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The effect of high-intensity interval training (HIIT) on cardiopulmonary and metabolic function

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Abstract

Aims: The study aims to test the effectiveness High-Intensity Interval Training (HIIT) on metabolic parameters, such as maximal oxygen consumption (VO₂ max), Hemoglobin level (HB), and heart rate variability (HRV).

Method: In an experimental approach, the participants (N=30) were divided into two (i)an experimental group doing HIIT training and(ii) a control group involved in their ordinary training session. Experimental groups underwent 8 weeks of high-intensity cycle ergometer interval training. Pre and two post-test between four weeks of the test included the above parameters.

Results: The finding shows that there is a significant difference in the effect of high-intensity interval training on the (VO₂ max) and Heart Rate Variability (HRV) on the pre-test and post-test of Kedah Under 17 Footballers but no significant difference in the effect of high-intensity interval training on the Hemoglobin level (HB). Apart from that, there is also analysis showing that the control group (S) had only improved at a minimum level over the training period while the (H) group had shown good improvement while the (HE) group had portrayed excellent improvement throughout training and testing.

Impact: The study is to help the country improve the performance of athletes, this study is expected to inspire and spark ideas in the country's sports activists, especially coaches and national athletes.

Conclusions: The eight-week HIIT program improved cardiorespiratory fitness and hematological variables in all participants. Future research would be useful to further investigate the physiological changes resulting from HIIT programs.

Keywords: High-intensity interval training (HIIT), heart rate variability (HRV), hemoglobin (HB), hematology

Introduction

Physical fitness and overall well-being have become paramount concerns in today's fast-paced world. As people seek efficient and effective exercise methods, High-Intensity Interval Training (HIIT) has garnered increasing attention for its ability to deliver significant results in a short period. HIIT involves alternating between periods of maximum effort and rest or lower intensity, leading to enhanced cardiovascular fitness, improved metabolic function, and other positive health outcomes. This article aims to present a detailed overview of HIIT, drawing from the latest scientific literature and references.

HIIT has its roots in athletic training dating back to the early 20th century. Coaches and athletes used interval-based training to enhance performance. However, it was not until the 1950s that Dr. Hans Reindell and his colleagues introduced the concept of interval training in scientific literature. Over time, researchers refined and expanded the methodology, eventually giving rise to the modern High-Intensity Interval Training we know today. (Weston *et al.*, 2014) ^[3].

Principles of HIIT

The fundamental principle of HIIT is the alternation between short bursts of maximal effort, typically lasting between 20 seconds to 2 minutes, and periods of active recovery or rest.

The goal is to push the body to its limits during the high-intensity intervals, eliciting a higher heart rate and metabolic response, followed by a brief recovery period to allow the body to partially recuperate before the next intense effort. (Gibala *et al.*, 2012) [2].

Physiology and mechanisms

The physiological effects of HIIT are diverse and multifaceted. During high-intensity intervals, the body engages its anaerobic energy systems, depleting glycogen stores and increasing the production of lactate. This triggers a phenomenon known as excess post-exercise oxygen consumption (EPOC), resulting in a prolonged calorie-burning effect even after the exercise session has ended. Additionally, HIIT leads to improvements in mitochondrial function, insulin sensitivity, and cardiovascular capacity. (Ramos *et al.*, 2015) [4].

Health benefits of HIIT

Numerous studies have demonstrated the potential health benefits of HIIT. Some of the key advantages include:

- **Improved cardiovascular fitness:** HIIT can lead to significant improvements in cardiovascular health by enhancing heart function and increasing stroke volume.
- **Increased aerobic and anaerobic capacity:** HIIT improves the body's ability to use oxygen during exercise (aerobic capacity) and enhances the anaerobic energy systems, allowing for better performance during short bursts of intense activity.
- **Fat loss and weight management:** HIIT is effective in burning calories and promoting fat loss, making it a valuable tool for weight management.
- **Insulin sensitivity:** HIIT can improve insulin sensitivity, which is beneficial for individuals at risk of or with type 2 diabetes.
- **Time efficiency:** Due to the shorter duration of HIIT workouts, it is an attractive option for individuals with busy schedules seeking an effective exercise routine.

Safety considerations

While HIIT offers numerous benefits, it may not be suitable for everyone. Individuals with certain health conditions, such as heart problems, orthopedic issues, or those new to exercise, should consult a healthcare professional or fitness expert before starting a HIIT program. Proper warm-up and cool-down routines are also essential to prevent injuries.

Individualized HIIT programs

HIIT can be adapted to various fitness levels and goals. The intensity, duration of intervals, and recovery periods can be adjusted to suit individual needs. This adaptability makes HIIT accessible to a wide range of individuals, from beginners to seasoned athletes.

Conclusion

High-Intensity Interval Training (HIIT) is a time-efficient and effective exercise method that has gained immense popularity in recent years. Its ability to induce various physiological adaptations, promote fat loss, and improve cardiovascular fitness has made it a preferred choice for many fitness enthusiasts. However, like any exercise regimen, HIIT should be performed with care and consideration of individual health and fitness levels. As research continues to explore the various aspects of HIIT, its potential benefits and applications in different populations will likely become even more evident. Always consult a fitness professional or healthcare provider before starting any new exercise program, including HIIT.

Cardiopulmonary and metabolic function

On the other hand, Cardiopulmonary and metabolic functions are critical physiological processes that work together to maintain homeostasis, sustain life, and support the body's energy demands. The cardiopulmonary system involves the heart, lungs, and blood vessels, which work in tandem to deliver oxygen and nutrients to tissues while removing carbon dioxide and metabolic waste products. Whereas, metabolic function encompasses a wide array of biochemical processes that involve the conversion of nutrients into energy, the synthesis of biomolecules, and waste elimination. (Berg *et al.*, 2019) [5]

From another angle, the cardiopulmonary system, consisting of the heart, lungs, and blood vessels, is responsible for transporting oxygen and nutrients to tissues while eliminating carbon dioxide and metabolic waste products. The heart functions as a muscular pump that propels oxygenated blood to the body's tissues and deoxygenated blood to the lungs for reoxygenation. Meanwhile, the lungs facilitate gas exchange, where oxygen is taken up from the inhaled air and carbon dioxide is expelled during exhalation. This synchronized process ensures that all body cells receive the necessary oxygen to carry out their metabolic functions efficiently. (McArdle *et al.*, 2014) [6]

Conclusion

Cardiopulmonary and metabolic functions are fundamental physiological processes that ensure the body's proper functioning and energy balance. The interplay between these systems highlights their intricate connection and the importance of a holistic approach to understanding and managing various health conditions. Advancements in research and technology continue to shed light on these intricate processes, paving the way for improved healthcare interventions and better quality of life for individuals worldwide.

Objective and Significance

This study focused on identified answers for objectives and hypotheses mentioned in Table 1.

Table 1: Research Objective with Its Significance

Research Objective	Research Hypothesis
i) To identify the effect of high-intensity interval training (HIIT) on the Maximal Oxygen Consumption (VO ₂ max) of Kedah under 17 footballers.	There was no significant difference in the effect of high-intensity interval training on maximal oxygen consumption (VO ₂ max) on the pre-test and post-test between the treatment group and the control group.
ii) To identify the effect of high-intensity interval training (HIIT) on the Hemoglobin level (HB) of Kedah under 17 footballers.	There was no significant difference in the effect of high-intensity interval training on the Hemoglobin level (HB) on the pre-test and post-test between the treatment group and control group.

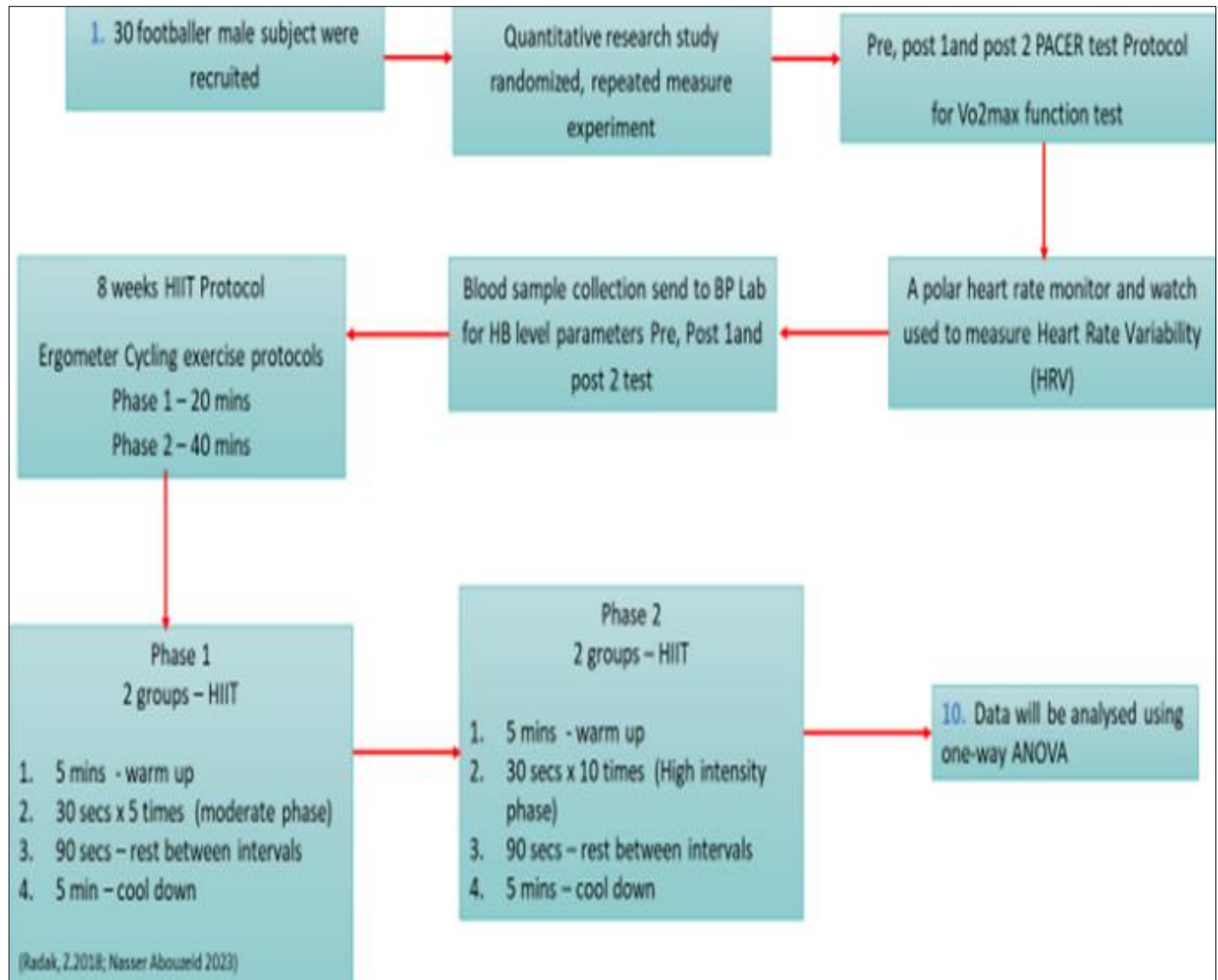
To identify the effect of high-intensity interval training (HIIT) on the Heart Rate Variability (HRV) of Kedah under 17 footballers.	There was no significant difference in the effect of high-intensity interval training on the Heart Rate Variability (HRV) on the pre-test and post-test between the treatment group and control group.
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Significance of Research

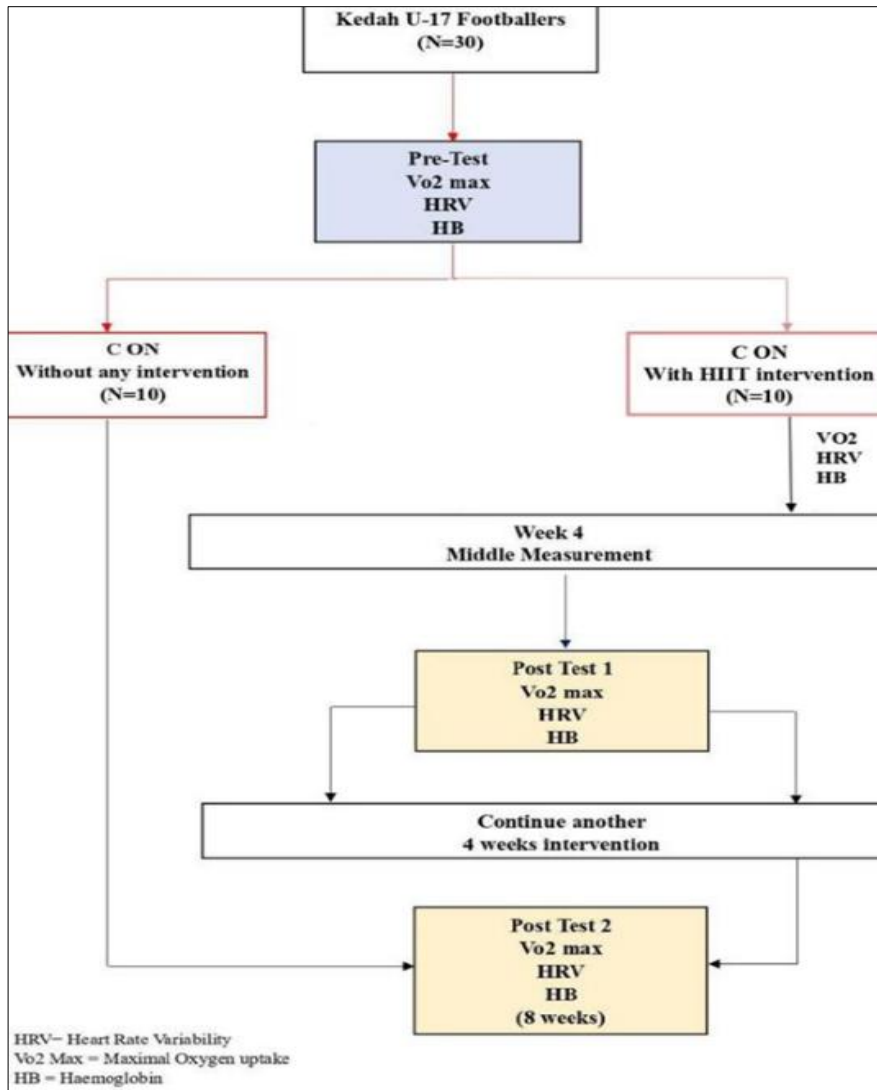
The significance of this study is to find answers and solutions to the issues and research hypotheses that have been identified. Therefore, the study here is to refer to the expected findings of the study, which in turn can contribute to the improvement of the quality of national sports, besides being a source of reference to sports organizations. To help the country improve the performance of athletes, this study is expected to inspire and spark ideas in the country's sports activists, especially coaches and national athletes.

Furthermore, the significance is to test the effectiveness High-Intensity Interval Training (HIIT) on metabolic parameters, such as maximal oxygen consumption (VO2 max), Hemoglobin level (HB), and heart rate variability (HRV). According to the researcher, these findings will provide additional information on HIIT's efficacy, which can improve cardiopulmonary fitness.

Research Method



Research Design



Research Finding

Table 2: Comparison of Effect by two groups on the Maximal Oxygen Consumption (VO2 Max), the Haemoglobin level (HB), and the Heart Rate Variability of Kedah Under 17 Footballer

		VO2 max			HB			HRV		
		N	Mean	Std. D	N	Mean	Std. D	N	Mean	Std. D
Control Group	Pre-Test	10	45.4	2.7	10	14.0	0.40	10	89.7	6.7
	Post Test 1	10	46.1	3.3	10	14.1	0.36	10	90.6	6.4
	Post Test 2	10	46.2	4.0	10	14.2	0.57	10	92.7	6.0
	Total	10	45.9	3.3	10	14.1	0.44	10	91.0	6.3
HIIT	Pre-Test	10	46.2	2.5	10	14.1	0.52	10	90.0	6.8
	Post Test 1	10	48.5	2.7	10	14.3	0.54	10	95.4	7.3
	Post Test 2	10	50.6	2.7	10	14.6	0.53	10	100.5	7.0
	Total	10	48.5	3.1	10	14.4	0.55	10	95.3	8.1

Table 3: Comparison of Effect by two groups on the Maximal Oxygen Consumption (VO2 Max), the Haemoglobin level (HB), and the Heart Rate Variability of Kedah Under 17 Footballer

ANOVA											
		VO2Max			HB			HRV			
		Df	F	Sig.	Df	F	Sig.	Df	F	Sig.	
VO2 Max test Control Group	Between Groups	2	.180	.836	2	.321	.728	2	.581	.566	
	Within Groups	27			27			27			
	Total	29			29			29			
VO2 Max test HIIT	Between Groups	2	7.046	.003	2	1.982	.157	2	5.576	.009	
	Within Groups	27			27			27			
	Total	29			29			29			

In this part, the focus will be on answering and showing the illustration for three research objectives raised in the study.

The table shows the comparison of the effect of high-intensity of interval training (HIIT) between two groups on three parameters of research objectives.

The first parameter test was conducted to see if there was a significant difference in VO₂ Max scores between three different tests which were the Pre-test before HIIT training, the Post-test 1 after HIIT training, and the Post-test 2. The analysis shows in Table 2 that there is a significant difference at the $p < .05$ level, $F(2,27) = 7.046$, $p = .003$. Post-Hoc comparison using Tukey's test showed that the mean VO₂ Max test score for Post-test 2 ($M = 50.6$, $SD = 2.66$) was significantly different from Post-test 1 ($M = 48.5$, $SD = 2.74$) and Pre-test ($M = 46.2$, $SD = 2.53$).

Next, the test was conducted to see if there was a significant difference in Haemoglobin (HB) scores between three different tests which were the Pre-test before HIIT training, the Post-test 1 after HIIT training, and the Post-test 2. Table 2 shows the analysis that there is no significant difference at the $p < .05$ level, $F(2,27) = 1.982$, $p = .157$. Post-Hoc comparison using Tukey's test showed that the mean Haemoglobin (HB) test score for Post-test 2 ($M = 14.6$, $SD = 0.53$) was not significantly different from Post-test 1 ($M = 14.3$, $SD = 0.54$) and Pre-test ($M = 14.1$, $SD = 0.52$).

Following up, the test was conducted to see if there was a significant difference in Heart Rate Variability (HRV)

scores between three different tests which were the Pre-test before HIIT training, the Post-test 1 after HIIT training, and the Post-test 2. Table 2 shows the analysis that there is a significant difference at the $p < .05$ level, $F(2,27) = 5.576$, $p = .009$. Post-Hoc comparison using Tukey's test showed that the mean Heart Rate Variability (HRV) test score for Post-test 2 ($M = 100.5$, $SD = 7.04$) was significantly different from Post-test 1 ($M = 95.4$, $SD = 7.28$) and Pre-test ($M = 90.0$, $SD = 6.77$).

The research focuses on the effect of high-intensity interval training (HIIT) on cardiopulmonary and metabolic function among Kedah under-17 footballers. The finding shows that there is a significant difference in the effect of high-intensity interval training on the (VO₂ max) on the pre-test and post-test of Kedah Under 17 Footballers but no significant difference in the effect of high-intensity interval training on the Hemoglobin level (HB). Overall, the finding concludes that there is a significant effect of high-intensity interval training (HIIT) on cardiopulmonary and metabolic function among Kedah under 17 footballers. Apart from that, there is also analyzed showing that the control group (S) had only improved at a minimum level over the training period while the (H) group had shown good improvement throughout training and testing.

Hypotheses Analysis

Table 4: Hypotheses Analysis

No	Hypotheses	Result
1	There was no significant difference in the effect of high-intensity interval training on the maximal oxygen consumption (VO ₂ max) on the pre-test and post-test of Kedah Under 17 Footballers	Rejected
2	There was no significant difference in the effect of high-intensity interval training on the Haemoglobin level (HB) on the pre-test and post-test of Kedah Under 17 Footballers	Accepted
3	There was no significant difference in the effect of high-intensity interval training on the Heart Rate Variability (HRV) on the pre-test and post-test of Kedah Under 17 Footballers	Rejected

Discussion and Conclusion

The study focused on examining The Effect of High-Intensity Interval Training (HIIT) On Cardiopulmonary and Metabolic Function among Kedah under-17 footballers', on specific parameters like Maximum Rate of Oxygen Consumption (VO₂ max), Hemoglobin (HB), and Heart Rate Variability (HRV) helps to assess the impact of HIIT on various aspects of the athletes' physiological and cardiovascular health. The improvements in VO₂ max, HB levels, and HRV in the experimental (H) group compared to the control group (S) indicate that the implementation of the HIIT protocol has positive effects on the cardiopulmonary and metabolic function of the under-17 footballers. An increase in VO₂ max reflects improved aerobic capacity, which is crucial for endurance and overall athletic performance. Higher Hemoglobin levels may suggest enhanced oxygen-carrying capacity in the blood, potentially leading to improved oxygen delivery to muscles during exercise, but unfortunately, there was no significant difference in the effect of high-intensity interval training on the Haemoglobin level (HB). Additionally, positive changes in Heart Rate Variability indicate better autonomic nervous system regulation, which is associated with improved recovery and overall cardiovascular health.

In other aspects is an important contribution to the field of sports science and athlete training. This specific population of young footballers represents a relevant target group for

such research, as their physical fitness and performance can significantly impact their athletic development and future success.

The observed improvements in the (H) group compared to the control group (S) indicate that the implementation of the HIIT protocol was effective in eliciting positive changes in the footballers' cardiopulmonary and metabolic health. This suggests that incorporating HIIT into their training routines can be a valuable strategy for enhancing their overall fitness, which may ultimately translate into improved on-field performance.

The fact that the control group (S) showed only minimal improvements over the training period underscores the potential superiority of HIIT over more traditional training methods or a lack of structured training altogether. This further emphasizes the importance of structured and scientifically designed training programs, such as HIIT, to optimize the physical development of young athletes.

The findings from this study can have practical implications for coaches, trainers, and sports organizations working with young footballers in Kedah or similar contexts. Implementing HIIT as part of their training regimens could be a viable approach to enhance the physical fitness and performance of the athletes.

However, it is essential to acknowledge some limitations of the study and potential areas for future research. The study's sample size, duration of the training period, and specific

HIIT protocol used may influence the generalizability of the results. Additionally, the study might benefit from further investigations into other factors that could have influenced the observed improvements, such as nutritional habits, recovery strategies, and other training components.

Future research could also consider comparing the effects of HIIT to other training methods commonly used in football player development or exploring the long-term effects of sustained HIIT training on athletes' performance and injury rates. Moreover, understanding how individual variations in responses to HIIT may impact the outcomes could be relevant for personalized training program design.

In conclusion, the finding that HIIT has a significant effect on cardiopulmonary and metabolic function among Kedah under-17 footballers is valuable for both sports science and athlete development. The study highlights the potential benefits of incorporating structured HIIT into training programs for young athletes to optimize their physical capabilities. However, ongoing research is needed to further explore the specific mechanisms and potential long-term impacts of HIIT training in this population.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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