Journal of
Clinical Medicine

MDPI

Editorial

Interval Training in Sports Medicine: Current Thoughts on an Old Idea

Sascha Ketelhut [1,*], Reinhard G. Ketelhut [2], Burkhard Weisser [3] and Claudio R. Nigg [1]

[1] Institute of Sport Science, University of Bern, 3012 Bern, Switzerland
[2] Cardiology and Sports Medicine, Medical Center Berlin (MCB), 10559 Berlin, Germany
[3] Institute of Sports Science, Christian-Albrechts-University of Kiel, 24118 Kiel, Germany
* Correspondence: sascha.ketelhut@unibe.ch

check for updates

Citation: Ketelhut, S.; Ketelhut, R.G.; Weisser, B.; Nigg, C.R. Interval Training in Sports Medicine: Current Thoughts on an Old Idea. *J. Clin. Med.* **2022**, *11*, 5468. https://doi.org/10.3390/jcm11185468

Received: 13 September 2022
Accepted: 14 September 2022
Published: 17 September 2022

1. Introduction

In light of the global physical inactivity pandemic, the increasing prevalence of non-committable diseases, and mounting healthcare costs, effective and feasible prevention and treatment approaches are urgently needed. In this regard, the value of physical activity and exercise are well recognized [1,2]. An optimal dose, frequency, duration, intensity, and type of exercise can improve aerobic and metabolic capacity and cardiac function, reduce the risks of cardiovascular disease, diabetes, hypertension, and some cancers and prevent musculoskeletal disorders and mental illness [3,4].

For many years, exercise training has been recommended as an integral part of prevention and rehabilitation approaches by major international societies [5,6]. Most traditionally, exercise guidelines recommend moderate-intensity continuous training (MICT) at an intensity of 60–85% of maximum heart rate [7–9]. Based on broad evidence from randomized controlled trials, MICT has become a widely recommended exercise protocol. Nonetheless, long-term adherence remains challenging for most people, with a lack of time being cited as one of the most common barriers [10].

In the last two decades, there has been a resurgence in interest in interval training. Interval training refers to an intermittent style of exercise in which repeated bouts of exercise are broken up by active or passive recovery periods. Research indicates that similar, if not greater, improvements in VO_2max and other performance and health variables are possible with interval training compared to continuous aerobic training [11,12]. The advantage of intermittent exercise is that it enables individuals to achieve greater total exercise time at higher exercise intensities compared to continuous training. It is widely accepted that exercise of higher intensity leads to greater adaptations and more pronounced health benefits [13].

One type of interval training that has progressively increased in popularity among scholars and practitioners is high-intensity interval training (HIIT). The latest exercise guidelines suggest HIIT as an alternative protocol to improve aerobic capacity and cardiac function [14]. Despite the promising effects of intermittent exercise programs, there are still numerous open questions concerning the program designs, the effects for specific target groups, and how these programs can be made suitable for everyday use.

2. Definition and Protocols

Starting as a training approach for athletes, interval training has advanced as a training modality applied in prevention and treatment programs for different diseases and health issues. Lately, research into the physiological adaptations to interval training in healthy individuals and people with diseases has exploded. Today, HIIT is recommended in particular as an adjunct to MICT in the treatment guidelines of various professional societies. However, interval training can also involve less demanding activity characterized by alternating periods of light and moderate exercise (e.g., interval walking).

Notably, the term HIIT is not consistently defined, and multiple descriptions and exercise protocols are used [15]. In the current literature, a range of protocols are employed, which consist of exercise bouts lasting a few seconds and intensities close to maximum [16] and bouts lasting up to 4 min and correspondingly lower intensities [17,18]. The differences in the training variables are expected to reflect changes in the metabolism and adaptations of organic systems [19].

A distinctive feature of intermittent exercise training is the possibility to manipulate the different training variables, including the duration of the bouts and recovery phases, the intensity of bouts and recovery, and the total amount of bouts/recovery. This leads to numerous different protocols, making this training approach infinitely variable and individually adjustable.

3. Efficacy

There is growing interest in interval training, especially HIIT, due to the relatively robust evidence of its positive effects on cardiovascular and metabolic function in both healthy and diseased populations [11,20]. Multiple meta-analyses have reported superior effectiveness of HIIT compared with traditional MICT for improving cardiorespiratory fitness [21–23]. As accumulated evidence suggests that aerobic capacity (VO_2max) is one of the strongest predictors of all-cause mortality [24], it has become a major treatment goal to improve VO_2max in patients with lifestyle-related diseases [25].

Apart from cardiorespiratory fitness, HIIT shows better improvements in risk factors, vasculature [26], respiration [27], autonomic function [28], cardiac function [16,27], inflammation [16], quality of life [29], and endothelial function than MICT [25].

Metabolic Effects

In addition to cardiovascular effects, physical exercise has been shown to improve metabolism on various levels. For an increase in aerobic oxidative capacity, traditionally, only MICT was recommended. In contrast, HIIT is now perceived as a means to increase maximal anaerobic capacity and not as a typical training modality to improve lipid oxidation and aerobic carbohydrate metabolism. In a landmark study, Burgomaster et al. [30] compared the influence of sprint interval training (SIT) with a classical MICT. SIT is basically a form of HIIT, consisting of four to six repetitions of 30 s "all out" periods. Endurance training consists of 40–60 min cycling 5 days per week at approximately 65% of VO_2 peak.

Not only was the increase in exercise capacity between the two groups comparable, but there was also no difference in the effect on intracellular enzymes for lipid and carbohydrate oxidation. This and other studies have shown that despite markedly shorter training times, similar changes in lipid oxidation and glycogen utilization can be obtained by HIIT [30].

4. Feasibility and Safety

A benefit of HIIT is that it is relatively time efficient compared with MICT. Furthermore, many individuals report greater enjoyment during HIIT and show at least similar overall training adherence compared with MICT [31]. Thus, HIIT has been proposed as a time-efficient alternative or adjunct exercise approach to traditional MICT [11,12].

However, adherence to physical activity and exercise programs is known to quickly drop after completion of a supervised training period, and with it exercise-mediated benefits [32]. Even though HIIT sessions are relatively short, they require an extremely high level of subject motivation [18]. Given the extreme nature of HIIT, there is reasonable doubt that the general population could adopt this training mode over an extended period. This is supported by [33], who reported a high dropout rate following the supervised exercise period. Apart from dropout, adherence to the prescribed exercise intensity presents a major problem, especially in untrained populations [34,35].

Another highly relevant topic concerning interval training and HIIT is safety. Participant safety is central to using HIIT as a tool to reduce the risk of cardiometabolic disease among adults, especially those with cardiometabolic risk factors, diagnosed cardiovascular diseases, or other chronic diseases.

According to a systematic review by [36], the incidence of adverse events during or 24 h after a single HIIT session in patients with cardiometabolic diseases was around 8%. A review by Rognmo et al. [37] addressed the risk of cardiovascular events during HIIT and MICT in a total of 175,820 training hours. The authors reported one fatal cardiac arrest during MICT (129,456 exercise hours) and two nonfatal cardiac arrests during HIIT (46,364 exercise hours). An even lower incidence of adverse cardiovascular events was reported by Wewege et al. [38]. The authors identified only one major (and nonfatal) cardiovascular adverse event per 11,333 training hours in 23 studies involving 547 participants. Thus, it can be concluded that the risk of a cardiovascular event is low after HIIT.

5. Open Research Questions

The topic of interval training in sports science has attracted considerable interest among scholars and practitioners. This level of attention has coincided with a large number of related publications over the last few years. Future research should aim to further advance our understanding of the effect of interval training on indices of health in different populations and settings. Therefore, we summarize the future directions to motivate researchers in the field of sports medicine.

5.1. Determine Appropriate Protocol Recommendations for Different Patient Populations and Target Groups

Even though studies have assessed the effects of HIIT in different target groups, there is still insufficient evidence available to determine how the effects are influenced by age, sex, race/ethnicity, or socioeconomic status. There is still a paucity of research addressing interval training in younger demographics, and specific diseased populations. Additionally, a considerable gender gap can be identified in the current body of literature, with the number of studies addressing women being much lower.

5.2. Compare and Systematically Review/Meta-Analyze the Effects of Different Types of HIIT-Related Programs

As stated earlier, a distinctive feature of intermittent exercise training is the possibility to manipulate the different training variables making this training approach infinitely variable. To date, it is unclear which approach is the most effective for which target group, setting, and outcome. Apart from efficacy, program designs should aim for higher adherence. The optimal exercise prescription is likely that which can be maintained long-term [39]. Therefore, the merit of exercise approaches must be evaluated not solely based on health-related benefits that they produce in the short term but on their potential for long-term maintenance. The question should be which program shows the greatest effectiveness at the optimum cost.

5.3. Conduct Long-Term Randomized Controlled Trials Focusing on Medical Endpoints

A review of previous the literature on interval training reveals that most interventions lasted only a few months and long-term studies are lacking. Even though significant training effects are possible within a short period of time, it is unclear how stable the upregulation of various parameters is. Long-term studies report that a change in VO_2max was predicted by longer HIIT intervention duration but not by total time performing HIIT [20]. Furthermore, studies focusing on relevant medical endpoints are highly warranted, especially as research addressing the effects of HIIT on mortality is still sparse.

5.4. Capitalizing on Technology and Digital Approaches to Increase Adherence and Reduce Supervision

The digitalization and increasing reliance on technology presents unprecedented opportunities in reach, interactivity, tailoring, immediacy, and connections in order to promote, disseminate, monitor, and supervise exercise programs.

Smartphone applications, exergames (combination of video games and exercise), and wearables can especially help to promote, monitor, and supervise interval training programs not only in prevention and rehabilitation settings but, moreover, in home-based intervention approaches. Further research on the feasibility and efficacy of such approaches is highly warranted.

Author Contributions: Conceptualization, S.K., R.G.K., B.W. and C.R.N.; writing—original draft preparation, S.K.; writing—review and editing, S.K., R.G.K., B.W. and C.R.N. All authors have read and agreed to the published version of the manuscript.

Funding: This editorial received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

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

References

1. Pedersen, B.K.; Saltin, B. Evidence for prescribing exercise as therapy in chronic disease. *Scand. J. Med. Sci. Sports* **2006**, *16*, 3–63. [CrossRef] [PubMed]
2. Lewis, B.A.; Napolitano, M.A.; Buman, M.P.; Williams, D.M.; Nigg, C.R. Future directions in physical activity intervention research: Expanding our focus to sedentary behaviors, technology, and dissemination. *J. Behav. Med.* **2017**, *40*, 112–126. [CrossRef] [PubMed]
3. Lee, I.M.; Shiroma, E.J.; Lobelo, F.; Puska, P.; Blair, S.N.; Katzmarzyk, P.T.; Alkandari, J.R.; Andersen, L.B.; Bauman, A.E.; Brownson, R.C.; et al. Effect of physical inactivity on major non-communicable diseases worldwide: An analysis of burden of disease and life expectancy. *Lancet* **2012**, *380*, 219–229. [CrossRef]
4. Warburton, D.E.R.; Bredin, S.S.D. Health benefits of physical activity: A systematic review of current systematic reviews. *Curr. Opin. Cardiol.* **2017**, *32*, 541–556. [CrossRef] [PubMed]
5. Roffi, M.; Patrono, C.; Collet, J.P.; Mueller, C.; Valgimigli, M.; Andreotti, F.; Bax, J.J.; Borger, M.A.; Brotons, C.; Chew, D.P.; et al. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent st-segment elevation: Task force for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation of the European Society of Cardiology (ESC). *Eur. Heart J.* **2016**, *37*, 267–315. [CrossRef]
6. O'gara, P.T.; Kushner, F.G.; Ascheim, D.D.; Casey, D.E., Jr.; Chung, M.K.; De Lemos, J.A.; Ettinger, S.M.; Fang, J.C.; Fesmire, F.M.; Franklin, B.A.; et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: Executive summary: A report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines. *Circulation* **2013**, *127*, 529–555. [CrossRef]
7. Garber, C.E.; Blissmer, B.; Deschenes, M.R.; Franklin, B.A.; Lamonte, M.J.; Lee, I.M.; Nieman, D.C.; Swain, D.P. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med. Sci. Sports Exerc.* **2011**, *43*, 1334–1359. [CrossRef]
8. JCS Joint Working Group. Guidelines for rehabilitation in patients with cardiovascular disease (JCS 2012). *Circ. J.* **2014**, *78*, 2022–2093. [CrossRef]
9. Piepoli, M.F.; Corrà, U.; Adamopoulos, S.; Benzer, W.; Bjarnason-Wehrens, B.; Cupples, M.; Dendale, P.; Doherty, P.; Gaita, D.; Höfer, S.; et al. Secondary prevention in the clinical management of patients with cardiovascular diseases. Core components, standards and outcome measures for referral and delivery: A Policy Statement from the Cardiac Rehabilitation Section of the European Association for. *Eur. J. Prev. Cardiol.* **2014**, *21*, 664–681. [CrossRef]
10. Trost, S.G.; Owen, N.; Bauman, A.E.; Sallis, J.F.; Brown, W. Correlates of adults' participation in physical activity: Review and update. *Med. Sci. Sports Exerc.* **2002**, *34*, 1996–2001. [CrossRef]
11. Milanović, Z.; Sporiš, G.; Weston, M. Effectiveness of High-Intensity Interval Training (HIT) and Continuous Endurance Training for VO2max Improvements: A Systematic Review and Meta-Analysis of Controlled Trials. *Sports Med.* **2015**, *45*, 1469–1481. [CrossRef] [PubMed]
12. Ramos, J.S.; Dalleck, L.C.; Tjonna, A.E.; Beetham, K.S.; Coombes, J.S. The Impact of High-Intensity Interval Training Versus Moderate-Intensity Continuous Training on Vascular Function: A Systematic Review and Meta-Analysis. *Sports Med.* **2015**, *45*, 679–692. [CrossRef] [PubMed]
13. Schnohr, P.; Marott, J.L.; Jensen, J.S.; Jensen, G.B. Intensity versus duration of cycling, impact on all-cause and coronary heart disease mortality: The Copenhagen City Heart Study. *Eur. J. Prev. Cardiol.* **2012**, *19*, 73–80. [CrossRef] [PubMed]

14. Mezzani, A.; Hamm, L.F.; Jones, A.M.; McBride, P.E.; Moholdt, T.; Stone, J.A.; Urhausen, A.; Williams, M.A. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: A joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitat. *Eur. J. Prev. Cardiol.* **2013**, *20*, 442–467. [CrossRef]
15. Campbell, W.W.; Kraus, W.E.; Powell, K.E.; Haskell, W.L.; Janz, K.F.; Jakicic, J.M.; Troiano, R.P.; Sprow, K.; Torres, A.; Piercy, K.L.; et al. High-Intensity Interval Training for Cardiometabolic Disease Prevention. *Med. Sci. Sports Exerc.* **2019**, *51*, 1220–1226. [CrossRef]
16. Buchheit, M.; Laursen, P.B. High-intensity interval training, solutions to the programming puzzle: Part I: Cardiopulmonary emphasis. *Sports Med.* **2013**, *43*, 313–338. [CrossRef] [PubMed]
17. Helgerud, J.; Høydal, K.; Wang, E.; Karlsen, T.; Berg, P.; Bjerkaas, M.; Simonsen, T.; Helgesen, C.; Hjorth, N.; Bach, R.; et al. Aerobic high-intensity intervals improve VO_{2max} more than moderate training. *Med. Sci. Sports Exerc.* **2007**, *39*, 665–671. [CrossRef]
18. Gibala, M.J.; McGee, S.L. Metabolic adaptations to short-term high-intensity interval training: A little pain for a lot of gain? *Exerc. Sport Sci. Rev.* **2008**, *36*, 58–63. [CrossRef]
19. Laursen, P.B.; Shing, C.M.; Peake, J.M.; Coombes, J.S.; Jenkins, D.G. Highly Trained Endurance Cyclists. *Med. Sci. Sports Exerc.* **2002**, *34*, 1801–1807. [CrossRef]
20. Batacan, R.B.; Duncan, M.J.; Dalbo, V.J.; Tucker, P.S.; Fenning, A.S. Effects of high-intensity interval training on cardiometabolic health: A systematic review and meta-analysis of intervention studies. *Br. J. Sports Med.* **2017**, *51*, 494–503. [CrossRef]
21. Hannan, A.; Hing, W.; Simas, V.; Climstein, M.; Coombes, J.; Jayasinghe, R.; Byrnes, J.; Furness, J. High-intensity interval training versus moderate-intensity continuous training within cardiac rehabilitation: A systematic review and meta-analysis. *Open Access J. Sports Med.* **2018**, *9*, 1–17. [CrossRef] [PubMed]
22. Pattyn, N.; Beulque, R.; Cornelissen, V. Aerobic Interval vs. Continuous Training in Patients with Coronary Artery Disease or Heart Failure: An Updated Systematic Review and Meta-Analysis with a Focus on Secondary Outcomes. *Sports Med.* **2018**, *48*, 1189–1205. [CrossRef] [PubMed]
23. Gomes-Neto, M.; Durães, A.R.; dos Reis, H.F.C.; Neves, V.R.; Martinez, B.P.; Carvalho, V.O. High-intensity interval training versus moderate-intensity continuous training on exercise capacity and quality of life in patients with coronary artery disease: A systematic review and meta-analysis. *Eur. J. Prev. Cardiol.* **2017**, *24*, 1696–1707. [CrossRef] [PubMed]
24. Lee, D.C.; Sui, X.; Ortega, F.B.; Kim, Y.S.; Church, T.S.; Winett, R.A.; Ekelund, U.; Katzmarzyk, P.T.; Blair, S.N. Comparisons of leisure-time physical activity and cardiorespiratory fitness as predictors of all-cause mortality in men and women. *Br. J. Sports Med.* **2011**, *45*, 504–510. [CrossRef]
25. 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**, *11*, 171–188. [CrossRef]
26. Korhonen, M.; Halmesmäki, K.; Lepäntalo, M.; Venermo, M. Predictors of failure of endovascular revascularization for critical limb ischemia. *Scand J. Surg.* **2012**, *101*, 170–176. [CrossRef] [PubMed]
27. Wisløff, U.; Støylen, A.; Loennechen, J.P.; Bruvold, M.; Rognmo, Ø.; Haram, P.M.; Tjønna, A.E.; Helgerud, J.; Slørdahl, S.A.; Lee, S.J.; et al. Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: A randomized study. *Circulation* **2007**, *115*, 3086–3094. [CrossRef]
28. Dimopoulos, S.; Anastasiou-Nana, M.; Sakellariou, D.; Drakos, S.; Kapsimalakou, S.; Maroulidis, G.; Roditis, P.; Papazachou, O.; Vogiatzis, I.; Roussos, C.; et al. Effects of exercise rehabilitation program on heart rate recovery in patients with chronic heart failure. *Eur. J. Prev. Cardiol.* **2006**, *13*, 67–73. [CrossRef]
29. Freyssin, C.; Verkindt, C.; Prieur, F.; Benaich, P.; Maunier, S.; Blanc, P. Cardiac rehabilitation in chronic heart failure: Effect of an 8-week, high-intensity interval training versus continuous training. *Arch. Phys. Med. Rehabil.* **2012**, *93*, 1359–1364. [CrossRef]
30. Burgomaster, K.A.; Howarth, K.R.; Phillips, S.M.; Rakobowchuk, M.; Macdonald, M.J.; Mcgee, S.L.; Gibala, M.J. Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. *J. Physiol.* **2008**, *586*, 151–160. [CrossRef]
31. Vella, C.A.; Taylor, K.; Drummer, D. High-intensity Interval and Moderate-intensity Continuous Training Elicit Similar Enjoyment and Adherence Levels in Overweight and Obese Adults. *Physiol. Behav.* **2017**, *17*, 1203–1211. [CrossRef] [PubMed]
32. ter Hoeve, N.; Huisstede, B.M.A.; Stam, H.J.; van Domburg, R.T.; Sunamura, M.; van den Berg, R.J.G.E. Does cardiac rehabilitation after an acute cardiac syndrome lead to changes in physical activity habits? Systematic review. *Phys. Ther.* **2015**, *95*, 167–179. [CrossRef] [PubMed]
33. Tjønna, A.E.; Stølen, T.O.; Bye, A.; Volden, M.; Slördahl, S.A.; Ødegård, R.; Skogvoll, E.; Wisløff, U. Aerobic interval training reduces cardiovascular risk factors more than a multitreatment approach in overweight adolescents. *Clin. Sci.* **2009**, *116*, 317–326. [CrossRef] [PubMed]
34. Ellingsen, Ø.; Halle, M.; Conraads, V.; Støylen, A.; Dalen, H.; Delagardelle, C.; Larsen, A.I.; Hole, T.; Mezzani, A.; Van Craenenbroeck, E.M.; et al. High-Intensity Interval Training in Patients with Heart Failure with Reduced Ejection Fraction. *Circulation* **2017**, *135*, 839–849. [CrossRef] [PubMed]
35. Karlsen, T.; Aamot, I.L.; Haykowsky, M.; Rognmo, Ø. High Intensity Interval Training for Maximizing Health Outcomes. *Prog. Cardiovasc. Dis.* **2017**, *60*, 67–77. [CrossRef] [PubMed]

36. Levinger, I.; Shaw, C.S.; Stepto, N.K.; Cassar, S.; McAinch, A.J.; Cheetham, C.; Maiorana, A.J. What doesn't kill you makes you fitter: A systematic review of high-intensity interval exercise for patients with cardiovascular and metabolic diseases. *Clin. Med. Insights Cardiol.* **2015**, *9*, 53–63. [CrossRef]
37. Rognmo, O.; Moholdt, T.; Bakken, H.; Hole, T.; Mølstad, P.; Myhr, N.E.; Grimsmo, J.; Wisløff, U. Cardiovascular Risk of High-Versus Moderate-Intensity Aerobic Exercise in Coronary Heart Disease Patients. *Circulation* **2012**, *126*, 1436–1440. [CrossRef]
38. Wewege, M.A.; Ahn, D.; Yu, J.; Liou, K.; Keech, A. High-intensity interval training for patients with cardiovascular disease-is it safe? A systematic review. *J. Am. Heart Assoc.* **2018**, *7*, 1–19. [CrossRef]
39. Ekkekakis, P.; Vazou, S.; Bixby, W.R.; Georgiadis, E. The mysterious case of the public health guideline that is (almost) entirely ignored: Call for a research agenda on the causes of the extreme avoidance of physical activity in obesity. *Obes. Rev.* **2016**, *17*, 313–329. [CrossRef]