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Field based Comparison of Sprint Interval Training Protocols in Recreational Populations for Running

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Abstract
The primary aim of this study was to address gaps in sprint interval training (SIT) literature by comparing physiological and perceptual responses to three distinct SIT protocols in recreationally active adults, an area where research predominantly focuses on competitive athletes. This investigation uniquely contributes to field-based comparisons of SIT protocols in recreational populations, with implications for optimizing cardiovascular and endurance training for broader demographics in sports science. Twenty-five recreationally active university students completed three distinct sprint interval training (SIT) protocols involving varied sprint and recovery durations. Metrics included both physiological and perceptual responses were evaluated. Repeated measures ANOVA indicated no significant differences in speed and distance covered in the initial 10 seconds among the different protocols ($p>0.05$). However, there were notable distinctions in RPE, average heart rate, peak heart rate, squat jump variability and blood lactate levels ($p<0.05$). The results interpret that 8×15-second protocol offers physiological and perceptual advantages, including reduced cardiovascular strain and perceived exertion, comparable sprint performance and lactate levels to longer protocols, which may improve training adherence and sustainability.The results underscore that shorter SIT intervals with reduced cardiovascular strain may facilitate prolonged high-intensity output, offering practical implications for sport science and athletic conditioning. By optimizing interval duration and recovery, athletes and recreational participants alike may better achieve cardiovascular and endurance goals, contributing to individualized and adaptable SIT programs that support diverse fitness levels and athletic performance demands.

Keywords
sprint interval training (SIT), physiological responses, perceptual responses, recreational populations

1 Introduction

Sprint Interval Training (SIT) has gained significant attention as a time-efficient and highly effective alternative to traditional moderate-intensity endurance training. As a specific form of High-Intensity Training (HIT), SIT consists of short bursts of maximal effort, typically lasting no more than 30 seconds, interspersed with recovery periods of 2–4 minutes at a lower intensity (Buchheit & Laursen, 2013; Sloth et al., 2013; Viana et al., 2018). This training modality elicits rapid and substantial physiological adaptations, including enhanced cardiovascular function, improved muscle structure, and increased metabolic rate (Astorino et al., 2012; Mac-

Innis & Gibala, 2017). The efficiency of SIT lies in its ability to achieve these benefits with a significantly reduced training volume compared to traditional endurance exercise (Gibala et al., 2006).

Most research on SIT has focused on elite athletes, whose superior endurance capacity, recovery efficiency, and neuromuscular adaptations enable them to tolerate and benefit from high-intensity protocols (Gibala et al., 2012; Vollaard & Metcalfe, 2017). However, such findings may not directly apply to recreational populations, which exhibit greater variability in fitness levels, fatigue resistance, and recovery dynamics. It is crucial to investigate how different SIT protocols influence both physiological and perceptual responses in non-elite individuals, as these factors play a pivotal role in adherence and long-term training sustainability (Naves et al., 2019). Identifying protocols that optimize performance benefits while minimizing cardiovascular strain and perceived exertion can enhance the accessibility and practicality of SIT for a broader range of participants.

Traditional SIT regimens typically involve 4–7 sprints lasting up to 30 seconds, with recovery periods up to ten times the sprint duration (Gibala et al., 2012; Vollaard & Metcalfe, 2017). These protocols engage both anaerobic and aerobic energy systems, demanding high levels of neuromuscular effort (MacInnis & Gibala, 2017). However, recent evidence suggests that shorter sprint intervals, such as 8×15-second sprints with 2-minute recovery periods, may provide comparable cardiovascular and metabolic benefits while reducing perceived exertion and cardiovascular strain (Townsend et al., 2013; Naves et al., 2019). This has significant implications for the design of SIT programs tailored to recreational athletes, as reduced psychological strain can enhance adherence and long-term sustainability (Ikutomo et al., 2018; Wang et al., 2019).

The development of SIT protocols requires careful modulation of sprint duration, recovery intervals, and intensity to optimize physiological adaptations, improve fatigue resistance, and maximize power output (Gibala & McGee, 2008; Buchheit & Laursen, 2013; Frazão et al., 2016). Despite extensive research, the majority of studies have prioritized elite athletes, leaving a gap in understanding how SIT can be tailored to individuals with varying fitness levels and recovery capacities (Yeo et al., 2010; Widiastuti et al., 2022; Jacobs et al., 2013). Additionally, while the physiological benefits of SIT—such as increased skeletal muscle oxidative capacity and cardiovascular efficiency—are well-documented, the psychological impacts, particularly perceptions of exertion and training enjoyment, remain underexplored (Burgomaster et al., 2008; Gibala et al., 2006).

This study aims to address these gaps by systematically comparing the physiological and perceptual responses to three distinct SIT protocols that vary in sprint duration and recovery intervals in a recreationally active population. By evaluating key indicators such as blood lactate concentration, heart rate, perceived exertion, and sprint performance, this research seeks to identify protocols that balance training effectiveness with psychological comfort. Unlike prior studies that broadly assess SIT's effects, this investigation specifically examines how variations in protocol structure influence both perceived exertion and cardiovascular strain—two critical factors for long-term adherence in non-elite populations (Burgomaster et al., 2008; Gibala et al., 2006; Naves et al., 2019).

Furthermore, this study builds upon emerging evidence suggesting that shorter sprint durations (e.g., 8×15 seconds) may reduce perceived exertion without compromising performance (Smith-Ryan et al., 2017). The focus on optimizing protocol structure ensures that these findings are directly applicable to coaches and sports practitioners seeking individualized, adaptable SIT regimens. By integrating both physiological and psychological factors, this research makes a novel contribution to the existing SIT literature, offering evidence-based strategies for sustainable, high-intensity training programs. Given the growing recognition that training adherence is influenced not only by physiological effectiveness but also by perceived exertion and recovery dynamics, optimizing SIT protocols is essential for making high-intensity training more accessible to diverse fitness levels (Naves et al., 2019; Smith-Ryan et al., 2017).

2 Literature Review

Sprint Interval Training (SIT) has emerged as a highly efficient alternative to traditional high-volume endurance training, offering comparable physiological benefits with significantly reduced time commitments. SIT involves brief, high-intensity efforts interspersed with recovery periods, targeting both aerobic and anaerobic energy systems to maximize training efficiency (Buchheit & Laursen, 2013; Vollaard & Metcalfe, 2017). Extensive research has demonstrated that SIT improves cardiovascular function, skeletal muscle oxidative capacity, and metabolic health, achieving results similar to traditional endurance training despite a lower total training volume (Astorino et al., 2012; Gibala et al., 2006). Additionally, SIT has been shown to stimulate mitochondrial biogenesis, a key adaptation that enhances energy metabolism and endurance performance (MacInnis & Gibala, 2017).

Despite these benefits, the effectiveness of SIT depends heavily on specific interval structures, including sprint duration, intensity, and recovery length (Ito, 2019; Jacobs et al., 2013; Ojo, 2020). Variations in these parameters can significantly influence physiological adaptations and training outcomes, highlighting the need for refined SIT protocols that optimize both performance and adherence across different populations. While SIT has been widely studied in elite athletes, its application to recreationally active individuals remains underexplored, necessitating further investigation into how protocol modifications impact this demographic.

2.1 SIT in Recreational and Competitive Athletes

Recent studies have demonstrated the broad applicability of SIT across both recreational and competitive populations. Research by Mallol et al. (2020) and Santos et al. (2023) reported significant improvements in cardiovascular markers and endurance performance among middle-aged and recreationally active individuals, reinforcing SIT's effectiveness beyond elite athletes. Similarly, Yu et al. (2024) highlighted that interval adjustments can optimize cardiorespiratory efficiency, striking a balance between anaerobic and aerobic demands. These findings align with evidence suggesting that even low-volume SIT protocols can elicit substantial gains in VO_2 max and power output (MacInnis & Gibala, 2017; Fennell & Hopker, 2021).

However, while these studies underscore SIT's potential, several critical concerns remain. First, research on SIT's broad applicability often overlooks individual variability in fitness levels, recovery capacity, and psychological responses (Naves et al., 2019; Smith-Ryan et al., 2017). Recreational participants may require protocols with lower cardiovascular strain and perceived exertion to ensure sustained adherence over time. Second, while VO_2 max and power output improvements are frequently reported, long-term sustainability remains uncertain, as excessive SIT exposure may lead to overtraining or injury if not properly managed (Buchheit & Laursen, 2013). Lastly, the mechanisms by which different interval structures influence various populations remain unclear, particularly regarding neuromuscular fatigue and recovery dynamics (Jacobs et al., 2013; MacInnis & Gibala, 2017).

2.2 Skeletal Muscle Adaptations and Neuromuscular Fatigue

SIT has been shown to induce substantial skeletal muscle adaptations, including increased mitochondrial biogenesis and improved muscle fiber composition, which enhance endurance and power output (MacInnis & Gibala, 2017). For example, Burgomaster et al. (2008) found significant improvements in muscle oxidative capacity after only six SIT sessions, illustrating the rapid adaptive potential of this training modality. Additionally, Hall et al. (2023) emphasized SIT's role in enhancing muscle resilience and fatigue resistance, particularly in recreational athletes. However, inconsistencies remain regarding the optimal balance of intensity, sprint duration, and recovery intervals, which must be tailored to different populations to maximize benefits.

2.3 Psychological and Perceptual Responses to SIT

While most research focuses on physiological adaptations, psychological and perceptual responses to SIT have gained increasing attention in recent years. Shorter sprint durations and reduced recovery intervals have been shown to lower perceived exertion without compromising performance, suggesting that protocol modifications can influence psychological comfort (Townsend et al., 2013; Naves et al., 2019). These findings align with studies emphasizing the importance of training enjoyment and psychological factors in determining long-term adherence to high-intensity exercise (Farias-Junior et al., 2019; Frazão et al., 2016).

For example, Benítez-Flore et al. (2021) found that outdoor SIT protocols with variable sprint durations enhanced participant engagement and enjoyment, whereas Mao et al. (2022) demonstrated that resistance-based SIT reduced perceived exertion more effectively than cycling-based SIT. These studies suggest that training modality and protocol structure significantly influence psychological responses, affecting both adherence and overall effectiveness. Despite their varied approaches, these studies collectively underscore the adaptability of SIT to diverse populations. Hu et al. (2022) and Metcalfe and Vollaard (2024) extended this understanding by demonstrating that perceptually regulated SIT protocols, where individuals adjust effort based on subjective experiences, not only foster adherence but also minimize discomfort.

2.4 Research Gaps and Future Directions in Sprint Interval Training (SIT)

Despite the well-documented physiological and psychological benefits of Sprint Interval Training (SIT), critical gaps remain in understanding how variations in protocol structure influence training adherence and effectiveness across different populations. The interaction between sprint duration, recovery intervals, and their combined effects on physiological and perceptual responses remains inconclusive. Studies have demonstrated that modifying recovery durations can significantly impact physiological markers and subjective exertion levels, emphasizing the need for tailored SIT regimens (Ikutomo et al., 2018; Farias-Junior et al., 2019; Wang et al., 2019). However, the ideal balance between training intensity and recovery length to maximize both performance gains and adherence is yet to be determined.

Current research also highlights the neuromuscular and physiological benefits of SIT in team sports, reinforcing the importance of sport-specific protocol adaptations (Lee et al., 2017; Thurlow, 2024). However, evidence remains fragmented regarding the optimal sprint-recovery configurations that enhance both physiological performance and perceptual comfort. For instance, while shorter recovery periods may sustain cardiovascular workload, they may also increase discomfort, potentially reducing long-term adherence (Farias-Junior et al., 2019; Naves et al., 2019; O'Connor, 2017). Given these inconsistencies, a more systematic approach is required to refine SIT protocols that balance physical benefits with psychological tolerability for diverse populations.

This study directly addresses these research gaps by systematically comparing physiological and perceptual responsesto three distinct SIT protocols, each standardized by total sprint and recovery durations but varying in sprint intensity and recovery length. Key physiological and performance indicators—including blood lactate levels, heart rate (average and peak), rate of perceived exertion (RPE), sprint performance metrics, and neuromuscular fatigue assessed through squat jump tests—will be analyzed using repeated-measures ANOVA and non-parametric tests to detect protocol-specific differences.

By examining 4×30 seconds, 6×20 seconds, and 8×15 seconds protocols, this study aims to determine how sprint duration and recovery intervals influence physiological stress and perceived exertion. The findings will contribute to the development of evidence-based SIT regimens that optimize both training effectiveness and adherence, ensuring time-efficient, individualized protocols suitable for recreational and athletic populations alike.

3 Discussion

This study examined the physiological and perceptual responses to three distinct sprint interval training (SIT) protocols among recreationally active individuals. The findings provide insights into optimizing SIT regimens by balancing training effectiveness with psychological comfort, addressing key gaps in SIT research for non-elite populations.

3.1 Physiological Responses

The analysis revealed no significant differences in sprint performance metrics (first 10-second distance covered and mean sprint speed) across protocols, suggesting that reducing sprint duration does not compromise peak sprint performance (Gibala et al., 2012; Tschakert et al., 2015; Vollaard & Metcalfe, 2017). However, lactate accumulation varied significantly at the immediate post-exercise and 10-minute recovery time points, with the 8×15-s protocol producing lower lactate levels than the 4×30-s and 6×20-s protocols. This suggests faster metabolic clearance and improved recovery, aligning with findings from Buchheit & Laursen (2013) and Naves et al. (2019). Faster lactate clearance may enhance intracellular pH buffering capacity and delay fatigue onset (Smilios et al., 2018; Tomlin & Wenger, 2001; Wan & Guo, 2015).

Heart rate (HR) data further distinguished the protocols. The 8×15-s protocol resulted in significantly lower peak HR, indicating reduced cardiovascular strain (MacInnis & Gibala, 2017). However, it exhibited a higher average HR, suggesting sustained cardiovascular demand, which could contribute to aerobic adaptations (Townsend et al., 2013; Tschakert et al., 2013; Vollaard & Metcalfe, 2017). These findings align with previous research indicating that shorter sprints maintain training intensity while mitigating excessive physiological stress (Hazell et al., 2010; Gilen & Gibala, 2018; Ikutomo et al., 2018; Yin et al., 2023).

3.2 Perceptual Responses

The Rate of Perceived Exertion (RPE) was significantly lower in the 8×15-s protocol compared to the 4×30-s protocol, indicating reduced psychological strain. These results align with Smith-Ryan et al. (2017) and Naves et al. (2019), who found that shorter intervals improve perceived exertion and training enjoyment. Lower RPE values may result from reduced neuromuscular fatigue and lower cardiovascular load, making shorter protocols more sustainable and appealing (Townsend et al., 2013). Since perceived exertion strongly influences training adherence, optimizing interval duration can enhance long-term compliance with SIT (Burgomaster et al., 2008).

3.3 Neuromuscular Fatigue

Post-session squat jump tests indicated variations in neuromuscular fatigue, with the 6×20-s protocol showing the least fatigue accumulation, suggesting an optimal balance between sprint duration and recovery (Frazão et al., 2016; Jacobs et al., 2013). While the 8×15-s protocol reduced cardiovascular strain, it was less effective in mitigating neuromuscular fatigue, highlighting the trade-off between metabolic and neuromuscular recovery in SIT protocols.

3.4 Practical Implications

For beginners or individuals prioritizing adherence: The 8×15-s protocol provides a more manageable psychological and physiological workload, ensuring sustained participation.

For athletes focusing on power and endurance: The 6×20-s protocol offers an optimal balance between fatigue resistance and anaerobic energy utilization.

For cardiovascular adaptations and efficient recovery: Shorter sprints with adequate but controlled recovery periods can enhance aerobic conditioning without excessive physiological strain.

For neuromuscular fatigue management: Monitoring squat jump recovery trends can guide adjustments in SIT intensity and recovery, ensuring training adaptations without excessive fatigue accumulation.

3.5 Comparison to Existing Literature, limitations and Future Directions

Unlike studies focusing on elite athletes, this research provides evidence for SIT's effectiveness in recreational populations, addressing differences in fitness levels, recovery profiles, and neuromuscular efficiency (MacInnis & Gibala, 2017; Gibala et al., 2012). While previous research suggests that lactate clearance rates remain consistent across protocols (Townsend et al., 2013), our findings indicate that shorter sprint durations may enhance recovery, possibly due to reduced metabolic stress. Despite its strengths, this study has limitations. The sample size, while sufficient for detecting protocol-specific effects, limits generalizability. Additionally, excluding participants with prior SIT experience ensured uniformity but prevented analysis of adaptation effects in trained individuals.Future research should explore the effects of age, sex, and fitness level on SIT outcomes to refine population-specific training recommendations.

4 Conclusion

This study demonstrates that SIT protocols can be optimized for recreational populations by adjusting sprint duration and recovery intervals. The 8×15-s protocol offers an effective balance between performance outcomes and psychological tolerability, making it a promising time-efficient training option for non-elite athletes. By integrating physiological and perceptual factors, this research contributes to the development of individualized, high-intensity training regimens that enhance adherence and long-term fitness outcomes.

References

[1]Astorino, T. A., Allen, R. P., Roberson, D. W., & Jurancich, M. (2012). Effect of high-intensity interval training on cardiovascular function, VO max, and muscular force. Journal of Strength and Conditioning Research, 26(1), 138–145. https://doi.org/10.1519/JSC.0b013e318218dd77

[2]Benítez-Flores, S., Magallanes, C. A., Alberton, C. L., & Astorino, T. A. (2021). Physiological and psychological responses to three distinct exercise training regimens performed in an outdoor setting: acute and delayed response. Journal of Functional Morphology and Kinesiology, 6(2), 44.

[3]Buchheit, M., & Laursen, P. B. (2013). High-intensity interval training, solutions to the programming puzzle: Part I: cardiopulmonary emphasis. Sports medicine, 43(5), 313-338.

[4]Burgomaster, K. A., Howarth, K. R., Phillips, S. M., Rakobowchuk, M., MacDonald, M. J., McGee, S. L., & Gibala, M. J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. The Journal of physiology, 586(1), 151-160.

[5]Burgomaster, K. A., Hughes, S. C., Heigenhauser, G. J., Bradwell, S. N., & Gibala, M. J. (2008). Six sessions of sprint interval training increase muscle oxidative potential and cycle endurance capacity in humans. Journal of Applied Physiology, 98(6), 1985-1990. https://doi.org/10.1152/japplphysiol.01095.2003

[6]Farias-Junior, L. F., Macêdo, G. A. D., Browne, R. A. V., Freire, Y. A., Oliveira-Dantas, F. F., Schwade, D., ... & Costa, E. C. (2019). Physiological and psychological responses during low-volume high-intensity interval training sessions with different work-recovery durations. Journal of sports science & medicine, 18(1), 181.

[7]Frazão, D. T., de Farias Junior, L. F., Dantas, T. C. B., Krinski, K., Elsangedy, H. M., Prestes, J., ... & Costa, E. C. (2016). Correction: feeling of pleasure to high-intensity interval exercise is dependent of the number of work bouts and physical activity status. PloS one, 11(4), e0153986.
[8]Gibala, M. J., Little, J. P., MacDonald, M. J., & Hawley, J. A. (2012). Physiological adaptations to low-volume, high-intensity interval training in health and disease. The Journal of physiology, 590(5), 1077-1084.
[9]Gibala, M. J., Little, J. P., Van Essen, M., Wilkin, G. P., Burgomaster, K. A., Safdar, A., ... & Tarnopolsky, M. A. (2006). Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. The Journal of physiology, 575(3), 901-911.
[10]Gibala, M. J., & McGee, S. L. (2008). Metabolic adaptations to short-term high-intensity interval training: a little pain for a lot of gain?. Exercise and sport sciences reviews, 36(2), 58-63.
[11]Hall, A. J., Aspe, R. R., Craig, T. P., Kavaliauskas, M., Babraj, J., & Swinton, P. A. (2023). The effects of sprint interval training on physical performance: a systematic review and meta-analysis. The Journal of Strength & Conditioning Research, 37(2), 457-481.
[12]Hazell, T. J., MacPherson, R. E., Gravelle, B. M., & Lemon, P. W. (2010). 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. European Journal of Applied Physiology, 110(1), 153–160.
[13]Hu, M., Jung, M. E., Nie, J., & Kong, Z. (2022). Affective and enjoyment responses to sprint interval training in healthy individuals: A systematic review and meta-analysis. Frontiers in Psychology, 13, 820228.
[14]Ikutomo, A., Kasai, N., & Goto, K. (2018). Impact of inserted long rest periods during repeated sprint exercise on performance adaptation. European Journal of Sport Science, 18(1), 47–53. https://doi.org/10.1080/17461391.2017.1383515
[15]Ito, S. (2019). High-intensity interval training for health benefits and care of cardiac diseases-the key to an efficient exercise protocol. World journal of cardiology, 11(7), 171.
[16]Jacobs, R. A., Flück, D., Bonne, T. C., Bürgi, S., Christensen, P. M., Toigo, M., & Lundby, C. (2013). Improvements in exercise performance with high-intensity interval training coincide with an increase in skeletal muscle mitochondrial content and function. Journal of applied physiology, 115(6), 785-793.
[17]Jizheng Ma,Renxiang Zhang, Bo Gu,Xuan Feng & Wusheng Cheng.(2013). Research and progress of high-intensity interval training. Journal of Nanjing Institute of Physical Education (Natural Science Edition) (04), 8-14.
[18]Kannankeril, P. J., Le, F. K., Kadish, A. H., & Goldberger, J. J. (2004). Parasympathetic effects on heart rate recovery after exercise. Journal of investigative medicine, 52(6), 394-401.
[19]Karvonen, J., & Vuorimaa, T. (1988). Heart rate and exercise intensity during sports activities: practical application. Sports medicine, 5, 303-311.
[20]Lee, C. L., Hsu, W. C., & Cheng, C. F. (2017). Physiological adaptations to sprint interval training with matched exercise volume. Medicine & Science in Sports & Exercise, 49(1), 86-95.
[21]MacInnis, M. J., & Gibala, M. J. (2017). Physiological adaptations to interval training and the role of exercise intensity. The Journal of physiology, 595(9), 2915-2930.
[22]Mallol, M., Norton, L., Bentley, D. J., Mejuto, G., Norton, K., & Yanci, J. (2020). Physiological response differences between run and cycle high intensity interval training program in recreational middle age

female runners. Journal of Sports Science & Medicine, 19(3), 508.
[23]Mao, J., Wang, T., Zhang, L., Li, Q., & Bo, S. (2022). Comparison of the acute physiological and perceptual responses between resistance-type and cycling high-intensity interval training. Frontiers in Physiology, 13, 986920.
[24]Menzies, P., Menzies, C., McIntyre, L., Paterson, P., Wilson, J., & Kemi, O. J. (2010). Blood lactate clearance during active recovery after an intense running bout depends on the intensity of the active recovery. Journal of Sports Sciences, 28(9), 975–982.
[25]Metcalfe, R. S., & Vollaard, N. B. (2024). Reduced-exertion high-intensity interval training (REHIT): a feasible approach for improving health and fitness?. Applied Physiology, Nutrition, and Metabolism, 49(7), 984-992.
[26]Naves, J. P. A., Rebelo, A. C. S., Silva, L. R. B. E., Silva, M. S., Ramirez-Campillo, R., Ramirez-Vélez, R., & Gentil, P. (2019). Cardiorespiratory and perceptual responses of two interval training and a continuous training protocol in healthy young men. European Journal of Sport Science, 19(5), 653–660.
[27]O'Connor, D. (2017). The Physiological and Subjective Responses to Varying Doses of Sprint Interval Training.
[28]Ojo, O. R. (2020). Selected physiological responses to interval training in the enhancement of physical fitness. Sapientia Foundation Journal of Education, Sciences and Gender Studies, 2(3).
[29]Robergs, R. A., McNulty, C. R., Minett, G. M., Holland, J., & Trajano, G. (2017). Lactate, not lactic acid, is produced by cellular cytosolic energy catabolism. Physiology.
[30]Roelofs, E. J., Smith-Ryan, A. E., Trexler, E. T., Hirsch, K. R., & Mock, M. G. (2017). Effects of pomegranate extract on blood flow and vessel diameter after high-intensity exercise in young, healthy adults. European journal of sport science, 17(3), 317-325.
[31]Santos, D. A., Morais, N. S., Viana, R. B., Costa, G. C., Andrade, M. S., Vancini, R. L., ... & de Lira, C. A. (2025). Comparison of physiological and psychobiological acute responses between high intensity functional training and high intensity continuous training. Sports Medicine and Health Science, 7(1), 68-76.
[32]Sloth, M., Sloth, D., Overgaard, K., & Dalgas, U. (2013). Effects of sprint interval training on VO 2max and aerobic exercise performance: a systematic review and meta-analysis. Scandinavian journal of medicine & science in sports, 23(6), e341-e352.
[33]Smilios, I., Myrkos, A., Zafeiridis, A., Toubekis, A., Spassis, A., & Tokmakidis, S. P. (2018). The effects of recovery duration during high-intensity interval exercise on time spent at high rates of oxygen consumption, oxygen kinetics, and blood lactate. The Journal of Strength & Conditioning Research, 32(8), 2183-2189.
[34]Smith-Ryan, A. E. (2017). Enjoyment of high-intensity interval training in an overweight/obese cohort: a short report. Clinical physiology and functional imaging, 37(1), 89-93.
[35]Thurlow, F. (2024). The acute demands and physical adaptations of repeated-sprint training (Doctoral dissertation, Australian Catholic University).
[36]Townsend, L. K., Islam, H., Dunn, E., Eys, M., Robertson-Wilson, J., & Hazell, T. J. (2017). Modified sprint interval training protocols. Part II. Psychological responses. Applied Physiology, Nutrition, and Metabolism, 42(4), 347–353.
[37]Townsend, J. R., Stout, J. R., Morton, A. B., Jajtner, A. R., Gonzalez, A. M., Wells, A. J., ... & Co-

sio-Lima, L. (2013). Excess post-exercise oxygen consumption (EPOC) following multiple effort sprint and moderate aerobic exercise. Kinesiology, 45(1), 16.

[38]Tschakert, G., Kroepfl, J., Mueller, A., Moser, O., Groeschl, W., & Hofmann, P. (2015). How to regulate the acute physiological response to “aerobic” high-intensity interval exercise. Journal of sports science & medicine, 14(1), 29.

[39]Viana, R. B., de Lira, C. A. B., Naves, J. P. A., Coswig, V. S., Del Vecchio, F. B., Ramirez-Campillo, R., & Gentil, P. (2018). Can we draw general conclusions from interval training studies? Sports Medicine, 48, 2001–2009.

[40]Vollaard, N. B., & Metcalfe, R. S. (2017). Research into the health benefits of sprint interval training should focus on protocols with fewer and shorter sprints. Sports medicine, 47, 2443-2451.

[41]Wan, M.F. & Guo, K.K.. (2015). Research on the application of interval training method in sprint training. Sports World (Academic Edition) (05), 85-86.

[42]Wang, J., Qiu, J., Yi, L., Hou, Z., Benardot, D., & Cao, W. (2019). Effect of sodium bicarbonate ingestion during 6 weeks of HIIT on anaerobic performance of college students. Journal of the International Society of Sports Nutrition, 16, 1-10.

[43]Wang, Yi-Ho. (2009). Strategies for implementing interval training in sprint training. Sports Science and Technology (03),47-50+81.

[44]Widiastuti, W., Hasyim, H., Taufik, M. S., Muslim, B. A., Suharti, S., Solahuddin, S., ... & Karisdha, K. (2022). Comparison of Hollow Sprint and Interval Training in Increasing Speed of 100 M Sprint Test. International Journal of Human Movement and Sports Sciences, 10(1), 79-84.

[45]Yeo, W. K., McGee, S. L., Carey, A. L., Paton, C. D., Garnham, A. P., Hargreaves, M., & Hawley, J. A. (2010). Acute signalling responses to intense endurance training commenced with low or normal muscle glycogen. Experimental physiology, 95(2), 351-358.

[46]Yin, M., Li, H., Bai, M., Liu, H., Chen, Z., Deng, J., ... & Li, Y. (2023). Is low-volume high-intensity interval training a time-efficient strategy to improve cardiometabolic health and body composition? A meta-analysis. Applied Physiology, Nutrition, and Metabolism, 49(3), 273-292.

[47]Yu, H., Gao, Y., Liang, J., Fan, Y., & Jiang, S. (2024). Optimal dose of vigorous physical activity on cardiorespiratory and perceptual response for sedentary youths using internal load monitoring. Frontiers in Physiology, 15, 1406402.