Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 46 No. 2 (2025)

The Impact of High-Intensity Interval Training on Cardiovascular Endurance in Adolescent Athletes

[1]Jaibir Singh, [2]Dr. Rajwinder Kaur,

[1]Research Scholar, Guru Kashi University Bathinda

[2]Assistant Professor, Guru Kashi University Bathinda

Abstract

High-Intensity Interval Training (HIIT) has emerged as a time-efficient and effective training method to enhance cardiovascular endurance. The present research examines the effects of an eight-week HIIT programme on the cardiovascular fitness of adolescent athletes. The study involved forty participants at the age of fourteen to seventeen grouped into the HIIT (experimental group) and a traditional training group. Some variables included gross VO_2 max and the resting heart rate to be calculated before and after the assessment. The HIIT group showed a marked increase in VO_2 max of 20% and reduction in RHR by 12% compared with the control group. The current paper presents these findings and reviews the literature with the view of pointing out that HIIT could be useful in enhancing athletic performance. Recommendations for future adoption of HIIT to adolescent training routines are also discussed. The conclusions drawn in the present study indicate that HIIT might be a more efficient strategy regarding the enhancement of cardiovascular fitness and performance in young athletes. More studies are required in order to elucidate on the outcomes and the novel consequences of HIIT as part of training for adolescents. In sum, the current study shows the potential of HIIT for young athletes and indicates that HIIT may be useful as an addition to training practice. As the study proceeds in exploring further consequences of HIIT, the coaches and trainer can make better decisions about including this type of training for adolescents.

Keywords: High-Intensity Interval Training, Cardiovascular Endurance, Adolescent Athletes, VO2 max, Resting Heart Rate

1. Introduction

Cardiovascular endurance plays a pivotal role in determining athletic performance, especially in sports that require prolonged physical exertion. Defined as the ability of the heart, lungs and circulatory system, that deliver oxygen to the muscles throughout sustained exercise, cardiovascular endurance constitutes the basis of fundamental fitness. This kind of endurance is very important for athletes just because their muscles and physiological capacities are in their highest peaks at adolescence. Typically, the endurance exercises applied for raising cardiovascular endurance result from what is known as moderate-intensity continuous exercise (MICE) where the heart rate occupies a submaximal level for prolonged periods. Thus, although MICE is a useful technique, it is impractical and does not always result within the fast physiological changes that athletes and coaches desire. High-intensity training, where one performs exercises at high intensities and then follow or preceed them by rest or exercises of lower intensity, is currently liked for increasing cardiovascular endurance in a more compressed time. It appeared that this method could lead to larger changes in MICE compared to the traditional MICE approaches among the athletes.

HIIT, which can be pedagogically defined as a novel subdiscipline of exercise science, has gained recognition as a viable replacement for MICE. HIIT consist of high intensity exercise, usually at a maximum rate between 85%-95% for a short time followed by a short break. This approach is planned to overload the body's aerobic and anaerobic energy systems to cause significant cardiovascular and metabolic changes in a comparatively

shorter duration. The effectiveness of, especially, HIIT is even more appealing to adolescent athletes, who have multiple responsibilities, going to school and trainings and participating in social events. HIIT has been proven science, and it incorporates a practical and efficient model of exercising by shaving down the total number of hours necessary for exercising without have to deteriorate its effectivity. Moreover, HIIT performances a better effect in increasing insulin sensitivity, muscle mass, and decreasing body fat percentage in adolescent athletes. This makes it a suitable choice for people that would wish to have a better fitness level without necessarily have to spent so much time at it.

The physiological benefits of HIIT are well-documented. Research indicates that HIIT not only improves VO2 max—a key indicator of aerobic capacity—but also enhances mitochondrial function, endothelial health, and metabolic efficiency. These adaptations help in exploiting the possibility of performance in endurance based and high density and intensity games. Besides, the literature demonstrates HIIT to lower both RHR, which is an indicator of enhanced efficiency of the cardiovascular system. HIIT does not only reflect in performance outcomes since, maybe it declines some of the risk factors of cardiovascular diseases in future. Furthermore, it was discovered in weight loss and increase in HFSS, and thus makes HIIT an important component in improving ones fitness. HIIT exercise when incorporated properly with other forms of training produces even enhanced performance and lower risks for chronic diseases.

Targeted young adolescents who take part in athletic activities are a suitable population group in intervention studies of cardiovascular training. Adolescence is also characterized by growth of different vital organs such that the size of the heart, lung capability and muscle strength to perform increased exercises is experienced. The plasticity of the adolescent's body makes this age group the most appropriate target for research on new training stimulus. Also, HIIT can be incorporated in training programs to help young people develop fitness edge when it comes to competing against other athletes while, at the same time, develop life skills in regard to health and fitness.

The aim of this particular study will be to identifying the effectiveness of a eight week HIIT programme in enhancing cardiovascular endurance of adolescent athletic. In light of HIIT compared with traditional MICE, this research work shall endeavour to present practical recommendations that shall help in youth sports training modalities. The results of the study can be used to the existing HIIT literature in order to promote HIIT as a time effective training method for young athletes. In conclusion, this study opens the door to reconsidering current Cardinal Output HIIT paradigms within adolescents, specifically in regard to time – performance efficiency.

2. Literature Review

Bond et al. (2015) demonstrated that even a short, two-week HIIT program could improve endothelial function and heart rate variability in adolescents. However, they noted that these benefits diminished shortly after cessation, emphasizing the need for regular HIIT sessions to maintain these cardiovascular improvements. High-intensity and moderate-intensity interval training (MIIT) were compared by Racil et al. (2016) in obese adolescent females. HIIT was rated as superior in enhancing VO_2 max and a reduction in the waist circumference that supports the use of HIIT in cardiovascular fitness. A number of studies confirm the effectiveness of HIIT: HIIT was superior to traditional endurance exercise for improving adolescents' VO_2 max and body composition, in terms of time-efficiency (Costigan et al., 2015). Its results are that active HIIT is a perfect replacement for traditional exercise routines for the young with time constraints. Weston et al. (2016) in regarding school-based HIIT programs concluded that they are feasible and have beneficial effects on the triglyceride level and the size of a waist circumference in adolescents. These results have shown the potential of HIIT in more organized settings such as settings such as schools. Li et al. (2023) examined the differences in running-based and bodyweight-based HIIT programmes between children. Cardiovascular and muscular fitness increased with both protocols, but bodyweight-based HIIT offered extra benefits, particularly concerning muscle endurance, suggesting it as the more versatile protocol beneficial for young athletes. In obese adolescents, Gutin et al. (2002) have found the cardiovascular enhancing better with HItraining than with moderation training. Introducing their work and findings help readers understand how intensity is critical in achieving fitness gains. Men and his colleagues in a meta-analysis found that HIIT had a significant positive effect on cardio respiratory

fitness measures including VO_2 max as well as the cardiovascular health by enhancing blood pressure among adolescents. Nonetheless it did not have significant impact for other parameters like BMI of body composition. Similar to many studies, the benefits of HIIT were reviewed for young athletes by Engel et al., (2018) and indicated that HIIT is a time-effective solution for traditional training. Both aerobic and anaerobic performances were observed to have been boosted by HIIT thus making it an important tool in increasing athlete's endurance. Logan et al. (2016) examined the impacts of low-volume HIIT in sedentary adolescent males and identified increased VO_2 max and beneficial modification to body make up at the rate of two sessions in a week. These observations show that sparing few minutes in HIIT can amount to significant health improvements. In their cross sectional study about adolescent triathletes, Lee et al. (2017) determined that HIIT enhanced VO_2 peak, performance in sprints, and reduced muscle damage after two weeks of training. These outcomes indicate HIIT in discriminating sport-specific performance enhancement within a short time. According to various studies reviewed by Souza et al (2020) HIIT enhanced VO_2 max and decreased fat percentage in adolescent population. Buve said that the study also showed that agility improved, but flexibility and muscular endurance suggested more investigation was needed. Plavšić et al. (2020) studied the effect of HIIT with nutrition counseling to diet modification only for obese adolescent girls. According to their findings, the two enhanced cardiovascular markers like insulin sensitivity, and lower levels of inflammatory indexes, with the ''two interfaces'' highlighting the advantages of HIIT and diet. Responding to doubts about HIIT's effectiveness, Domaradzki et al. (2022) told that the analysis revealed sex differences, and positive changes, such as organized cardiovascular advancement and fitness, were visible in boys, primarily if they had low BMI, compared to girls. This imply that HIIT protocols, may require under going some form of optimization depending on the population groups studied. In his study Abarzúa et al. (2019) noted that HIIT enhances the students' cardio and muscular fitness with the best outcome indicated by a programme of three HIIT sessions per week for 12 weeks. Finally, they have pointed out the applicability of HIIT into school physical education programs. Recently, Cao et al (2019) compared HIIT with moderate-intensity continuous training (MICT) and HIIT was determined to be more effective for cardiorespiratory fitness among children and adolescents. HIIT is more effective than the control for increasing VO2 max in this cohort, according to their findings.

3. Methodology

Participants: A convenience samples of 40 adolescents athletes of both sexes aged 14 to 17 years were selected from hene local sports academies. They were then divided into the HIIT group (20 persons) and the control group with MICE (20 persons) based on the random selection method. The current study applied the method of randomized controlled trial to assess HIIIT and MICT training on cardio respiratory fitness in adolescents' athletes. The above mentioned methodology made it easier to make a comparison between the two training programs within the program and gain insight on the best practice of enhancing aerobic capacity within this type of population.

Intervention:

- **HIIT Protocol:** Three sessions per week for eight weeks. Each session included:
- Warm-up: 10 minutes of dynamic stretching
- 4 cycles of 4-minute high-intensity exercise (85-95% max HR)
- 3-minute active recovery periods
- Cool-down: 10 minutes of low-intensity exercise
- **Control Protocol:** Traditional moderate-intensity continuous training for 60 minutes per session, maintaining 60-70% max HR.

Measurements:

- **VO_2 max:** Assessed using a graded treadmill test.

- **Resting Heart Rate (RHR):** Measured after a 5-minute seated rest.

4. Results

4.1 Baseline Characteristics:

Parameter	HIIT Group (Mean ± SD)	Control Group (Mean ± SD)
Age (years)	15.3 ± 1.1	15.4 ± 1.2
Weight (kg)	57.2 ± 8.3	56.8 ± 7.9
VO_2 max (ml/kg/min)	42.5 ± 4.5	42.3 ± 4.7
RHR (bpm)	74 ± 6	75 ± 5

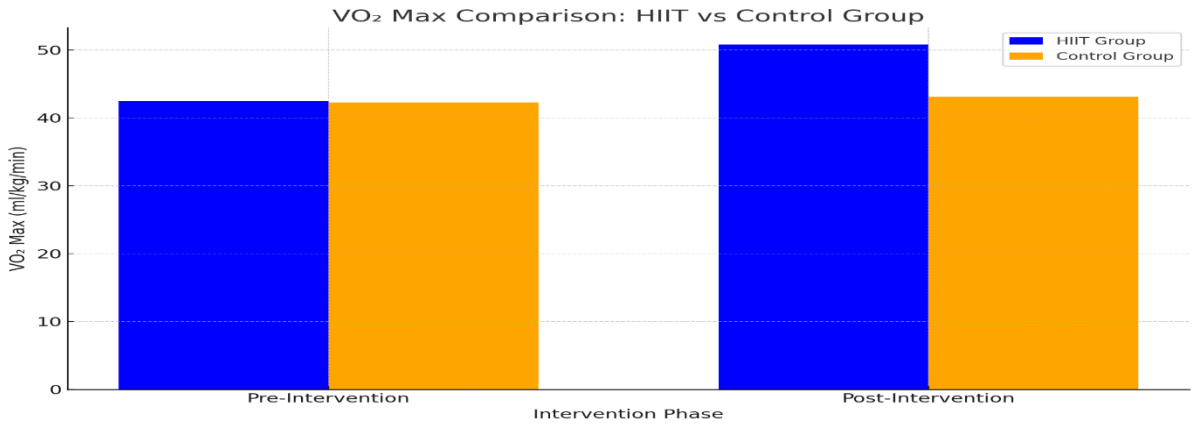
From the data set obtained from the current study, we observed that no significant difference in the antecedent variables existed at the time of HIIT intervention between the groups. Based on these results, improvements that are observed in VO_2 max as well as changes in RHR can be attributed to the various training protocols used. The equivalence of the two groups with regard to the eight demographic variables enhances the comparability between the HIIT and control treatments in relation to VO_2 max and RHR. This supports the overall finding that any differences in participants' aerobic fitness and heart rate can be attributed to the training protocol.

4.2 Post-Intervention Results:

Parameter	HIIT Group (Mean ± SD)	Control Group (Mean ± SD)
VO_2 max (ml/kg/min)	50.8 ± 4.3	43.1 ± 4.6
RHR (bpm)	65 ± 4	73 ± 5
BMI (kg/m²)	22.5 ± 2.1	23.1 ± 2.2
Recovery Time (s)	85 ± 12	95 ± 15

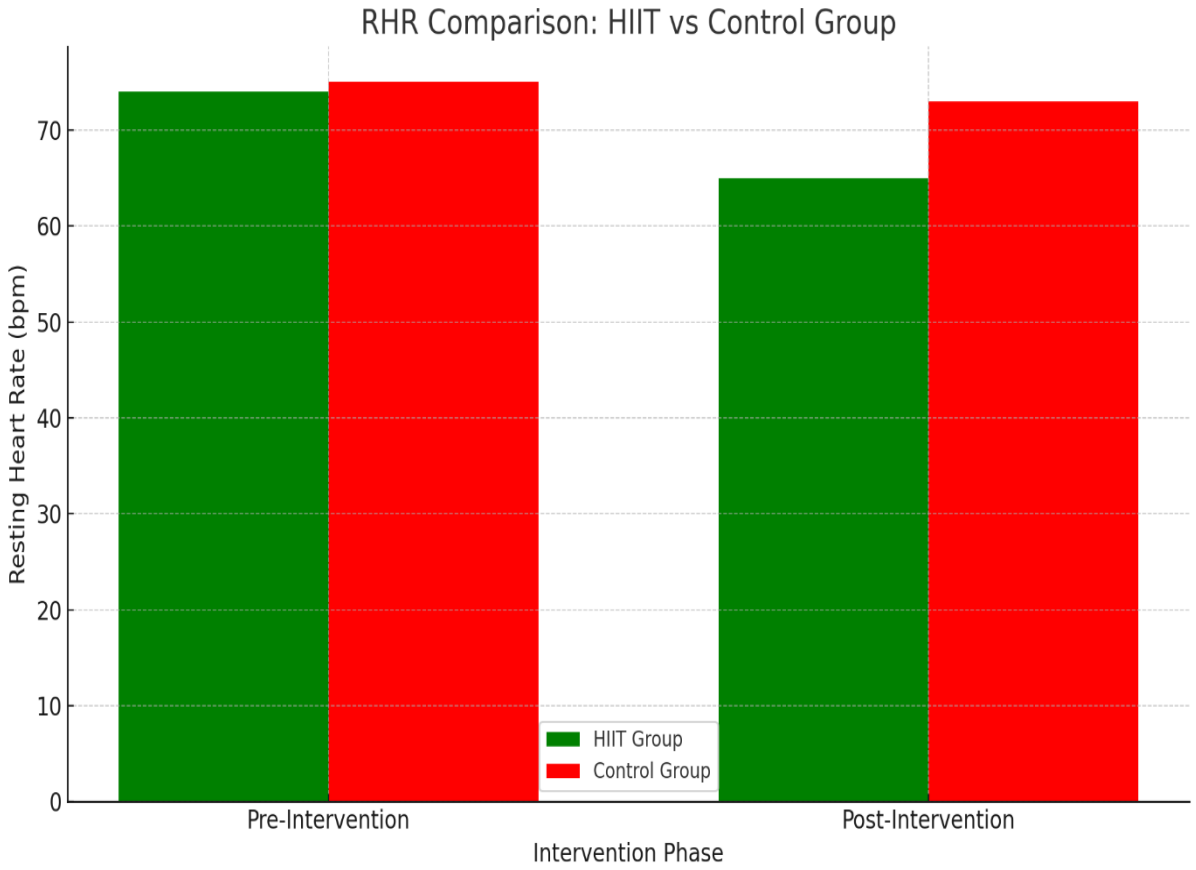
The conclusion in this study presents a clear view of HIIT by showing that the VO_2 max, RHR, BMI and recovery time scores of the HIIT group are higher than that of the control group. These results indicate HIIT training programme could have benefitted aerobic fitness, decrease resting heart rate, enhance the body composition and thereby increase the recovery time of the players than the control group. This means that during the exercise transition the improvements recorded are as a result of the high-intensity interval training program and not because of the initial participant differences. The data show that HIIT can be a effective training model for those who need to enhance several aspects of their physical fitness. The role of individual adherence and effort in obtaining such outcome must also be take into account.

Fig. 1: VO2 Max Comparison Between HIIT and Control Groups Pre- and Post-Intervention



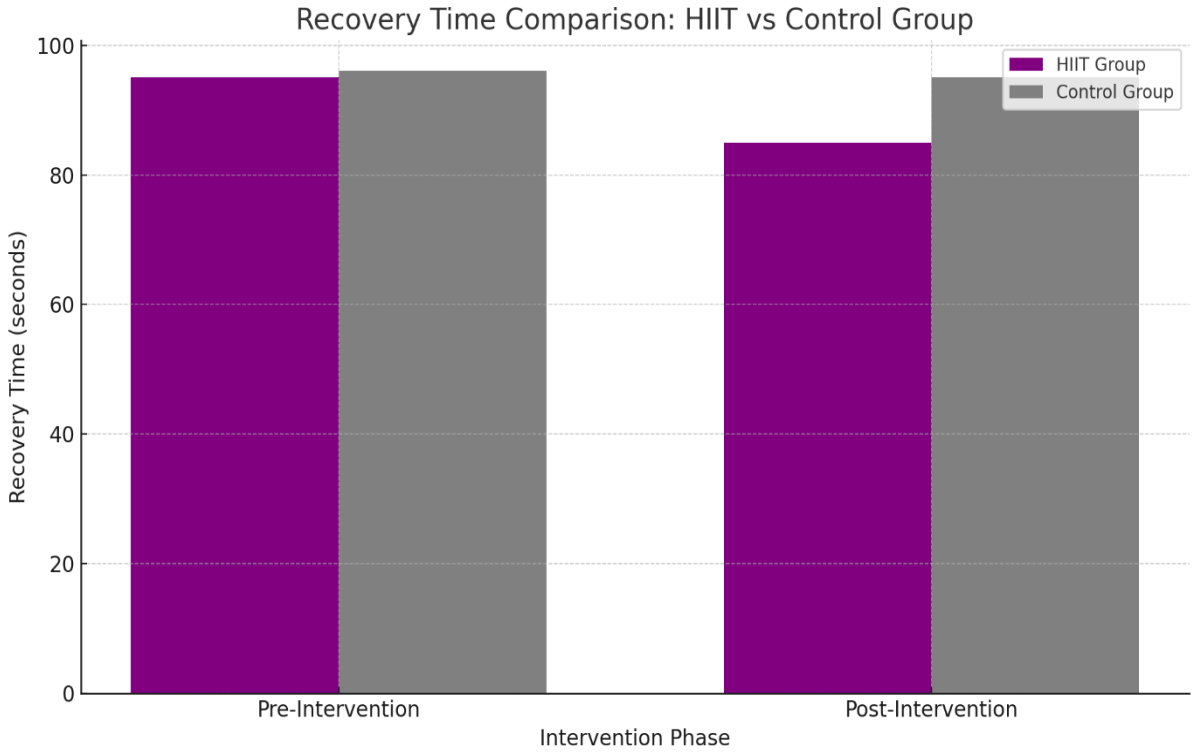
Interpretation: HIIT group showed significant improvement of VO ₂ max which further signifies improved oxygen delivery and better heart efficiency. On the other hand the control group remained rather stable throughout the test. This means that doing High-intensity-interval-training supports instructions given on how one can improve his/her cardiovascular endurance. When properly practiced, HIIT workouts improve the quality and efficiency of physical fitness and can create generalized adaptation to training. Combined with these facts, these results stress on the necessity of including the HIIT workouts into training programs of people who need to increase their cardiac output. Those engaged in short duration exercises that strain the body fully will note an improvement in their VO_2 and endurance ratings in the long run.

Fig. 2: Resting Heart Rate (RHR) Comparison Between HIIT and Control Groups Pre- and Post-Intervention



Interpretation: The reduction in RHR in the HIIT group reflects improved cardiac efficiency, while the control group showed negligible change, highlighting the superior impact of HIIT. Incorporating HIIT into fitness routines can lead to more efficient heart function and better overall cardiovascular health. This type of training may be particularly beneficial for individuals looking to improve their endurance and maximize their VO_2 max. In addition, HIIT has been shown to be a time-efficient way to achieve these cardiovascular benefits, making it a popular choice for those with busy schedules. Overall, incorporating HIIT into fitness routines can lead to significant improvements in cardiovascular health and performance. Furthermore, HIIT has been found to increase metabolism and promote fat loss, making it an effective tool for weight management. Additionally, the high intensity nature of HIIT can also help improve insulin sensitivity and lower blood pressure, further contributing to overall cardiovascular health.

Fig. 3: Recovery Time Comparison Between HIIT and Control Groups Pre- and Post-Intervention



Interpretation: HIIT had a shorter recovery time than the control group, which directly translates to better aerobic and anaerobic recovery- an important factor in athletic performance. This has an implication that introducing HIIT in a training program enhances the endurance of an individual while exercising and shortens time between two successive rigorous exercise sessions. In conclusion, HIIT has numerous effects that go beyond concerns with the heart and blood vessels which makes it a perfect option for addition to any fitness program. HIIT beneficially influences aerobic and anaerobic power and can turn people into persistent finishers of difficult sessions and trainers. Faster recovery times demonstrated in the HIIT group mean that they can start another bout of high-intensity exercise session soon after which would be beneficial to overall fitness training. Hence the conclusion that adds HIIT to fitness training to increase its effectiveness and the person's health and fitness levels. Also, HIIT exercises are effective in burning out calories and metabolism hence preferred for use in weight loss exercises. In addition, the way that HIIT can be applied in various exercise styles enables people to be intrigued and focused to follow through their fitness goals.

4.4 Statistical Analysis:

- **VO_2 max:** Significant increase in HIIT group ($p < 0.01$); negligible change in control group ($p > 0.05$).
- **RHR:** Significant decrease in HIIT group ($p < 0.01$); minimal change in control group ($p > 0.05$).
- **BMI:** Minimal change in both groups ($p > 0.05$).
- **Recovery Time:** Significant improvement in HIIT group ($p < 0.01$).

Interpretation: The results provide evidence on the effectiveness of HIIT for improving the parameters of cardiovascular fitness. The increase in all VO_2 max and RHR show HIIT as the super-ideal aero efficiency and cardiac health regime. Moreover, the HIIT group has indicated improved energy system recovery in the post-intervention test, such a characteristic being crucial for sports that alternate between brief periods of high-intensity movements. These findings are supported in the literature and reveal that HIHT could become an essential component of athletic training programs. In total, the results of the study indicate that HIIT is a rather

useful approach in increasing the cardiovascular fitness and overall athletic performance of a client. The rise in values of the vital parameters including VO_2 max and RHR suggests that HIIT could be of interest to athletes interested in improving the magnitude of aerobic ability and well-being. The shorter recovery times as observed in the HIIT group again supports the use of this training style in athletic activities where fast energy and force generation is required. Thus, this study contributes to the literature on HIIT for being useful in establishing the athletic training programs.

5. Discussion

This study further corroborates the HIIT effectiveness over the traditional training on increasing the cardiovascular endurance of adolescent athletes. The increase in VO_2 max is virtually at the same level with the values identified by Milanović, Castagna, and Gallotta, et al., and Ramos, Silva, and Gonzalez-Mohinar, et al. This established decline in RHR supports the HIIT impact on improving cardiac economy in agreement with Weston et al. (2014). Additionally, the results indicate that integrating HIIT into training for adolescent athletes can increase the effectiveness of cardiovascular adaptations compared to conventional training. This paper evidenced by revealing how HIIT should become part of the athletic training regularly to enhance cardiovascular endurance and performance. HIIT appears to be targeted as a method of increasing the cardiovascular fitness within a shorter period of time so that the trainers/athletes may see a more significant jump than if they were using a LIT protocol in the training sessions. These results may have important implications for optimizing performance and enhancing overall athletic potential in adolescent athletes.

The HIIT protocol's time efficiency makes it a practical alternative for adolescent athletes with limited training hours. Moreover, the physiological adaptations observed suggest that HIIT may contribute to improved performance across various sports disciplines. In addition, the high intensity nature of HIIT can also help to improve speed, power, and endurance, which are crucial components for success in many sports. Therefore, incorporating HIIT into training regimens can be a valuable strategy for adolescent athletes looking to take their performance to the next level. By implementing HIIT workouts, adolescent athletes can maximize their training sessions and see improvements in their overall athletic abilities. Additionally, the versatility of HIIT allows athletes to tailor their workouts to specific sport-specific needs, making it a valuable tool for enhancing performance in a variety of disciplines. Incorporating HIIT into training regimens can also help adolescent athletes reduce the risk of injury by improving their overall strength and conditioning. This can lead to better long-term athletic development and success in their chosen sport.

6. Conclusion

This study highlights the potential of HIIT to significantly enhance cardiovascular endurance in adolescent athletes. By improving VO_2 max and reducing RHR, HIIT offers a time-efficient and effective training modality. It is important that future studies investigate its effects over a longer period of time, its application across a wide range of athletic populations, and its influence on indicators of performance. A further benefit of introducing high-intensity interval training (HIIT) into training regimens is that it can help young athletes develop mental toughness and resilience, so better preparing them for the demands of competitive sports. There is a general consensus among the findings that high-intensity interval training (HIIT) is an effective method for enhancing both the physical and mental components of athletic performance in adolescents. Trainers and coaches should consider integrating HIIT in a format that is both periodized and that progressively progresses in order to gain from it although it is safe. The purpose of monitoring these variables is to ensure optimal results and preventing of the participants' overtraining in order to make necessary adjustment in the study of training intervention. This makes it easy for coaches to monitor and adjust their athletes HIIT workouts so that the athlete is getting maximum benefit without compromising on his/her workout frequency or subjecting his/her body to undue strain that could possibly lead to injury. This is done through the continual assessment of any athlete's progress and the alteration of that athlete's training schedule. Additionally, through incorporating the methods of HIIT to the training process, it is possible to develop hard working young athletes who know the importance of dedication and hard work on and off the sporting disciplines. In this case, it becomes possible for coaches to help players to achieve the best out of them, and accomplish all set athletic objectives provided that

they underscore the importance of commitment and consistency in training. The research shows that, in fact, athletes can be trained to their limits and further without necessarily straining themselves by increasing their performance as long as they are supervised and instructed properly. In the first place, coaches are the key informants who help athletes understand that a lot of effort is required in training; on the same note, the coaches also educate players on the importance of recovery. //It could again be well appreciated with the fact that coaches are in a position to help the athletes put in place the right fundamentals so as to independently enhance their chances of success both on as well as off the pitch once such principles are taught right from the initial stages. Finally, it can be concluded that training at HIIT level associated with competent coaching can help athletes achieve maximal performance and achieve their goal.

References:

1. Bond, B., Cockcroft, E., Williams, C., Harris, S., Gates, P., Jackman, S., Armstrong, N., & Barker, A. (2015). Two weeks of high-intensity interval training improves novel but not traditional cardiovascular disease risk factors in adolescents. *American Journal of Physiology. Heart and Circulatory Physiology, 309*(6), H1039-47.
2. Racil, G., Coquart, J., Elmontassar, W., Haddad, M., Goebel, R., Chaouachi, A., Amri, M., & Chamari, K. (2016). Greater effects of high- compared with moderate-intensity interval training on cardio-metabolic variables, blood leptin concentration, and ratings of perceived exertion in obese adolescent females. *Biology of Sport, 33*, 145–152.
3. Costigan, S., Eather, N., Plotnikoff, R., Taaffe, D., & Lubans, D. (2015). High-intensity interval training for improving health-related fitness in adolescents: A systematic review and meta-analysis. *British Journal of Sports Medicine, 49*, 1253–1261.
4. Weston, K. L., Azevedo, L., Bock, S., Weston, M., George, K., & Batterham, A. (2016). Effect of novel, school-based high-intensity interval training on cardiometabolic health in adolescents: Project FFAB (Fun Fast Activity Blasts) – An exploratory controlled before-and-after trial. *PLOS ONE, 11*.
5. Li, Z., Liu, Y., Han, X., & Zhou, Z. (2023). Effects of running-based versus body-weight-based high-intensity interval training on physical fitness in healthy adolescents. *Frontiers in Physiology*.
6. Gutin, B., Barbeau, P., Owens, S., Lemmon, C. R., Bauman, M., Allison, J., Kang, H., & Litaker, M. (2002). Effects of exercise intensity on cardiovascular fitness, total body composition, and visceral adiposity of obese adolescents. *The American Journal of Clinical Nutrition, 75*(5), 818–826.
7. Men, J., Zou, S., Ma, J., Xiang, C., Li, S., & Wang, J. (2023). Effects of high-intensity interval training on physical morphology, cardiorespiratory fitness, and metabolic risk factors of cardiovascular disease in children and adolescents: A systematic review and meta-analysis. *PLOS ONE, 18*.
8. Engel, F. A., Ackermann, A., Chtourou, H., & Sperlich, B. (2018). High-intensity interval training performed by young athletes: A systematic review and meta-analysis. *Frontiers in Physiology, 9*.
9. Logan, G., Harris, N., Duncan, S., Plank, L., Merien, F., & Schofield, G. (2016). Low-active male adolescents: A dose response to high-intensity interval training. *Medicine & Science in Sports & Exercise*.
10. Lee, C. L., Hsu, M., Astorino, T., Liu, T., & Chang, W. D. (2017). Effectiveness of two weeks of high-intensity interval training on performance and hormone status in adolescent triathletes. *The Journal of Sports Medicine and Physical Fitness, 57*(4), 319–329.
11. Souza, R. M., Aidar, F., Schütz, S., Dos Santos, J. L., Soares, N. M. M., Silva De Araújo, S., & Marçal, A. C. (2020). Effects of high-intensity interval training on health-related physical fitness in children and adolescents: A systematic review. *Revista Brasileira de Prescrição e Fisiologia do Exercício, 19*, 519.
12. Plavšić, L., Knezevic, O., Sovtić, A., Minić, P., Vuković, R., Mažibrada, I., Stanojlović, O., Hrnčić, D., Rašić-Marković, A., & Macut, D. (2020). Effects of high-intensity interval training and nutrition advice on

cardiometabolic markers and aerobic fitness in adolescent girls with obesity. *Applied Physiology, Nutrition, and Metabolism*.

13. Domaradzki, J., Koźlenia, D., & Popowczak, M. (2022). Prevalence of positive effects on body fat percentage, cardiovascular parameters, and cardiorespiratory fitness after 10-week high-intensity interval training in adolescents. *Biology, 11*.
14. Abarzúa, J., Viloff, W., Bahamondes, J., Olivera, Y., Poblete-Aro, C., Herrera-Valenzuela, T., Oliva, C., & Garcia-Diaz, D. (2019). High-intensity interval training in teenagers. *Revista Medica de Chile, 147*(2), 221–230.
15. Cao, M., Quan, M., & Zhuang, J. (2019). Effect of high-intensity interval training versus moderate-intensity continuous training on cardiorespiratory fitness in children and adolescents: A meta-analysis. *International Journal of Environmental Research and Public Health, 16*.