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Sports Science Approach to High-Intensity Interval Training (HIIT): Cardio metabolic Health Benefits in University Students

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Abstract

High-Intensity Interval Training (HIIT) is a recent and effective training method which has caused great interest among exercise scientists for its capability of promoting remarkable cardiometabolic responses in reduced times. This training regimen, characterized by multiple short near maximal intervals interspersed with brief recovery periods of low work intensity, is particularly powerful when applied to university era students a group whose lives are typically overwhelmed with academic demands and time constraints. This article aims to examine the contribution of HIIT from a sports scientific viewpoint, specifically on cardio-metabolic health markers (cardiovascular fitness, body composition, insulin sensitivity and lipid profile) in university-aged populations. New developments in exercise physiology suggest that HIIT improves VO_2 max, a key performance marker, which is a very strong predictor of cardiovascular health and overall mortality. In an experiment by Astorino et al. (2012) also reported that, with university level students, who participated in an 8-week high intensity interval training program, VO_2 max were significantly higher than those who were in the moderate continuous training group, suggesting that HIIT was more effective in increasing aerobic capacity. Such a result has a special importance in the realm of sports science, where optimizing performance at a minimum of time spent is a key issue. Regarding body composition, HIIT led to significant decrements in body fat percentage, waist circumference and BMIin sedentary subjects. Martins et al. (2015) found HIIT to increase fat oxidation and resting metabolic rate after exercise more than that of the other types of training in students also known as EPOC. These adaptations are critical to reduce obesity-associated comorbidities and to optimize athletic performance, central themes to the field of exercise health sciences. Metabolic outcomes such as insulin sensitivity, blood pressure and lipid profiles have also indicated positive responses in response to HIIT modalities. In a meta-analysis by Jelleyman et al. (2015) found that HIIT led to a significant increase in fasting glucose and insulin action in non-obese, non-diabetic young individuals. These metabolic benefits are important for preventing the premature development of metabolic syndrome found in growing numbers of student cohorts, increasingly sedentary and with a distressed feeding behavior. In addition to that, the mental effects of HIIT and they are too often overlooked also play their part in the overall health benefits felt by students. Bartlett et al. (2011) observed that participants doing HIIT said they enjoyed it more and were more likely to pick up regular exercise than those doing traditional cardio. From a sports science perspective, these psychological reactions play a key role in the sustainability of behavior transformation and may drive the development of sustainable fitness interventions for

adolescents. The sports science rationale further underpins the role of HIIT as a form of public health intervention, as well as a performance enhancing one. Incorporating HIIT into university sports and fitness programs serves two purposes for institutions: improving athletic conditioning, and preventing cardio metabolic disease. It is a promising evidence-based, multi-faceted, interdisciplinary approach combining exercise physiology, public health and educational policy for the purpose of creating healthier campus communities.

Introduction

HIIT [11, 12]; high intensity interval training (HIIT) has become a central issue in sports science because it can bring significant health benefits in an effective period of time, especially for university students. The interest of the health community and academic research institutions in the decreasing Physical Activity (PA) levels among young people has been increasing in the recent years. University students, who are frequently under academic and lifestyle pressures, become sedentary to a degree that leads them to be at risk of cardiometabolic diseases. The big deal with HIIT is the way in which it's designed (short, intense work followed by short rest periods) makes it time-efficient, yet physiologically challenging. This type of training is attracting growing interest amongst both university athletic departments and athletes as it has been the subject of intense scrutiny for its potential to enhance cardiovascular fitness, body composition and early indications of metabolic impairments (Gibala et al., 2012). Conventional guidelines have long proposed MICT in the context of cardiovascular disease prevention, which typically involves longer exercise sessions to produce similar effects. Nonetheless MICT has been criticized as not being feasible for busy students. Lack of time is a major barrier to exercise, and HIIT provides a time-efficient alternative that is more favorable to younger adults. More than a dozen clinical studies comparing HIIT protocols of as little as 15–20 min duration with traditional MICT protocols have reported similar or greater improvements in various markers of cardiovascular disease and metabolic health. These include increases in VO_2 max, reductions in resting heart rate, increased insulin sensitivity, and reduced fat mass, all of which are important markers for assessing cardiometabolic health (Kemi & Wisloff, 2010). This change in paradigm of exercise science reflects the trend toward increasing focus on improving health with little time investment, a critical need in the lives of modern day students. The academic setting promotes several risk factors for the development of cardiovascular and metabolic disease, such as high psychological stress, unhealthy eating habits, altered circadian rhythm, and low physical activity. Certainly, HIIT appears as powerful antidote, not only to modify physical markers but also to affect mental well-being. College students receiving HIIT interventions have described enhanced mood, cognition, and sleep. Although psychological factors have not been the central interests in exercise physiology, they play an important role in adherence to physical activities in the long run. For instance, Bartlett et al. (2011) reported that participants enjoyed and found more rewarding HIIT protocols as compared to steady-state cardio, which could result in better adherence to training. Such subjective responses may be especially important in young adult samples who might lack motivation to exercise when they fail to experience immediate benefits.

For sports science a wide range of implications concerning HIIT goes beyond the scope of general health. HIIT can be used as performance tool to improve aerobic and anaerobic power among student-athletes and active students. The conditioning work also enhances muscle endurance, speed, and metabolic flexibility, attributes that are vital to athletic performance in multiple sports. And other research has shown that HIIT enhances mitochondrial density and oxidative enzyme activity to a greater extent than low-intensity aerobic exercise, which means more efficient and faster recovery following intense workouts. These modifications are advantageous not just for sport, but for overall health. For these

reasons, sport scientists are now promoting the integration of HIIT protocols in sports training and physical education programs at university level (Burgomaster et al., 2008). What sets HIIT apart from traditional aerobic exercise is its ability to elicit a robust acute physiological response at a lower volume of exercise. The inherent design of HIIT under a ratio of 2:1 between work and recovery sucks in several energy systems (i.e. phosphagen, glycolytic, and oxidative pathways). This multifactorial involvement results in adaptations of both cardiovascular and musculoskeletal systems. As an example, a work of Little et al. (2011) reported that insulin sensitivity in healthy young subjects improved by 23% following only 6 sessions of low volume HIIT. With the rising trend of prediabetes conditions in university students, these results underscore the potential benefits of evidence-based exercise interventions such as HIIT in youth focused health programs.

Cardiometabolic health, a collective term for cardiovascular, metabolic and inflammatory health, has received increasing attention in clinical and sports performance research. Cardiometabolic health in early adulthood is crucial as it is an antecedent to chronic diseases such as type 2 diabetes mellitus, atherosclerosis and hypertension, which in many cases develop silently over time. Consistent engagement in HIIT has favorable effects on cardiometabolic risk factors, such as triglycerides, HDL cholesterol, and blood glucose. A randomized trial by Kessler et al. (2012) found that waist circumference and systolic blood pressure, markers of cardiovascular risk, had decreased during a 10- week intervention of HIIT in people. These results are potentially encouraging for college health administrators and policy makers concerned about the chronic public health consequences of NCDs. In terms of theoretical framework for health behavior change and maintenance, HIIT fits well with health adoption and maintenance theories other than the physiological and psychological effects. Models such as the Health Belief Model and the Theory of Planned Behavior imply that interventions should be perceived as effective, convenient, and interesting to promote continued compliance. HIIT's time efficiency and quick results tackle these two barriers, which may make even more sedentary adults more likely to get active. To students in university that routinely list lack of time and motivation as the two primary reasons, the evidence based solution of HIIT is also probable. In addition, HIIT is also adaptable to training status and can be adjusted to all fitness levels, ensuring diversity and scalability in different student populations (Weston et al., 2014). Despite its potent benefits, the application of HIIT does demand careful consideration, particularly with non-athletic populations. As the workouts are intense, the participants may develop musculo-skeletal injuries and overtraining if not programmed adequately. The lack of skilled sports scientists, trainers and physiologists in the development and monitoring of HIIT programs is therefore essential. Teach proper technique, rest periods and individual thresholds when training to help optimize benefits while minimizing risk. Moreover, longer duration follow-up studies are required to determine if the benefit from HIIT is sustainable over time in normal and high fitness participants (Tjønna et al., 2008).

In order to facilitate the incorporation of HIIT into the context of university life, campus policies need to acknowledge PA as an integral component of student well-being. Incorporating different types of HIIT programmes in student health services, sports clubs and physical education programmes on campus holds promise for a broad range of both academic performance and health benefits. Furthermore, the accumulating evidence base for HIIT as a therapeutic modality demonstrates its potential beyond health, such as for use in rehabilitation and in the management of disease. Programs from sports sciences should work together with exercise physiologists, educators, psychologists and public health professionals in each country, if HIIT is to be used effectively as a strategy to improve the health of students in universities (Gillen & Gibala, 2014).

Literature Review

High-Intensity Interval Training (HIIT) is gaining popularity amongst the sports sciences community as it can deliver substantial physiological benefits in a short time. This form of training, which alternates short bursts of high-intensity exercise with brief recovery periods, has received growing attention for its effects on cardiometabolic health. College students represent a key target group for HIIT interventions, given that they experience academic pressures and have little time to engage in physical activity. Sedentary behaviour in this population has been associated with a range of cardiometabolic risk, metabolic syndrome and obesity. It is suggested from prior research that HIIT has a positive effect on typical fitness markers, as well as accounts for specific time limitations of students and is, therefore, a feasible and efficient exercise modality (Gillen & Gibala, 2014). Cardiorespiratory fitness, as assessed by maximal oxygen uptake (VO_2 max), is a fundamental aspect of cardiovascular health and global endurance performance. Research has constantly shown that HIIT may lead to a substantial increase in VO_2 max in young adults, such as university student. Astorino et al. (2012) reported that a mere 8 weeks of HIIT would induce significant increases in VO 2 max in young adults, similar to, or in addition to, gains associated with MICT. Such findings are particularly pertinent because enhanced aerobic capacity decreases the occurrence of cardiovascular disease and contributes to superior sports and physical working skills. These improvements highlight that HIIT is a conditioning strategy that may have utility as preventive/health maneuver and as a sport preparation modality (Astorino et al., 2012). Changes in body composition are also a significant effect related to the participation in HIIT. University students also tend to experience higher levels of overweight and obesity that is in part caused by sedentary attitudes and unhealthy eating habits. It was found that HIIT interventions resulted in greater reductions in fat mass and waist circumference and better metabolic health. Martins et al. (2015), who systematically reviewed the area and reported that HIIT protocols induced a significantly reduction in body fat percentage and abdominal adiposity in young adults. The increased post-exercise oxygen consumption (i.e., EPOC) that occurs after HIIT is an added bonus that leads to additional calories being burned long after workouts have been completed, furthering the fat-loss effects. Crucially, such body composition alterations not only lower the risk of metabolic syndrome but enhance sports performance by increasing the power/weight ratio and movement efficiency (Martins et al., 2015).

HIIT has also led to improvements in other metabolic health indices including insulin sensitivity, blood pressure and lipid profiles. Jelleyman et al. (2015) showed in a meta-analysis HIIT to be effective for improving glycemic control and insulin resistance, main factors for type 2 diabetes prevention. It was accompanied by improvements in HDL cholesterol and fasting glucose was reduced. These findings are particularly important for college students who, unbeknownst to them, may be incurring early metabolic damage from unhealthy lifestyle. These data support that HIIT should be used as a primary means for improving fitness and preventing future cardiometabolic diseases in young adults (Jelleyman et al., 2015). In addition to its physiological effects, HIIT also appears to have positive effects on psychological variables that could improve exercise adherence. Bartlett et al. (2011) showed that people enjoyed HIIT sessions more than CMI exercise, which could result in higher motivation and adherence to exercise. This psychological aspect is very important for university populations in whom motivation to keep exercising may diminish because of conflicting academic and social obligations. It is a win-win situation: because HIIT is linked with a better mood, lower anxiety and better cognitive performance, you're looking after both your mind and your body. This dual impact is particularly useful when targeting long-term participation in physical activity programs with students (Bartlett et al., 2011). In terms of sports science, the main effect of HIIT is to optimise both the aerobic and anaerobic

energy systems – ever useful when it comes to being a runner, swimmer or cyclist. Burgomaster et al. (2008) together with our own results, advocate that brief low-volume (load), all-out SCT-sprints also elicits similar metabolic adaptations of traditional ET. Increases in the number of mitochondria and oxidative enzyme levels increase the muscles' ability to generate energy at an efficient rate, which can improve endurance and recovery time. These physiological adjustments not only enhance athletic competitive performances but also serve recreationally active students who want to optimize physical fitness in a highly time-effective manner. Keep exercises as varied as possible Research orthies such as Aernouts (2015) report that strong correlations between change in VO2max and changes in elite and recreational performances are often observed in athletes doing mixed-exercise HIIT.

The utilization of the three energy pathways (phosphagen, glycolytic and oxidative pathway) is another measure which separates HIIT from traditional endurance training. This widespread activation-induced building promotes really widespread physiological changes that are beneficial for metabolic health in general. Little et al. (2011) who demonstrated that as little as six lower-volume HIIT sessions increased insulin sensitivity by 23% in young healthy individuals, underlining the rapid exercise benefits that this type of training can provide. Given the number of individuals with insulin resistance and metabolic syndrome in younger populations, this suggests a role for the inclusion of HIIT in university health promotion programs (Little et al., 2011). Common exercise targets include cardiometabolic risk factors (e.g. blood pressure, waist circumference and lipid profiles). Kessler et al. (2012), young adults witnessed considerable decreases in both waist circumference and SBP following a 10-week HIIT regimen. These changes are associated with reduced hypertension, type 2 diabetes, and cardiovascular diseases in adulthood. As university students are in a critical stage for developing long-term health habits, 27^, 30 HIIT is a potential strategy for reducing future cardiometabolic disease burden (Kessler et al., 2012). According to behavioral models including the Health Belief Model and the Theory of Planned Behavior, participants need to perceive an exercise program as effective, accessible, and enjoyable for adherence to occur. HIIT can overcome all these issues it's a quick and effective way of exercising and comes in all sorts of types so you can pester yourself throughout it in many ways. Weston et al. (2014) observed, the time efficiency of HIIT is appealing for young adults, allowing continued participation. Furthermore, the versatility of HIIT permits diversity of programming that is appropriate for all levels of fitness, improving accessibility across a range of students. It is these considerations that are important for effective delivery in the university context (Weston et al., 2014).

Although the advantages of HIIT are extensively documented, risk, especially injury and overtraining, should be recognized. The high level of relative intensity involved in HIIT would be best managed with appropriate supervision, individual programming and appropriate periods of rehabilitation, in order to decrease the risk of musculoskeletal overload. Tjønna et al. (2008) stressed that adjusting HIIT programs to the fitness levels and skilled supervision of participants are crucial for ensuring safety and effectiveness. In the inclusive university setting where participants' fitness histories could differ widely, these individualized approaches are essential to avoid negative responses and to sustain lasting exercise participation (Tjønna et al., 2008). Institutional backing is important in integrating HIIT into university health programming. Including organized HIIT sessions within sports clubs, PE curriculum and university wellness services is a way to increase student involvement and expose more individuals to HIIT. An integrated approach between the sport scientist, health promotion educator and the psychologist is necessary for providing targeted, evidence-based programs designed specifically for students. Thus, comprehensive strategies are needed in order to bridge the gap between evidence and practice, and improve the health

and academic success of students by promoting physical activity in schools (Gillen & Gibala, 2014).

High-Intensity Interval Training in Sports Science

High-Intensity Interval Training (HIIT) has quickly entered the field of sports science in recent years for its diverse potential applications, with its contribution to the field of exercise prescription receiving particular attention. According to old dogma, exercise was about doing continuous moderate intensity exercise and it took a lot of time to leverage cardio-vascular and metabolic benefits. Nonetheless, due to the growing demand for time-effective exercise in today's society, these sports scientists looked for alternative and more time-effective yet theoretically equally or more effective training methods. HIIT fulfills this need by combining short bursts of near-maximal effort exercise with short periods of recovery, and is thereby known to promote rapid and extensive physiological adaptations16 (Gillen & Gibala, 2014). This model of training stimulates the body in a maximal way both aerobically and anaerobically, which is unique in sports science and represents a diverse and holistic exercise protocol. Physiologically, HIIT leads to complex cardiovascular, respiratory, and muscular adaptations. At a cardiac level, cardiac output and stroke volume are enhanced following repeated bouts of high-intensity intervals, improving oxygen delivery and utilisation (Astorino et al., 2012). These adaptations correspond to increased VO_2 max, a gold-standard index of cardiorespiratory fitness that is consistently associated with a lower risk of death and a greater ability to perform physical work (Burgomaster et al., 2008). HIIT also has a positive impact on vascular function through enhanced endothelial health, decreased arterial stiffness, and enhanced blood pressure regulation (Kessler, Sisson, & Short, 2012). These cardiovascular adaptations cumulatively reverse risk factors of chronic diseases such as hypertension and atherosclerosis, hence HIIT is of worth not only to sports performance, but also to public health.

Beyond cardiovascular health, HIIT has a profound effect on metabolism and as such is an important area within sports science in relation to energy balance, insulin sensitivity, and lipid metabolism. The episodic stressor of HIIT leads to metabolic distress, which promotes mitochondrial biogenesis, the cellular event responsible for increasing mitochondrial density and function in muscle cells (Little et al., 2011). Increased mitochondrial capacity enhances muscles' capacity to oxidize fat and glucose, leading to increased metabolic efficiency and reduced insulin resistance (Jelleyman et al., 2015). Biologically, these changes translate into better glycemic control, lipid profiles and body composition, key markers concerning the escalating prevalence of metabolic syndrome and type 2 diabetes in young adults, such as university students. The striking positive effect of MIIT on metabolic risk indicators after only a few weeks suggests the potency of HIIT and further cements the method in sports as a part of the toolbox of preventive or performance-enhancing variety. The muscular adaptations of HIIT are important in the applied sports and exercise sciences. High-intensity intervals activate fast-twitch fibers leading to strength, power, and endurance gains that are greater than those obtained with moderate-intensity continuous training in as short or shorter period of time (Burgomaster et al., 2008). These kinds of muscle-building advances not only translate to your work on the court, but to functional fitness in real life settings, as well. Furthermore, the rise of EPOC after HIIT session enhances total energy expenditure that will have beneficial effects against weight and body fat in the long term, an issue of interest in populations with risk of sedentarism and obesity among many other conditions (Martins et al., 2015). Therefore, it also explains from a holistic view point how HIIT can elicit such a multifaceted response in muscle and metabolic function and illustrates the pursuit of sports science to target full body optimization and health.

Beyond physical advantages, HIIT also contributes to within sports psychology and science in terms of psychological and behavioural consequences. Compliance with exercise continues to be a major issue for athletic and general populations and motivational constructs are critical for maintaining physical activity level over time. Studies have shown that individuals enjoy HIIT more and find it to be less monotonous than continuous moderate-intensity exercise (Bartlett et al., 2011). This is thought to be due to the variable intensity and duration of the intervals, which makes for interesting training that can mitigate the sense of weariness and monotony that can plague steady-state proponents. From a sports science, or mind game, perspective the involvement of the mind in HIIT is invaluable; the fact that people are more likely to continue to use this type of training and respond to a truth there is in a different form of training behaviour has much to offer for health and performance (Weston et al., 2014). Whist University students are immersed in an environment that is full of academic and social pressures, the time-efficient and fun attribute of HIIT provides a potential solution to overcome the barriers of exercising consistently. Sports science also investigates the practical implications and how to program HIIRT training, also understanding that it is only effective when suitable design and individualization are applied. Numerous types of HIIT protocols are available and vary on variables such as interval length, intensity, recovery time and overall session duration. Standardized formats vary from short 'sprint interval training' (SIT) comprising repeated 20-30 second 'all-out efforts' with a period of recovery to longer work intervals (85-95% of maximal heart rate) (Gillen & Gibala, 2014). Sports scientists place great value on this fine-tuning of these variables to the individual's exercise capacity, fitness, health status and targets so as to maximize the returns from the exercise and minimize the risk of injury (Tjønna et al., 2008). Aspirant university girls the modified version of the program should address that girls have different initial physical training status and free time, and practice funding your personal program to increase engagement and reduce the dropout rate. In addition, periodization approaches that include HIIT blocks of training can be combined with other training types to manage the stress/recovery continuum and thereby promote progressive adaptation in the context of academic and sporting calendars. Of note, sports science is still exploring the long-term impacts and sustainability of HIIT, world-important for translating any acute physiological phenomenon into actual long-lasting health improvements. At least in those short-term trials, PROMOTE participants demonstrate substantial improvements in measures of fitness and metabolism, however how well participants will adhere to the exercise interventions, as well as potential risks of overtraining and injury on the longer term remain questionable (Kessler et al., 2012). It is the longitudinal studies in sports science that endeaved to provide safe and effective recommendations for sustained HIIT application, especially, in non-athletes, of which university students are an example. In laboratory environments, and increasingly beyond this, wearable technology and remote monitoring are also being studied as strategies to improve adherence and monitor training intensity. These developments illustrate that sport science is dedicated to evidence-based, practical interventions that fit the constraints of the real world and contribute to regular physical activity throughout the lifespan. Furthermore, the crossover of HIIT with other domains of sports science spans nutritional supplementation, recovery techniques and psychological interventions. Diet management to promote 17 energy availability for HIIT and recovery promotes adaptation and prevents fatigue; in addition, recovery strategies such as active recovery, stretching and sleep hygiene can also reduce the risk of injuries and maintain the performance (Martins et al., 2015). Also, sport psychologists have added knowledge with respect to motivation, goal setting and stress management--which may be particularly useful with university students who are managing a number of different tasks at once. Interindustry, This interdisciplinary approach highlights the totality of sports science, where HIIT is not perceived in isolation, but rather is integrated into a multifaceted health and performance infrastructure.

Physiological Benefits of High-Intensity Interval Training (HIIT) on Cardiometabolic Health

High-Intensity Interval Training (HIIT) has been widely researched in relation to its effects on cardio-metabolic health, a field of large importance regarding cardiovascular and metabolic mechanisms essential for the preservation of the homeostasis of the organism. Cardiometabolic health is the finely tuned network of blood pressure control, lipid homeostasis, glucose homeostasis, and body composition that influences the risk for cardiovascular disease, type 2 diabetes, and metabolic syndrome. In the sports science domain, HIIT has been acknowledged, as a facilitator for athletic performance, as well as transversely as a therapeutic tool aiding in the treatment or secondary prevention of these CVD and metabolic risk factors. In the same vein, the physiological effects of HIIT are diverse, including improvements in cardiovascular function, metabolic adaptations, and skeletal muscle adaptations that contribute to its overall health-enhancing effects (Gillen & Gibala, 2014).

Increased cardiovascular function is the most notable physiological effect of HIIT. The repeated high-intensity elements of HIIT cause adaptations in the heart and vasculature increasing cardiac output and stroke volume. Cardiac output (the quantity of blood pumped by the heart per unit of time) is enhanced by improved myocardial contractility and ventricular remodeling, resulting in a more efficient heart that can provide active tissues with oxygenated blood under resting and exercising conditions (Astorino et al., 2012). HIIT also induces vascular adaptations including improved endothelial function, which increases vasodilatation by nitric oxide-dependent mechanisms. Better endothelial function leads to decreased arterial stiffness, which is associated with decreased systolic and diastolic blood pressure two key factors associated with cardiovascular risk. These cardiovascular adaptations are evidenced by elevated maximal oxygen consumption capacity (VO2 max), an important indicator of cardiorespiratory fitness and an independent prognosticator for cardiovascular death (Burgomaster et al., 2008). When it comes to VO2 max, HIIT's influence is especially important as this is considered to be one of the most repeatable predictors of cardiovascular wellbeing. Research has demonstrated that very short HIIT protocols can result in similar or greater increases in VO_2 max compared with traditional, longer endurance-based MICT, and involving just a small proportion of the time investment (Gillen & Gibala, 2014). The time saving factor of HIIT is an appealing benefit for university students and young adults who are commonly time-restricted. Enhanced VO_2 max not only improves endurance and physical performance it also decreases the likelihood of hypertension, stroke, and coronary artery disease due to increased oxygen delivery to tissues as well as increased O2 uptake by tissues (Astorino et al., 2012). These findings suggest that HIIT represents an effective exercise mode for CVD health promotion and disease prevention.

HIIT not only provides cardiovascular benefits, but there's quite a bit of positive impact on metabolic health such as glucose regulation, insulin sensitivity, and lipid metabolism. Metabolic perturbations including insulin resistance and dyslipidemia, underlie the aetiology of type 2 diabetes and metabolic syndrome diseases that are becoming increasingly common in young adults worldwide (Jelleyman et al., 2015). Insulin sensitivity is increased by HIIT through the increased glucose muscle uptake, a process mediated by the upregulation and translocation of glucose transporter type 4 (GLUT4) proteins in skeletal muscle cells (Little et al., 2011). This enhanced glucose uptake results in a lower blood glucose concentration, and decreases hyperglycemia, reducing the risk of diabetes. Furthermore, HIIT had a significant reduction in fasting insulin and glucose, which is beneficial for better glycemic control and metabolic health (Jelleyman et al., 2015). Lipid metabolism is a related

cornerstone of CM and lipids metabolism is no less affected by HIIT. Dyslipidemia, with increased levels of triglycerides and low levels of high-density-lipoprotein (HDL) cholesterol, is a prominent risk factor for atherosclerosis and cardiovascular disease. Evidence demonstrates that high intensity interval training (HIIT) has been shown to elevate HDL cholesterol and decrease triglycerides for a more optimal lipid profile (Kessler, Sisson, & Short, 2012). This enhanced lipid utilization is associated with the HIIT-mediated mitochondrial biogenesis and enzyme activity in skeletal muscle to increase the muscles' ability to oxidize fatty acids (Burgomaster et al., 2008). This metabolic flexibility not only enhances substrate oxidation during exercise, but also accelerates fat loss and promotes favorable body composition to help attenuate cardiometabolic risk factors.

Another important physiological adaptation associated with HIIT is favorable effects on body composition with respect to cardiometabolic health. Higher adiposity, particularly visceral fat deposited in the body, is positively correlated with the risk of metabolic syndrome, insulin-resistance and cardiovascular disease (Martins et al., 2015). HIIT has been found to promote total and abdominal fat loss to a greater extent than that of moderate-intensity continuous exercise, but for a much shorter duration (Gillen & Gibala, 2014). The increased EPOC effect in response to HIIT workouts prolongs the calorie burning after the completion of workouts, which will increase the total energy expenditure (Martins et al., 2015). These alterations in body build lead to improvements not only of metabolic markers, but also of physical performance and body image that perhaps act as facilitators of adherence to physical activity in university students.

The benefits of HIIT to cardiometabolic health at the cellular level are achieved through increases in mitochondria. Mitochondria are responsible for the aerobic respiration and ATP production in cells. Increased Mitochondrial Biogenesis HIIT enhances mitochondrial biogenesis via activation of signaling pathways that include peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1α) to increase mitochondrial number and function in skeletal muscle (Little et al., 2011). By increasing mitochondrial capacity, more efficient oxidative metabolism is achieved, thereby making muscles more capable of utilising oxygen, glucose and fatty acids. This adaption is essential to promote metabolic health through increased energy expenditure, decreased oxidative stress, and improved insulin sensitivity (Jelleyman et al., 2015). The mitochondrial remodeling initiated by HIIT is at the root of many of its cardiometabolic improvements. HIIT also affects inflammatory markers of cardiometabolic diseases. Chronic systemic low grade inflammation with increased production of proinflammatory adipocytokines is considered an underlying determinant of insulin resistance, endothelial dysfunction and atherosclerosis (Kessler et al. 2012). Research has shown that HIIT can decrease pro-inflammatory cytokines such as TNF-α and IL-6 and increase anti-inflammatory markers in the body, leading to less systemic inflammation (Gillen & Gibala, 2014). Such anti-inflammatory effect translates to enhanced vascular function and metabolic health, whereby expanding the therapeutic potential of HIIT in the management of cardiometabolic diseases.

Finally, HIIT has a beneficial impact on autonomic nervous system control, which is crucial for cardiovascular health. HIIT increases parasympathetic activation with attenuated sympathetic over activity and this augmentation of HRV, a measure of cardiovascular autonomic balance and stress resilience, is improved as a result (Astorino et al., 2012). Higher HRV is linked to a reduced risk of arrhythmias and sudden cardiac events, therefore increasing other levels of cardiovascular protection. This autonomic function modulation enhances the other cardiovascular beneficial effects produced by HIIT, providing a comprehensive approach to heart health induction. Its effectiveness in promoting these

selected physiological adaptations is particularly beneficial to university students who may experience academic demands or lifestyle constraints that restrict their time for prolonged exercise. HIIT overcomes common factors that prevent people from the necessary levels of physical activity due to the relatively small time commitment to achieve substantial cardiometabolic gains (lack of time, motivation) (Bartlett et al., 2011). Since there is also flexibility in the delivery of HIIT programs, not just in terms of intensity, but also to fit differences in underlying fitness levels and preference, HIIT appears well suited and acceptable in young adult populations, provided that appropriate tailoring is adopted (Weston et al., 2014). HIIT involves important physiological adaptations that improve some cell energy metabolism processes; cardiovascular function; metabolic regulation and the body composition, being a good strategy for the prevention and/or-treatment of the impaired metabolism that leads to cardio-metabolic diseases. Cumulatively, these adaptations will minimize the risk factors for cardiovascular disease, diabetics and metabolic syndrome. The strong evidence over the past decades from sports science research supports the importance of employing this time-inexpensive and effective exercise modality especially in populations like university students who benefit when offered a form of physical activity that is both flexible and potent. This evidence supporting HIIT as a health promotion strategy provides promise for advancing improvements in cardio metabolic health outcomes at a population level.

HIIT and Its Impact on Body Composition and Fitness Levels

High-intensity interval exercise (HIIT) is receiving growing interest in sports science, as research demonstrates its potential as a time-efficient training method to improve exercise performance and health status in a variety of populations. Body composition describes the relative amounts of fat mass, lean muscle mass, skeletal mass and total body water and its impact on health, physical health and disease risk (Martins et al., 2015). Fitness exists in multiple components including cardiovascular capacity, muscular strength, flexibility, and metabolic function. Thus, integration of HIIT into exercise programming becomes an attractive proposal to maximize these variables in limited periods of time, especially for population such as college students who experience time constraints and have sedentary lifestyles (Gillen & Gibala, 2014). The current section explores the physiological and functional adaptations to HIIT, focusing on the impact of HIIT on body composition and overall health. Among the most impressive effects of HIIT on body composition, stands its role in reduction of adiposity, especially of visceral fat, which is strongly associated with metabolic syndrome and cardiovascular disease (Martins et al., 2015). The short periods of hard exercise raise metabolism (increases the rate at which your body burns calories or fuel) during and after workout as well, referred to as (EPOC) or the afterburn effect. This increased O2 consumption extends the burning of calories, helps maintain the body's fat burning state, even at rest (Børsheim & Bahr, 2003). HIIT studies have consistently shown to be superior to moderate intensity continuous training (MICT) in the long-term production of decreases in total body, abdominal and subcutaneous fat, with fewer exercise time commitment (Boutcher, 2011). Loss of adipose tissue not only improves aesthetic and functional outcomes, but also reduces inflammation and insulin resistance, thereby enhancing metabolic health. It also promotes lean muscle growth and muscle quality in addition to fat loss. Compared to traditional endurance training that is likely neutral or even negative when it comes to muscle hypertrophy, HIIT can promote muscle stimulation through high intensity contractions recruiting both slow-twitch and fast-twitch fibers (Burgomaster et al., 2008. This fiber utilization results in increased muscle strength, power, and endurance and hence improves functional capacity. The maintenance or induction of the lean body mass is crucial during weight loss treatment to avoid sarcopenia and to counteract metabolic rate reduction (Moro et al., 2016). As such, HIIT may elicit a favorable response to body composition, both

promoting lean mass and reducing fat mass, and therefore may be an efficient training regimen to change body composition for both health and performance needs.

Cardiorespiratory fitness, an important part of overall fitness, is enhanced with HIIT. VO_2 max, which is the maximum oxygen consumption during exercise, being a key determinant of aerobic capacity and cardiovascular fitness. Literature consistently demonstrates that HIIT provokes marked increases in VO_2 max in a range of populations including, inactive and active people, and patients with disease (Gillen & Gibala, 2014). The gains in VO_2max are commonly obtained with smaller total amount of exercise relative to moderate intensity continuous exercise, which demonstrate the effectiveness of HIIT. A higher maximum amount of oxygen the body can utilize (VO_2 max) means better endurance performance, more energy, and a lower risk for cardiovascular disease (Astorino et al., 2012). For college students whose time may be limited for exercise, HIIT is a good way to skyrocket your cardiorespiratory fitness and physical capacity. Make utmost power is another aspect of fitness that is beneficially impacted by HIIT. The high exercise intensity during intervals induces neuromuscular adaptations such as greater muscle fibre recruitment and synchronization (Burgomaster et al., 2008). These changes lead to increased force output and quicker muscle contractions, which are important with regards to performance in any number of sport and activities of daily living. In addition, HIIT formats including resistance or plyometric training also increase muscle strength and power, which extend the fitness equation beyond only an improvement in endurance (Laursen & Jenkins, 2002). This versatile effect on $\dot{V}O_2$ max makes HIIT a balanced method in sports science. Flexibility and mobility, lesser known aspects of fitness, may also indirectly improve as a result of engaging in HIIT exercise. While most of the beneficial effects associated with HIIT are related to cardiovascular and muscular adaptations, the high impact nature of a high percentage of HIIT protocols (e.g. sprinting/jumping/agility work) may play a role in improving joint mobility and neuromuscular coordination (Paoli et al., 2012). These findings indicate that while targeted flexibility training is required to achieve substantial gains in ROM, participation in regular HIT is not detrimental to, and can actually preserve or increase functional mobility, which may reduce the risk of injury and promote general health.

The metabolic changes that lead to improvements in body composition and performance are at the heart of HIIT's efficacy. High intensity interval training (HIIT) also increases mitochondrial mitochondrial density and function in skeletal muscle, thereby potentially increasing reliance of fat derivation for energy production (Little et al.; 2011). This mitochondrial biogenesis is controlled by the activation of signaling molecules such as PGC-1α, which in turn regulate cellular bioenergetics. Better mitochondrial health makes for better endurance, more available energy during both daily life and focused stress, and a preference to burn fat, ultimately aiding fat loss and workout performance (Jelleyman et al., 2015). It gets better…HIIT enhances insulin sensitivity and glucose metabolism, which in turn explains how it supports positive shifts in body composition and fitness (Jelleyman et al., 2015). Fitness- or body composition-associated psychological moderators also influence the efficacy of HIIT interventions. The enjoyment and perceived time efficiency are the key factors that drive exercise adoption, issues on which HIIT rates high (Bartlett et al., 2011). Increased enjoyment is associated with more frequent training, which is required to achieve and sustain physiological adaptations. Moreover, quick changes in body construction and sports test may be motivating and help promote sustained physical activity. Such a psychological feedback loop is particularly applicable to college students who might find it challenging to maintain their motivation given their heavy workload and a multitude of external demands. Safety and injury susceptibility are relevant to the deployment of HIIT as a means to enhance body composition and fitness. The high intensity of the HIIT has led to

questions about injury risk, however it is now believed to be safe when correctly prescribed and supervised for the most part of the population, including those who have chronic diseases (Weston et al., 2014). Slow progression, sufficient warm-up and cool-down, and consideration for individual fitness levels are key factors in using HIIT safely. Sports science studies are still developing recommendations on how to maximize benefits whilst minimizing risks where HIIT is concerned and it is clear that HIIT is here to stay as a powerful tool to lose fat and improve fitness.

Practicality and Feasibility of HIIT for University Populations

High-Intensity Interval Training (HIIT) has received significant interest as a potentially superior means of enhancing physical health status across the lifespan. The ease of use and applicability of implementing HIIT within academic institutions is potentially important if maximum student involvement and health gains are to be realized. The unique conditions that university students encounter such as, academic stress, variable routines, and a lack of gym access, warrant investigation of HIIT's usability as one such option. The practicality of HIIT, time-efficient and cost-effective, in university setting has been previously reported, and the feasibility of implementing HIIT in tertiary institutions (student motivation and adherence and availability of a supporting environment in the university) could be mentioned. The primary benefit of HIIT and which makes it possible for university students is the time efficient nature. Whereas standard MICT typically consists of 30–60 minutes of continuous exercise per session, HIIT protocols can involve as few as 10–20 minutes of exercise (Gillen and Gibala, 2014). This minimum number of hours worked fits in the flexible, on-demand lives of the students that have work to take care of for school. The opportunities of making big fitness gains on short time have made HIIT an appealing exercise form to students who regard as lack of time a major barrier to exercise (Bassett-Gunter et al., 2013). And such efficiency shouldn't undermine the effectiveness of the routine science has shown that short sessions of high-intensity training, or HIIT, can boost heart health and metabolic markers of well-being (Weston et al., 2014). Another key factor that affects accessibility to HIIT among university populations is higher education. Most HIIT formats need very little in the way of equipment, just bodyweight, like jumping jacks, burpees, or high knees, or even bouts of simple cardio such as sprint intervals (Kessler, Sisson, & Short, 2012). This gives single individuals to perform HIIT from a variety of venues such as dormitory rooms, the outdoors, or campus recreation facilities without the need for a specialized environment. The flexibility of being able to train anywhere removes obstacles such as not being able to get to the gym or the costs of being tied into a fitness membership. Additionally, the incorporation of advanced technology with apps or websites that provide guided HIIT exercise workouts is one way to make structured exercise accessible to students to perform in isolation and potentially broadens the reach of structured exercise opportunities (Vandelanotte et al., 2016).

Even though it is effective, the applicability of HIIT interventions in the university context relies heavily on student motivation as well as adherence. Although HIIT provides a fun and effective work out, it's high-intensity nature could potentially deter students, especially new students and those with low baseline fitness (Dalleck et al., 2016). Psychological preparedness and perceived competence are crucial factors determining whether individuals will continue to participate. There is some evidence that interventions that include motivational techniques including goal setting, feedback and encouragement have the potential to improve adherence to HIIT (Plotnikoff et al., 2015). For instance, HIIT sessions on campus in a group-based format may create close communities and a sense of responsibility, which is a strong motivator in young adults (Smith et al., 2015). Notably, social interaction during exercise provides enjoyment as well as psychological need fulfilment for relatedness and the latter is a cornerstone of long-term engagement according

to Self-Determination Theory (Ryan & Deci, 2017). Institutional backing is critical for improving the practicability of HIIT among universities. For examples, universities that invest in the development of accessible fitness environments (with quality gyms and outdoor exercise spaces) for the purposes of enabling student HIIT participation (Levesque et al., 2007). Further, the integration of HIIT classes into physical education instruction, health and wellness workshops, or after-school programs can help make this exercise modality more acceptable. University health services, student organizations and fitness professionals can partner to create customized HIIT programs that reflect the unique wants and goals of student constituents. Programs which provide safe exercise education along with information about progression and recovery, can also address concerns related to potential injury risk and over-training and decrease perceived risk associated with HIIT (Smith 2003). The importance of technology in increasing the availability of HIIT in university students also cannot be underestimated. This trend is poised to scale using fitness apps or online platforms above geography and time limits (Vandelanotte et al., 2016). There are many apps for HIIT workouts with personalized routines, video tutorials and progress reports, which allow students to be in control over their own workout. Moreover, 4Other virtual communities of these platforms provide peer assistance and competition that would improve adherence, motivation (Levesque et al., 2007). At the same time, technological dependence brings with it challenges, such as digital literacy gaps, or connectivity problems that institutions will need to take into account as they promote digital HIIT solutions.

Safety concerns are paramount when considering HIIT in collegiate populations. The vigorous intensity of HIIT means that it should be screened for carefully and carefully guided, especially for less healthy and unfit individuals as students (Gillen & Gibala, 2014). Universities should guarantee the availability of expert personal trainers/commercial operators who are capable of creating safe and effective HIIT programs and monitoring the participation of students to avoid injuries. Proper technique, warm-up and cool-down exercises, and awareness of the signs of overexertion are important information for injury risk reduction (Meeusen et al.., 2013). Moreover, flexible program designs, which support delta changes in intensity, provides the ability to reach larger groups of people, and thus a more inclusive and sustainable potential for participation. Environmental and cultural aspects within universities can also affect the feasibility of HIIT. A campus culture focused on health and wellness helps motivate activity among students. An environmental approach such as campus-wide fitness competitions, incentives for involvement, and incorporation of HIIT into existing sports clubs can create a supportive milieu (Plotnikoff et al., 2015). On the other hand, the academic demands and inactivity in university students could be a barrier to participation. MEASURES STRATEGIES ASSESSED WITH MODERNITY OBSERVATIONS Measures that involve the inclusion of HIIT in the daily life of students, i.e., such as active breaks during the study hours or in providing commuting activities such as cycling that are designed to overcome the identified barriers that include the physical activity in the routine as behaviors can be included in existing habits (Bassett-Gunter et al., 2013).

Economic viability is a further factor influencing the use of HIIT in university settings. Due to financial restrictions experienced by a large cohort of students, free or low-cost HIIT programs enhance accessibility and participation (Kessler et al., 2012). HOW TO IMPLEMENT HIIT IN UNIVERSITIES could utilize their already existing facilities such as campus gyms, sports facilities and student-led fitness clubs to deliver these affordable HIIT sessions. Grant and health organization partnerships can also support the development and marketing of programs. HIIT's equipment light profile also reduces financial entry barriers compared to other forms of fitness that require costly equipment or memberships. The further assessment of the effectiveness and sustainability of HIIT interventions are also

important for ongoing improvement and for future resource allocation. Routine measures such as participant attendance, participant feedback and health-related outcomes should be used to evaluate the program's effectiveness and inform program improvement within Universities (Weston et al., 2014). On-going modification according to student's preference and new evidence ensures the relevancy of HIIT offerings in addition to efficacy. A program that promotes student engagement in program development and decision-making fosters a sense of ownership and response- veness to the various needs of the university community (Ryan & Deci, 2017). Despite the optimism about the practicality and feasibility of HIIT, there are still some barriers. HIIT is often regarded as too hard to apply to beginner exercisers who might avoid, Likelihood of dropouts. Customized intervention to focus on slow escalation in exercise intensity and safety may alleviate these concerns (Dalleck et al., 2016). It is also accustomed among HIIT programs that equity in offering HIIT to different groups of students that such as students with disabilities and or those who are having chronic health conditions are ensured through intentional program modifications and the application of universal design (Plotnikoff et al., 2015). Ultimately, these conflicting demands on student time and effort require flexible programming and multiple entry points for participation to suit diverse lifestyles.

Strategies for Sustaining Long-Term Adherence to HIIT Programs in Academic Settings

High-Intensity Interval Training (HITT) has been the focus of attention as a health-enhancing exercise prescription method, particularly among university students who frequently report time-based barriers. Despite the robust physiological and psychological outcomes, sustaining adherence to HIIT programmes in a longer term could pose a substantial challenge within academic context. Sustained participation over the long term is essential to obtaining long-term health benefits of HIIT but there are many barriers to consistent HIIT adoption. Consequently, there is a need to create and apply programmes specifically designed for university life if continuous in depth involvement is to be achieved.

Discussion

This paper analyzes evidence-based strategies to enhance adherence to HIIT programs within schools by targeting motivational components, programming, social engagement, models of behavior change and environmental factors. Motivation is a key factor for maintaining engagement in exercise and is particularly critical among the transient and dynamic university setting. Intrinsic motivation, or when one does something because one enjoys it and not for any external reward, is a robust longitudinal predictor of exercise maintenance (Ryan & Deci, 2017). In order to promote intrinsic motivation, HIIT programmes in university settings should focus on enjoyment, challenge and mastery of a task, beyond the effect on fitness or losing weight. Including diverse and new types of activities in HIIT protocols may help maintaining people’s interest and avoiding boredom, which in turn would be determinant in preventing withdrawal (Bassett-Gunter, Brawley & Mummery, 2013). Furthermore, providing choice in exercise selection or modulating intensity allows students to feel empowered, which adheres to the principles of Self Determination Theory, created for students to have more control and ownership and support sustained participation (Deci & Ryan, 2000). Motivational interviewing and goal-setting interventions that are included in university programs were also found to be effective in enhancing adherence because they help students to find personal reasons for exercising and define realistic targets (Plotnikoff et al., 2015).

Social support is also an important modifiable determinant of maintaining HIIT over time. College enrollees experience social influence and support, and such a social context is likely

to have an impact on their exercise behaviors (Levesque et al., 2007). HIIT in a group format also provides an environment for social support and has been shown to provide greater enjoyment, social connectivity, social influence, belonging, and support compared with individual HIIT (Smith, Ntoumanis, & Duda, 2015). Furthermore, the use of digital resources (e.g. social media groups, apps with community elements, virtual challenges) can enhance the level of social support during periods outside of the physical sessions and help to maintain motivation (Vandelanotte et al., 2016). Creating student-led fitness clubs or employing the "change agents" and influential students to advocate for HIIT in academic settings can help to shift social norms and normalize using HIIT. On the other, programs that ignore social determinants may not be exciting to students who value or rely on relationships with others to be healthy.

The design of the program is critical for adherence, especially in terms of scheduling, varying the intensity and progressing. In university students must often manage ridiculous academic schedules, in addition to part time work, and a social life also. Providing flexibility in session timing, with durations as short as 10–20 minutes for HIIT, or asynchronous digital training opportunities empowers students to fit exercise around their variability in schedules (Gillen & Gibala, 2014). HIIT is quick and can be adhered to and this matches well students' preferences, and it needs to be highlighted in programs marketing when students are recruited and retained in classes. Intensity modulation, which allows intensity to be self-determined at the participant level based on fitness level, may help reduce dropout due to mental and physical strain and loss of interest (Kessler, Sisson, & Short, 2012). Progressive factors, such as increasing the interval length or the frequency, keep the challenge up and prevent the plateau of the hampsters, as well as minimizing the compensating risk of injury. A program that is well designed in terms of expected challenge versus ability allows subjects to develop more adaptive self-efficacy and confidence, which are robust and well established predictors of continued engagement in exercise (Bandura, 1997).

Incorporating behavioral modification theories into the development of HIIT programs promotes exercise adherence by targeting psychological exercise determinants. The Transtheoretical Model (TTM) suggests behaviors change through integration, or phase, from precontemplation to maintenance and interventions should be matched to these stages to promote long-term adherence (Prochaska & DiClemente, 1983). For example, the students at the preparation stage need information to enable them to initiate exercise and skills to begin exercising, whereas those at the maintenance stage need reinforcement and relapse prevention skills. Including self-regulation tools such as exercise logs or wearables allows for goal setting with tracking of progress as well as accountability (Michie, Abraham, Whittington, McAteer, & Gupta, 2009). Furthermore, it is effective to make plans with implementation intentions — precise "if-then" plans for performing the behaviour in a certain context to close the intention-behavior gap and to exercise regularly in the context of HIIT (Gollwitzer & Sheeran, 2006). Universities could facilitate such behaviour change techniques via workshops, counseling facilities and digital interventions personalized for student requirements.

Environmental and institutional determinants also have a strong impact on the long-term adherence of HIIT in an academic context. Access to safe, convenient, and well-appointed exercise sites can provide motivation to continually engage. Other universities that offer HIIT-specific spaces or equipment and make that equipment accessible outside peak hours (Vandelanotte et al., 2016) would enable more students to engage. Incorporating HIIT programs into larger campus wellness campaigns (e.g., health promotion programs, mental health services, and nutrition education) also promotes a comprehensive strategy to student

well-being and demonstrates institution-wide support. Program visibility and resourcing can be better achieved through partnership of academic departments, student organizations and fitness centers. Financial issues might also impede participation; indeed, by providing HIIT training for free or at low cost, economic barriers are overcome by students, in a more inclusive service. Additionally, by fostering a campus climate that prioritizes physical activity, by way of events and reward programs, activity becomes a regular part of the college environment and motivation continues to be maintained through time (Plotnikoff et al.

Lastly, long-term adherence can be maintained by continuous evaluation and feedback from the process. Capturing attendance data, participant satisfaction and health fitness measurements to provide program coordinators with the data needed to tailor HIIT discoveries to align with student wants and needs. Having students feedback through surveys or focus groups can both empower them and make them feel part of the program. Positive reinforcement by milestone recognition or rewards may improve adherence owing to recognition of effort and progress (Smith et al. Technology or apps that both provide real-time feedback (for monitoring exercise intensity) and enable virtual coaching could also be adopted by universities to "gamify" HIIT sessions, making both participation and adherence more interactive (Vandelanotte et al., 2016). Early recognition of adherence patterns and barriers to care is crucial to prevent discontinuation and to make timely interventions.

Enhancing HIIT Engagement among University Students

High-Intensity Interval Training (HIIT) is an increasingly popular form of exercising among college students because it is time-efficient and results in improved cardiovascular fitness and health. Yet there are barriers to participation in HIIT programmes, particularly in academic environments when students are time poor. Technology, herein, takes a forefront role in increasing university students' HIIT participation. The objective of this essay is to discuss the various contributions of technology to HIIT engagement, and how technology can support motivation, accessibility, adaptation (individualization), and social support.

It is highly important to reinforce motivation as a determinant of exercise adherence, and technology as well as its tools can provide novel ways to do so. Fitness tracking apps and websites offer instant feedback to students on their performance and are able to help them measure and track their success as they make progress. For example, apps that track workout progress and reward users for reaching certain milestone goals can increase intrinsic motivation by serving students' individual fitness goals. In addition, the game-like features, including challenges and leaderboards, appeal to the competitive nature of students even more, giving them more reasons to participate in HIIT on a regular basis.

Hard schedules for college students tend to make regular exercising and playing sports almost impossible. Technology has a solution for this, with adaptable workout routines that can be accessed from the comfort of home. Students can carry out HIIT activities online and through mobile apps, which makes a daily commute to the gym unnecessary. This option is especially helpful to students with other obligations to meet. There are a range of workout programs online for students to access to suit their level of fitness and preferences, which can help facilitate ongoing participation.

Personalization is a strong determinant to sustain adherence to exercise programmes. With the advent of technology, there are now apps available that customize HIIT training to a person's fitness needs, goals, and personal preferences. Such apps use algorithms to build personalized fitness plans to prevent students from being either bored or overworked. Customized plans improve workouts' efficiency and ensure that students are more satisfied

with, and adherent to the program. Wearable technology which measures physiological parameters (e.g. heart rate and calorie expenditure) can give an immediate display of the results and may allow students to adapt the intensity of the work for greatest effect.

Exercise adherence is largely predicted by social support. Technology has the potential to help create virtual communities where students can talk about their fitness journey, swap ideas, and support one another. Some online fitness applications and social media groups and forums that include community features allow students to interact with other students who have similar fitness aspirations. This sense of belonging encourages accountability and support which is also important in the outcome of keeping yourself motivated. You can also join virtual group challenges or events which will add a social element to your workout and keep you more engaged and motivated.

A number of obstacles prevent students from being physically active on a regular basis, such as lack of time, restricted facility access, and low self-efficacy. Technology addresses these issues by offering convenient and quick exercise alternatives. Mobile apps and streaming services provide a plethora of HIIT workouts you can do from the comfort of your home, even if you don't have access to fancy equipment or a gym membership. Additionally, the anonymity inherent in digital platforms may help mitigate potential feelings of self-consciousness or intimidation in traditional gym settings, enabling students to start, build and maintain exercise routines.

The Minnesota Vikings are among the first companies and organizations to add virtual reality (VR) to HIIT programs and raise the level of engagement. Workouts in the VR put college students in interactive settings, making exercise more fun and less repetitive. For instance, there are VR boxing games built on High Intensity Interval Training (HIIT) principles that make for high intensity exercises. The end result is an engaging experience that not only makes for fun exercise, but it also offers the kind of immediate feedback the students need in order to keep progressing – something that's a little bit more difficult if a student is just standing in place and throwing punches.

Although technology has several strong advantages in facilitating HIIT behavior, it comes with barriers in its integration. "Anything from tech access issues and tech use (literacy/privacy)" can be a barrier to the effectiveness of technology tools. Furthermore, excessive reliance on technology can shift social interactions away from the face-to-face format and could dilute the quality of social support. Thus, it is important to provide equal opportunities to technology and also to develop digital literacy among the students for better utilization of technology in HIIT programmes.

Technology has the potential to be transformative in increasing university students' involvement in HIIT by mitigating motivational, accessibility, personalization and social supports issues. The use of digital devices and platforms enables flexible and personalized as well as socially supportive exercise sessions which may help users to maintain participation over longer periods in HIIT programs. But to maximize the role of technology in this environment, we need to overcome issues of access, digital competence, and privacy. In achieving this, technology can be used by universities to instill a culture of health and well-being among students and support their general academic and personal development.

Limitations and Considerations in Implementing HIIT

High-Intensity Interval Training (HIIT) is a highly effective exercise modality for improving cardiometabolic health and fitness in a variety of populations, including university students.

While HIIT exercise programs are clearly beneficial, there are several caveats that should be considered before embarking on such a training regimen to protect individuals from exercise-induced injury, ensure effectiveness and maximize compliance. Recognition of these limitations is important to fitness professionals, university administrators, and health promoters who wish to implement HIIT for university health and wellness.

Barriers

This section will address the main barriers regarding physiological and psychological, access, and social or contextual related to the implementation of HIIT programs in academic contexts. One of the major deterrents in the adoption of HIIT is the possibility of injury and ill effects on body due to its heavy Meanwhile, several affective responses related to the among of exercise in the body. Repetitive periods of all-out, or near-all-out work have been used in a number of HIIT protocols and can impose significant cardiac, musculoskeletal, and metabolic stress (Gillen & Gibala, 2014). For those with underlying health considerations (such as cardiovascular disease, hypertension or musculoskeletal injury) participating in HIIT may add significantly to the risk of complications if not under the appropriate supervision or adjustment (Weston et al., 2014). Students not accustomed to regular exercise or those physically inactive who are abruptly exposed to strenuous exercise are also at risk of acute injuries, such as muscle strains, ligament sprains, and overuse syndromes (Meeusen et al., 2013). Thus, pre-participation screening for health risks and individual fitness levels is essential prior to the commencement of such HIIT programs. University health service personnel should institute protocols to evaluate a participant's readiness and adjustment when necessary in order to decrease any injury risks (Kessler, Sisson, & Short, 2012).

Another physiological restriction is overtraining/under-recovery in HIIT subjects. Such high intensity exercise may result in profound fatigue, hormonal imbalances, and a compromised immune system if rest is neglected (Smith, 2003). Overtraining The overtraining syndrome (OTS) is a condition described as a decline in performance, increased susceptibility to illness, and psychological symptoms of irritability and mood alterations (Meeusen et al., 2013). University students tend to experience a high level of academic stress and irregular sleeping patterns, and may therefore be more vulnerable to potential negative outcomes if HIIT is poorly programmed without considering recovery requirements (Plotnikoff et al., 2015). Teaching athletes the role of recovery, tracking the training loads, and promoting attention to bodily sensations are necessary to counterbalance the risks of over training.

The psychological aspects are also important limitations to HIIT application in the university context. While the time spent in HIIT is low, the intensity is high, and could be perceived as threatening or unpleasant by some students, in particular those with poor fitness levels, or with exercise phobia (Dalleck et al., 2016). The unpleasantness associated with high-intensity exercise can potentially result in negative exercise experiences that undermine motivation and compliance over time (Bassett-Gunter et al. 2013). Moreover, college students may present different psychological needs and preferences for exercising that act as moderators of the propensity to be involved into HIIT. Theoretical background According to the Self-Determination Theory intrinsic motivation, autonomy, and relatedness are key features for long-term engagement in physical activities (Ryan & Deci, 2017). If HIIT programmes are viewed as too strenuous, or exclusive, then attending students may feel compelled or ostracised, which can lower the levels of attendance. Such psychosocial concerns and the feasibility of the programme may be mitigated by including supportive environments, flexible intensities and using strategies of motivation, such as goal setting or social support (Smith), Ntoumanis, & Duda, 2015).

Accessibility and equity barriers also prevent widescale adoption of HIIT in the university context. While a large number of HIIT exercises use simple equipment, differences in access to safe and suitable exercise environments are still an issue. Students do not all have similar access to on-campus gym facilities, outdoor locations, or technology for self-guided HIIT sessions (Vandelanotte et al., 2016). Such inequity may have an increased detrimental impact upon students from a lower socioeconomic background, students with a disability, or students who engage in off-campus living where opportunities for fitness may be limited (Plotnikoff et al., 2015). These disparities must be taken into account at universities, offering multiple spaces for exercising, cost-free or low-cost exercise programs and an accessible digital representation, to be inclusive. On the other hand, cultural and social norms may affect students' attitudes toward HIIT and involvement in exercise. Adaptation of interventions informed by cultural preference and reduction of stigmatization about physical activity may improve the participation of students from diverse origins (Levesque et al., 2007).

Finally, the difficulty in designing and delivering program material is another factor that may limit the implementation of HIIT. HIIT protocols can differ greatly in interval length, intensity, work-to-rest ratios, and type of activity (Gillen & Gibala, 2014). Moreover, the general lack of standardized protocols could make it challenging for fitness instructors and program managers to develop safe and effective programs for university students. Mismatch of the programming may lead to poor outcomes related to health or susceptibility of injuries. In addition, it is difficult to monitor exercise intensity without requiring equipment (e.g., heart rate monitors) when students are asked to exercise in prescribed intensities (Kesslere Educating fitness professionals in HIIT-specific protocols and the use of inexpensive intensity monitoring devices may improve program quality and safety.

Time constraints and conflicting priorities among students add another layer of difficulty in applying HIIT. Although HIIT is known for time efficiency, college students may have variations in the schedule resulting from academic deadlines, exams, social activities, and jobs (Bassett-Gunter et al., 2013). This variability may interfere with continuous adherence to HIIT and, thus, long-term sustainability of such programs. Additionally, students who prefer to work out at their own pace or whose schedules do not allow for a set group class or individual coaching session might not be drawn to a fixed group class or scheduled session. Providing a range of delivery models (e.g., on-demand digital workouts, bite-sized videos between classes, or embedded in sport or physical education classes) which are tailored to the user's context may help to optimize adherence and feasibility (Vandelanotte et al., 2016).

HIIT is not readily adaptable to digital delivery due to the nature of its prescription. But such apps and videos are dependent on students' digital literacy, access to consistent internet and the motivation to self-regulate their workouts (Levesque et al., 2007). Unsupervised, students can do exercises improperly, potentially leading to injury or ineffectiveness. On top of that, digital fatigue and distractions can sabotage workout quality and continuity. Universities need to be mindful of employing technology while allowing for face-to-face support and education to maximize HIIT program benefits.

Finally, campaigns to evaluate and monitor implementation of HIIT in universities are logistically constrained. Specialized equipment and expertise may not be as readily available in other institutions limiting measurements of health outcomes that include measures of cardiorespiratory fitness, body composition, and metabolic markers (Weston et al., 2014). And without robust evaluation, the effectiveness of a program is tough to assess and to justify continued investment. Furthermore, gathering data on participants' feedback and adherence takes administrative time and requires student cooperation that may be difficult to

sustain. The design of standard evaluation procedures and use of technology for long distance monitoring could be used to increase program accountability.

Conclusion

HIIT is an exercise approach that is extremely time-efficient and versatile in nature and is particularly relevant to university students' lifestyle constraints. Although its cardiometabolic benefits, such as improving cardiovascular fitness, body composition and metabolism, are well established, 26 it's challenging to maintain long-term commitment to engage in HIIT in school settings. Nevertheless, technology has appeared as an indispensable element to break the existing barriers as well as facilitate the sustained use of HIIT among students. Technology is disruptive in several dimensions. It brings motivation to life with real-time feedback, personalized goal setting, and game-like interfaces on fitness apps and wearables. This facilitates formation of intrinsic motivation and practice of self-efficacy, both of which are important factors for the long-term acceptance (Ryan & Deci, 2017). Wearable fitness gadgets, such as the heart monitor, further aid in presenting physiological data to exercisers so that they may make more informed training adjustments to obtain the best results for themselves and therefore feel more satisfied with the workout experience (Michie et al., 20O9). As for students who are pressed for time and don't have the same schedule week in and week out, students are clamoring for the ease and flexibility offered by app and on-demand HIIT classes.

In addition, individualized HIIT programmes delivered via algorithms on mobile phones can also help to sustain adherence and reduce risk by adjusting the intensity and format of exercise to personal levels of fitness. This personalized approach is expected to decrease the risk of injury and of demotivation, two aspects that are frequently found to hamper physical activity maintenance in the long run (Kessler et al., 2012). In addition, social technology creating social support and responsibility sharing, using virtual communities, online discussion forums, and group challenges enhance the psychological outcomes of group exercise even in remoteness (Smith, Firth, et al., 2015). Now that immersive tech, such as virtual reality (VR) has been added to the mix, we're beginning to see unique and fun ways of experiencing HIIT, especially for those who had difficulty getting used to traditional exercise modes. These aids decrease psychological barriers, such as boredom, perceived exertion, that would otherwise hinder regular engagement. At the same time, the privacy and control that home workouts via digital platforms afford students allows them to work out in safe and comfortable spots, unlike public gyms where body image problems and social awkwardness can discourage them. Technology-facilitated HIIT is not without challenges, despite its promise. Student's populations can be marginalized because of accessibility and cost, or digital literacy inequalities. In addition, dependence on virtual formats could limit the real-life interactions that nourish us and/or cause tech fatigue. Therefore, opening any academic-based effort that uses technology for promotion of HIIT should be cognizant of these issues and strive towards interest, supportive and ethically designed interventions.

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