (age: 19.7 ± 2.2 years; height: 173.3 ± 4.5 cm; weight: 63.59±8 kg; BMI: 21.13 ± 1.99 kg/m^2). All athletes were informed about the study, and the possible benefits and risks were explained. After verbal notification, all athletes were given a written informed consent form prepared according to the Declaration of Helsinki. The study was conducted per the ethical principles of the European Convention and the Declaration of Helsinki [9] and was approved by the University Clinical Research Ethics Committee (No: 02/09/E.U).

2.2. Study design and procedures

The study was completed in four consecutive phases (Figure 1). The first phase of the study was completed in one day and included registration, information and recording demographic characteristics. The second phase of the study was the pre-test process, and this phase was completed in 3 working days with one-day intervals. In this phase, the athletes participated in pulmonary function tests on the first day. After a day of rest, they visited the laboratory again for the Wingate anaerobic power and capacity test. Then the athletes were allowed to rest for one more day to recover and participated in the final test of the second phase, the YO-YO aerobic power and capacity test. After the pre-tests were finished, the 4 weeks of high intensity RST for the 2IRG and 4IRG groups started. The exercise intensity was controlled with the athletes' heart rates, and the HR values were recorded (Table 2). After the 4-week RST period, the post-test phase (phase 4) initiated in the same order and sequence as the pre-test phase.

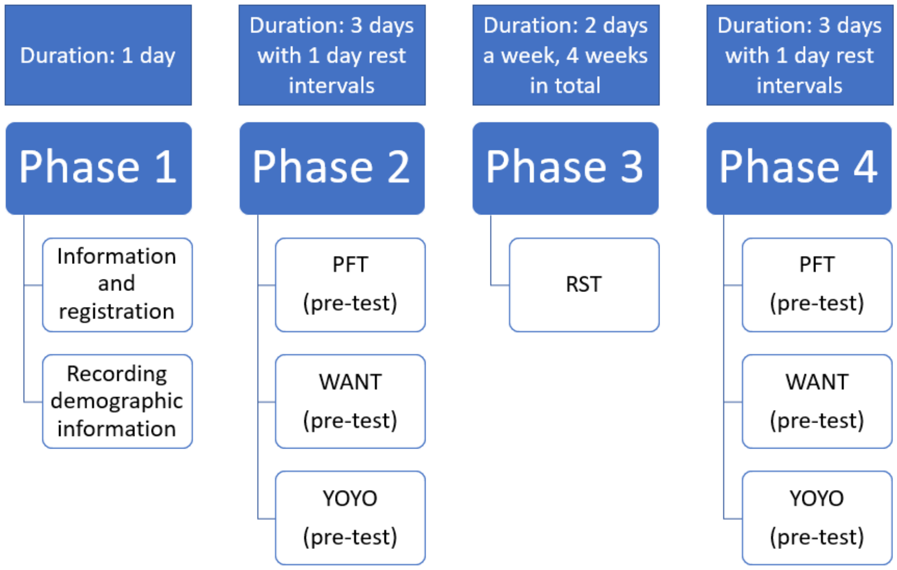

Figure 1. Flow chart of the research.

2.3. Data collection

Pulmonary function tests (PFT): forced vital capacity (FVC) and peak expiratory flow (PEF) were determined using a portable pneumotachograph spirometer (FirstMed Sp-10). Measurements were made according to the European Respiratory Society's recommendations [10].

Determination of VO_2max: The Yo-Yo intermittent recovery test was used to determine the athletes' VO_2max levels. All tests were realized at the same time of day, avoiding circadian effects on test performance [11]. Before the test, the participants were instructed to do a standardized warm-up at a subjectively determined intensity in the range of 9–11 on the BORG scale [12] by running 20 m back and forth for 10 min with direction changes of 180° [11]. The participants were asked to progressively increase the intensity toward the end of the warm-up, nonetheless without reaching maximal speed. A 2-min passive recovery preceded each test. On the day before testing, the participants refrained from performing vigorous physical activity [11]. The Yo-Yo Intermittent Endurance Test Level 1 (initial speed: 10 km; final speed: 19 km) was designed to evaluate the ability to perform intense exercise repeatedly during a prolonged intermittent exercise [13]. In the test, each participant performed a series of 20-m shuttle runs at a pace set by an audio metronome from an Android tablet (Samsung Galaxy Tab S2 SM-T813). In this version of the Yo-Yo test, a 5-metre recovery area is added to the 20-metre running area. The athlete takes 10 seconds (5 m) of active rest in addition to every 40 meters of run [14, 15]. The test was terminated when a subject failed twice to reach the starting line, or felt unable to complete another shuttle at the dictated speed [11, 14, 15]. VO_2max levels of the athletes were determined according to their running performance [14].

Anaerobic Power measurements: The athletes' anaerobic power performance was determined by a Wingate cycle ergometer (Monark Peak Bike 894-E). The athletes warmed up for 5 minutes at 60–80 rpm before the test. After the warm-up, the saddle, handlebar, and seat heights were adjusted for each athlete. The seat height was adjusted as the knee angle was 175° in flexion position, while the athlete's foot was on the pedal with the pedal in its lowest position. Before the test, 7.5% of the athlete's body weight was equally placed on the weight baskets. The test started when the athlete was ready. The athlete was asked to show maximum performance for 30 seconds. After the test started, when the pedaling force reached 150 rpm, the weight baskets automatically dropped and the athlete pedaled at maximal speed against the resistance in the weight baskets [16, 17].

2.4. Intermittent high intensity training period (RST)

Repetitive sprint is defined as the ability to apply repetitive sprints with minimum recovery time or presenting the best mean sprint performance of successive sprints [18]. Both straight-line repetitive sprints and multi-directional repetitive sprints are frequently used to increase physical capacity in many sports disciplines [19–21]. The repetitive sprint training sessions were held on a 25-meter-long straight running field with 5-meter-spaced marker lines (Figure 2). The instructions were to cover the greatest distance possible in 30 seconds, making trips of 5, 10, 15 m, etc. During the 4-minute recovery period, the athletes walked back to the start line where they waited for the following repetitions [20, 21].

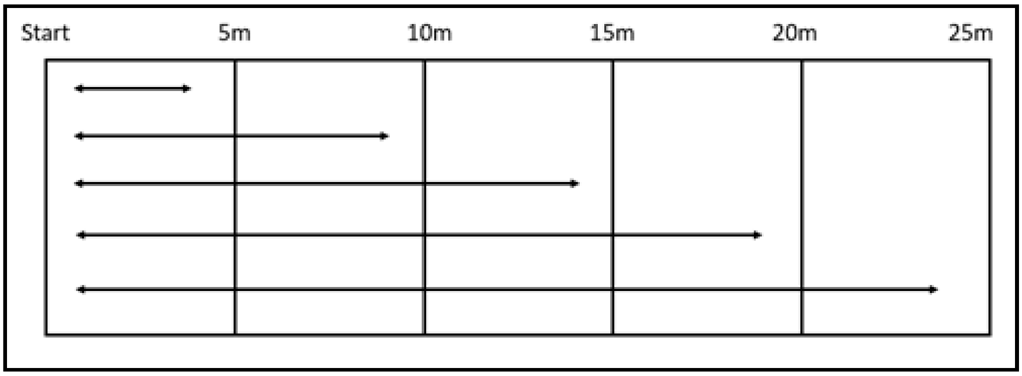

Figure 2. Interval high intensity repetitive sprint training.

The athletes performed RST 2 days a week for four weeks. A total of 4 sets of RST were performed in each training session. Athletes performed 30 seconds of maximal (all-out effort) loading each set during RST. A rest period of 2 minutes was given to the 2IRG group and 4 minutes to the 4IRG group between each set.

The athletes' maximum effort was controlled by the heart rate (Figure 3). The heart rate was recorded using Polar S610i heart rate monitors (Polar USA, Lake Success, NY, USA). Once the raw data were collected, it was downloaded to a computer using Polar Precision Performance software (Polar USA).

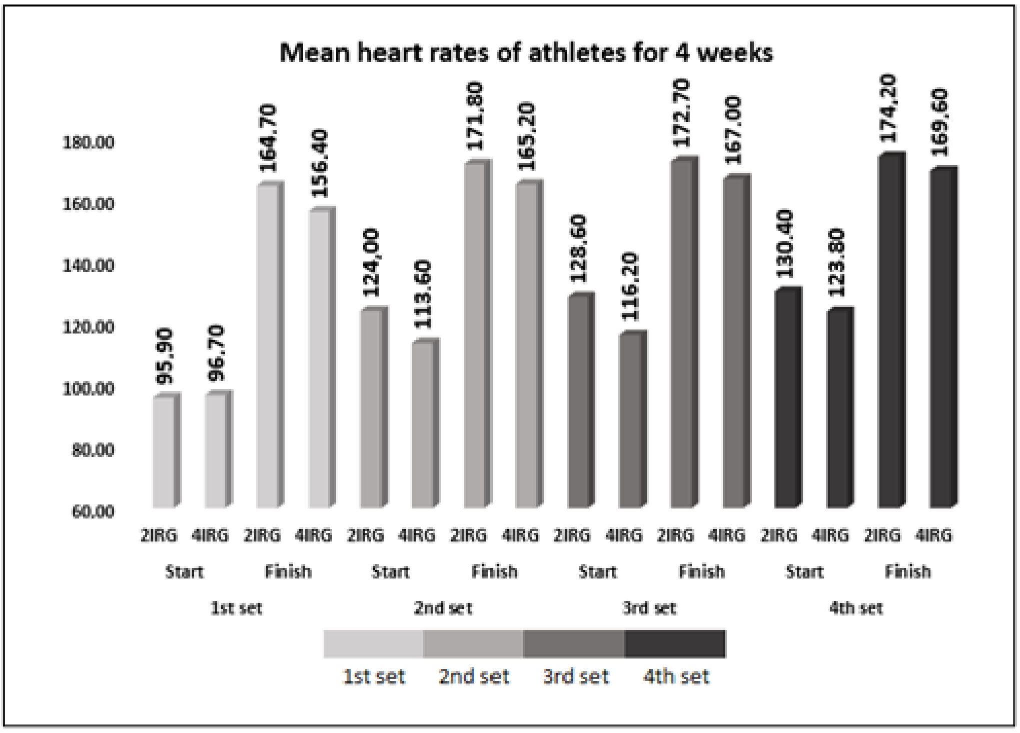

Figure 3. Mean heart rates of the athletes.

2.5. Statistical analysis

The statistical analyses were conducted using SPSS (version 25.0, Chicago, IL). The results are presented as mean values ± standard deviation and 95% confidence interval (95%CI). Data normality was assessed using the Shapiro-Wilk test and Q-Q plot, while variance equality was evaluated using the Levene test. The differences between the groups' performances of the athletes before and after the RST were analyzed using the One-Way Analysis of Variance (ANOVA). Additionally, the differences between the pre-test and post-test measurements were analyzed using the Paired Samples T-Test. All statistical results were considered significant at a probability level below 0.05 ($p < 0.05$). To assess the magnitude of the differences between the variables, the effect size (Cohen's d) was examined. Threshold values for Cohen's d statistics were 0.20, 0.60, 1.20, 2.0, and 4.0 for small, moderate, large, very large, and extremely large effects, respectively [22].

3. Results

When examining the athletes' Pulmonary Function Test (PFT) results, it was found that the differences in Forced Vital Capacity (FVC) and Peak Expiratory Flow (PEF) capacities between the 2IRG and 4IRG groups before the repetitive sprint training (RST) were not statistically significant ($p > 0.05$). However, after the 4-week RST performance of the athletes, it was determined that the difference in FVC capacities between the 2IRG and 4IRG groups was significant ($F(1.18) = 15.66$; $p = 0.001$; $d = 1.784$), while the difference in PEF capacities was not significant ($p > 0.05$). The differences in PFT results between the pre-test and post-test measurements for both groups were not statistically significant ($p > 0.05$) (Table 1).

Table 1. Results of the PFT analysis for the athletes.

		Pre-test		Post-test	
		X ± SD	%95CI	X ± SD	%95CI
FVC	2IRG	4.06 ± 1.19	3.21–4.91	4.73 ± 0.51**	4.36–5.09
	4IRG	3.64 ± 0.55	3.25–4.03	3.92 ± 0.39	3.64–4.20
PEF	2IRG	9.93 ± 4.10	7–12.87	9.94 ± 1.79	8.66–11.22
	4IRG	8.07 ± 2.28	6.44–9.70	8.38 ± 1.77	7.12–9.65

**$p > 0.01$ (statistical difference between groups); FVC: Forced Vital Capacity; PEF: Peak Expiratory Flow

When examining the VO_2max results obtained through the Yo-Yo test for the athletes, it was determined that the intergroup comparisons between the 2IRG and 4IRG groups before and after the RST were not statistically significant ($p > 0.05$). However, when the effects of the 4-week RST were analyzed, it was found that there were significant differences between the pre-test and post-test results for both the 2IRG ($t_{(1.9)} = -4.082$; $p = 0.003$; $d = 9.82$) and 4IRG ($t_{(1.9)} = -4.391$; $p = 0.002$; $d = 9.49$) groups (Table 2).

Table 2. Results of the VO_2max analysis of athletes.

		Pre-test		Post-test	
		X ± SD	%95CI	X ± SD	%95CI
VO_2max	2IRG	48.01 ± 4.45	44.82–51.19	53.20 ± 4.24^{++}	50.17–56.23
	4IRG	46.90 ± 4.67	43.56–50.24	53.47 ± 5.57^{++}	49.49–57.45

$^{++}p > 0.01$ (statistical difference between pre-test and post-test)

When examining the athletes' anaerobic power performance obtained through the Wingate Anaerobic Power Ergometer, it was determined that the absolute (W) peak power (PP) and average power (AP) performance differences between the 2IRG and 4IRG groups before and after the RST were not statistically significant ($p > 0.05$). However, when examining the athletes' inter-group relative power (W/kg) performances, significant differences were found between the pre-test PP ($F_{(1.18)} = 4.507$; $p = 0.048$; d =0.949), post-test PP ($F_{(1.18)} = 5.968$; $p = 0.025$; $d = 2.331$), pre-test AP ($F_{(1.18)} = 8.009$; $p = 0.011$; $d = 1.266$), and post-test AP ($F_{(1.18)} = 4.608$; $p = 0.046$; $d = 0.960$) performances. When examining the athletes' progress over time, it was found that there were significant differences in the pre-test and post-test PP (W) performances ($t_{(1.9)}$=-3.366; $p = 0.008$; $d = 1.205$) and PP (W/kg) performances ($t_{(1.9)}$=-3.405; p = 0.008; d = 1.476) of the 2IRG athletes, but no significant differences were observed in the AP (W) and AP (W/kg) performances ($p > 0.05$). When examining the time-dependent anaerobic power development of the 4IRG athletes, similar to the 2IRG athletes, significant differences were found in the pre-test and post-test PP (W) performances ($t_{(1.9)}$=-2.478; $p = 0.035$; $d = 0.969$) and PP (W/kg) performances ($t_{(1.9)}$=-2.394; $p = 0.040$; $d = 0.837$), but no significant differences were observed in the AP (W) and AP (W/kg) performances ($p > 0.05$) (Table 3).

Table 3. Analysis results of athletes' anaerobic power performance

		Pre-test		Post-test	
		X ± SD	%95CI	X ± SD	%95CI
PP (W)	2IRG	760.74 ± 96.52	691.70–829.78	949.04 ± 198.86^{++}	806.79–1091.29
	4IRG	692.97 ± 208.21	544.03–841.91	851.76 ± 102.02^{++}	778.78–924.74
PP (W/kg)	2IRG	14.33 ± 3.31*	11.96–16.70	17.82 ± 4.80*$^{++}$	14.38–21.26
	4IRG	11.01 ± 3.68	8.38–13.64	13.64 ± 2.49^{++}	11.86–15.42
AP(W)	2IRG	538.82 ± 77.89	483.10–594.54	567.26 ± 108.41	489.71–644.81
	4IRG	470.61 ± 128.87	378.42–562.80	545.77 ± 44.17	514.17–577.37
AP (W/kg)	2IRG	10.08 ± 2.15*	8.54–11.62	10.62 ± 2.69*	8.70–12.54
	4IRG	7.44 ± 2.02	5.99–8.89	8.69 ± 0.92	8.03–9.35

$^{++}p > 0.01$ ($^{+}$ statistical difference between pre-test and post-test); $^{*}p > 0.05$ (* statistical difference between groups); PP: Peak Power; AP: Average Power; W: Watts

4. Discussion

This study was conducted to examine the changes in the respiratory function, aerobic, and anaerobic power performance of individuals participating in repeated sprint training designed with 2-minute and 4-minute rest intervals over a period of 4 weeks.

The most important finding of this research was the significant improvement in aerobic and anaerobic power and capacity of both the 2IRG and 4IRG athletes after the 4-week training period, with similar levels of improvement observed between the groups. No significant improvement was observed in respiratory function parameters over the 4-week period. However, there were intergroup differences in the FVC parameter during the post-test stage, indicating significant differences between the groups, although the level of improvement compared to the pre-test was not significant.

According to the search results, high-intensity interval training (HIIT) can have a positive effect on the respiratory function. Several studies have shown that HIIT can in-crease inspiratory muscle strength, which can lead to improvements in pulmonary function [23–25]. One study found that 4 weeks of either HIIT or endurance training (3 training sessions per week) resulted in a 25–43% increase in inspiratory muscle strength [23]. An-other study showed that HIIT increased cardiorespiratory fitness and exercise capacity when compared with no exercise and produced similar results to traditional endurance exercise [26]. Additionally, a 12-week HIIT program was found to be effective in improving body composition, pulmonary function, and respiratory muscle strength in sedentary individuals [24]. Overall, the evidence suggests that HIIT can be an effective way to im-prove the respiratory function.

In the present study, a 4-week training program consisting of repetitive sprint training was implemented, with a frequency of 2 training sessions per week. However, based on the findings and the review of existing literature, it can be concluded that the 4-week HIIT program with 2 training sessions per week may be insufficient to elicit significant improvements in lung and respiratory functions. It is worth noting that the adaptation of lung and respiratory functions to high intensity interval training can vary depending on various factors, such as the duration and intensity of the training sessions, the individual's initial fitness level, and their overall training regimen. While HIIT has been shown to have positive effects on respiratory functions in some studies [23, 25, 26], it is possible that a longer or more intensive training program may be required to achieve significant adaptations in this regard. Further research and longer-term training interventions may be necessary to better understand the effects of HIIT on lung and respiratory functions and to determine the optimal duration and frequency of training required to elicit these adaptations.

Short but intense sprint training can lead to increases in glycolytic and oxidative enzyme activity, maximum short-term power output, and VO_2max levels [27]. However, studies have suggested that interval and high-intensity training models may not necessarily be more effective than traditional training models in improving aerobic and anaerobic capacity. Nonetheless, they are often recommended due to their time efficiency [28, 29]. As a result, interval and high-intensity interval training can be used as an alternative to long-duration endurance runs and can lead to significant improvements in VO_2max levels [1,30].

Previous studies have reported that time of recovery during repetitive sprint exercise protocols can have a significant impact on sprint performance [6, 31, 32]. In all-out efforts with recovery durations of 120 seconds or less, there is a high correlation between the amount of sprint running and the increased recovery time [31, 32]. However, when the recovery time is extended to 60 or 120 seconds, the decrease in performance is significantly reduced (approximately 3% and 2%, respectively) [31]. Nevertheless, when the recovery time exceeds 120 seconds, the significant reduction in losses during exercise can lead to similar gains. In this study, it was observed that groups with 2-minute and 4-minute recovery intervals between all-out efforts achieved similar improvements after 4 weeks of training.

Buchheit et al. (2007) found that sprint training with 17-second rest intervals in-creased anaerobic capacity [19]. Gibala et al. [4] reported that repeated sprints with 30-second efforts and 4-minute rest intervals produced similar metabolic and performance outcomes to continuous aerobic exercises lasting 90–120 minutes [4]. Iaia and Bangsbo [5] examined performance improvements over a wider range and reported that exercise durations of 10–40 seconds, separated by rest intervals of 1–5 minutes and per-formed at near-maximal speeds, were beneficial for achieving physical and physiological adaptations [5]. These different findings create uncertainty about which rest interval is more effective. The results obtained in our study indicate that both 2-minute and 4-minute rest intervals led to similar improvements over a 4-week period. These findings suggest that when designing training programs, appropriate rest durations should be determined based on the athletes' goals and capacities to determine which rest interval is more effective.

Indeed, one of the major limitations of this study was the relatively short duration of the training period, which was limited to 4 weeks. It is possible that the respiratory function capacity, aerobic capacity, and anaerobic power changes may require a longer training period to be adequately examined. Future studies with longer training periods could provide a more comprehensive understanding of the effects of training on these variables.

5. Conclusions

The findings of this study indicate that engaging in high-intensity sprint training for four weeks leads to notable enhancements in athletes' aerobic and anaerobic power. Surprisingly, the duration of rest intervals (2–4 minutes) does not seem to impact these improvements. Nevertheless, it becomes evident that the 4-week training period, consisting of two sessions per week, falls short in producing significant advancements in athletes' respiratory function. While these results contribute to clarifying the effectiveness of rest intervals, further research is required, exploring diverse training periods, rest intervals, and durations, to achieve a more comprehensive understanding of this subject.

References

1. Hottenrott K, Ludyga S, Schulze S. Effects of high intensity training and continuous endurance training on aerobic capacity and body composition in recreationally active runners. J Sports Sci Med. 2012 Sep 1;11(3):483–8.
2. Buchheit M, Laursen PB, Ahmaidi S. Parasympathetic reactivation after repeated sprint exercise. Am J Physiol Heart Circ Physiol. 2007 Jul;293(1):H133-141. DOI: 10.1152/ajpheart.00062.2007
3. Dupont G, Akakpo K, Berthoin S. The effect of in-season, high-intensity interval training in soccer players. J Strength Cond Res. 2004 Aug;18(3):584. DOI: 10.1519/1533-4287(2004)18<584:TEOIHI>2.0.CO;2
4. Gibala MJ, Little JP, Van Essen M, Wilkin GP, Burgomaster KA, Safdar A, et al. Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. J Physiol. 2006;575(3):901-11. DOI: 10.1113/jphysiol.2006.112094
5. Iaia FM, Bangsbo J. Speed endurance training is a powerful stimulus for physiological adaptations and performance improvements of athletes. Scand J Med Sci Sports. 2010;20(s2):11-23. DOI: 10.1111/j.1600-0838.2010.01193.x
6. Spencer M, Bishop D, Dawson B, Goodman C. Physiological and metabolic responses of repeated-sprint activities. Sports Med. 2005 Dec 1;35(12):1025-44. DOI: 10.2165/00007256-200535120-00003
7. Billat VL, Flechet B, Petit B, Muriaux G, Koralsztein JP. Interval training at VO2max: effects on aerobic performance and overtraining markers. Med Sci Sports Exerc. 1999 Jan 1;31(1):156-63. DOI: 10.1097/00005768-199901000-00024
8. Burgomaster KA, Howarth KR, Phillips SM, Rakobowchuk M, MacDonald MJ, McGee SL, et al. Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. J Physiol. 2008;586(1):151-60. DOI: 10.1113/jphysiol.2007.142109
9. World Medical Association. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. JAMA. 2013 Nov;310(20):2191-4. DOI: 10.1001/jama.2013.281053
10. Quanjer PH, Tammeling GJ, Cotes JE, Pedersen OF, Peslin R, Yernault JC. Lung volumes and forced ventilatory flows. Eur Respir J. 1993 Mar 1;6(Suppl 16):5-40. DOI: 10.1183/09041950.005s1693
11. Albuquerque Freire L de, Tannure M, Sampaio M, Slimani M, Znazen H, Bragazzi NL, et al. COVID-19-Related restrictions and quarantine covid-19: effects on cardiovascular and yo-yo test performance in professional soccer players. Front Psychol. 2020;11. DOI: 10.3389/fpsyg.2020.589543
12. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982;14(5):377-81. DOI: 10.1249/00005768-198205000-00012
13. Krustrup P, Bradley PS, Christensen JF, Castagna C, Jackman S, Connolly L, et al. the yo-yo ie2 test: physiological response for untrained men versus trained soccer players. Med Sci SPORTS Exerc. 2015 Jan 1;47(1):100-8. DOI: 10.1249/MSS.0000000000000377
14. Bangsbo J, Iaia FM, Krustrup P. The yo-yo intermittent recovery test. Sports Med. 2008;38(1):37-51. DOI: 10.2165/00007256-200838010-00004
15. Castagna C, Impellizzeri FM, Chamari K, Carlomagno D, Rampinini E. Aerobic fitness and yo-yo continuous and intermittent tests performances in soccer players: a correlation study. J Strength Cond Res. 2006 May;20(2):320. DOI: 10.1519/R-18065.1
16. Bar-Or O. The Wingate anaerobic test an update on methodology, reliability and validity. Sports Med Int J Appl Med Sci Sport Exerc. 1987;4(6):381-94. DOI: 10.2165/00007256-198704060-00001
17. Inbar O, Bar-Or O, Skinner JS. The Wingate anaerobic test. Human Kinetics; 1996.
18. 18. Bishop D, Girard O, Mendez-Villanueva A. Repeated-sprint ability part II: recommendations for training. Sports Med. 2011;41(9):741-56. DOI: 10.2165/11590560-000000000-00000
19. Buchheit M, Haydar B, Ahmaidi S. Repeated sprints with directional changes: do angles matter? J Sports Sci. 2012 Mar;30(6):555-62. DOI: 10.1080/02640414.2012.658079

20. Koral J, Oranchuk DJ, Herrera R, Millet GY. Six sessions of sprint interval training improves running performance in trained athletes. J Strength Cond Res. 2018 Mar;32(3):617-23. DOI: 10.1519/JSC.0000000000002286
21. Ölmez C, Akcan IO. Repetitive sprint or calisthenics training: which is more successful for athletic performance? Acta Kinesiol. 2021;15(2):42-8. DOI: 10.51371/issn.1840-2976.2021.15.2.5
22. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009 Jan;41(1):3-12. DOI: 10.1249/MSS.0b013e31818cb278
23. Dunham C, Harms CA. Effects of high-intensity interval training on pulmonary function. Eur J Appl Physiol. 2012 Aug;112(8):3061-8. DOI: 10.1007/s00421-011-2285-5
24. Lapthanachai S. Effects of high-intensity interval training on body composition, pulmonary function and respiratory muscles strength in sedentary adults with obesity. J Sports Sci Health. 2022 Apr 30;23(1):102-17.
25. Wang Q, Yang F, Gao L, Gao W. Effects of inspiratory muscle training and high-intensity interval training on lung function and respiratory muscle function in asthma. Respir Care. 2022 Jul 19 [cited 2023 May 17]. Available from: https://rc.rcjournal.com/content/early/2022/07/19/respcare.09813
26. Sawyer A, Cavalheri V, Hill K. Effects of high intensity interval training on exercise capacity in people with chronic pul-monary conditions: a narrative review. BMC Sports Sci Med Rehabil. 2020 Mar 30;12(1):22. DOI: 10.1186/s13102-020-00167-y
27. MacDougall JD, Hicks AL, MacDonald JR, McKelvie RS, Green HJ, Smith KM. Muscle performance and enzymatic adaptations to sprint interval training. J Appl Physiol. 1998 Jun;84(6):2138-42. DOI: 10.1152/jappl.1998.84.6.2138
28. Engel FA, Ackermann A, Chtourou H, Sperlich B. High-intensity interval training performed by young athletes: A systematic review and meta-analysis. Front Physiol. 2018;9. DOI: 10.3389/fphys.2018.01012
29. Foster C, Farland CV, Guidotti F, Harbin M, Roberts B, Schuette J, et al. The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. J Sports Sci Med. 2015;14:747-55. DOI: 10.1249/01.mss.0000476771.63318.52
30. Ito S. High-intensity interval training for health benefits and care of cardiac diseases - The key to an efficient exercise protocol. World J Cardiol. 2019 Jul 26;11(7):171-88. DOI: 10.4330/wjc.v11.i7.171
31. Balsom PD, Seger JY, Sjödin B, Ekblom B. Maximal-intensity intermittent exercise: effect of recovery duration. Int J Sports Med. 1992 Oct;13(7):528-33. DOI: 10.1055/s-2007-1021311
32. Preen D, Dawson B, Goodman C, Lawrence S, Beilby J, Ching S. Effect of creatine loading on long-term sprint exercise per-formance and metabolism. Med Sci Sports Exerc. 2001 May;33(5):814-21. DOI: 10.1097/00005768-200105000-00022

Author Contributions: Study Design, IOA and CO; Data Collection, IOA and CO; Statistical Analysis, IOA and CO; Data Interpretation, IOA and CO; Manuscript Preparation, IOA and CO; Literature Search, IOA and CO.; Funding Acquisition, IOA and CO. All authors have read and agreed to the published version of the manuscript.

Funding: The research obtained no external funding.

Institutional Review Board Statement: The study was conducted per the ethical principles of the European Convention and the Declaration of Helsinki and was approved by the University Clinical Research Ethics Committee (No: 02/09/E.U)

Informed Consent Statement: All athletes were informed about the study, and the possible benefits and risks were explained. After verbal notification, all athletes were given a written informed consent form prepared according to the Declaration of Helsinki.

Data Availability Statement: Data available from the corresponding author on request.

Conflicts of Interest: The authors declare no conflict of interest.