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What is the relationship between vigorous physical activity and physical and mental health indicators in young adults?

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What is the Relationship Between Vigorous Physical Activity and Physical and Mental Health Indicators in Young Adults?

by

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Thesis

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Abstract

Young adults (18-24 years) are only slightly older than adolescents but are encouraged to follow adult physical activity (PA) guidelines. PA guidelines for adults do not specifically recommend regular vigorous-intensity PA (VPA), unlike guidelines for adolescents. This thesis aimed to conduct a systematic review to ascertain the influence of VPA on anxiety, body mass index [BMI], and blood pressure [BP] in young adults. Literature searches were conducted in PubMed, CINHAL, and MEDLINE. After applying inclusion/exclusion criteria and removing duplicates, 21 studies were reviewed (6 for anxiety, 10 for BMI, 8 for BP). The reviewed studies indicate that VPA can reduce BMI and BP in young adults (although the findings were heterogeneous). The effect of VPA on anxiety was unclear. Evidence on the benefits of VPA for young adults is limited and the findings are inconsistent. Further research is needed to determine whether VPA should be specifically recommended to young adults.

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Chapter 1: Introduction

At a time when life expectancy has drastically dropped (Centers for Disease Control and Prevention [CDC], 2018), focus has begun to be placed on factors that are likely to support not just a long life but a quality life as well. One of the factors that has gained increased attention is physical activity (PA), which has been proven to contribute to an enhanced quality of life (Rodríguez-Fernández et al., 2017). A number of research studies have supported the effectiveness of PA for improving people's health and quality of life. For example, PA has an effective role in modifying risk factors for cardiovascular diseases, such as high blood pressure, obesity, abnormal blood lipids, and irregular blood glucose level (Green et al., 2008). PA has proven beneficial when a person does it consistently, especially from a young age (Twisk, 2001). PA has been adopted in fields such as medicine to promote the general well-being of patients and even in corporate management to promote employee productivity and well-being. Exercise is beneficial to people of all ages (CDC, 2020b) and is therefore recommended across the lifespan.

Due to an increase in the amount of time people spend sedentary (Owen et al., 2010), exercise has become more important especially among the young generation who often have to work for long hours in offices and may not have time to engage in even a small amount of PA. Global population statistics show the number of young people is significantly increasing, making them a major target of public health concern (Beets et al., 2011). It is, therefore, crucial to provide the public with accurate health recommendations regarding the volume of PA that benefits their health. Emerging research suggests that vigorous physical activity (VPA) affords superior health benefits over light physical activity (LPA) and moderate physical activity (MPA) (Aadland, Andersen, et al., 2018), especially when carried out regularly (American College of Sports Medicine., and Pescatello, L. S., 2014).

Overview of the Problem

People in different stages of life need different amounts of PA to optimize their health and well-being. For example, higher amounts of PA are crucial during childhood and adolescence for building healthy and strong bones (2018 Physical Activity Guidelines Advisory Committee, 2018) as individuals during these stages are still growing and getting taller. The World Health Organization (WHO) has published PA guidelines for different age groups to support people in improving and maintaining their health and well-being. Specifically, the WHO recommends that children aged 5-17 years should engage in at least one hour of moderate-to-vigorous physical activity (MVPA) on a daily basis (equivalent to 420 minutes per week) and VPA on at least three days of the week. For individuals aged 18-64 years, WHO recommend 150 minutes of MPA or 75 minutes of VPA across the week, and unlike for youth, there is no specific recommendation for adults to regularly engage in VPA. Based on these age-specific guidelines, it follows that when an individual turn 18, the amount of PA they need to achieve changes suddenly (i.e., overnight). In fact, the current activity recommendation for an 18-year-old is less than half of that of a 17-year-old, and the recommendation to regularly engage in VPA is also removed for 18-year-old individuals.

Physical and psychological development is not fully complete at 18 years old, and as such, this creates questions about the appropriateness of the current adult PA guidelines for young adults (18-24 years old). Studies support the effectiveness of PA for growth and development. A positive association has been found between PA and bone strength. High bone mineral density is one indicator of good bone quality (Epstein, 2005). The importance of PA for increasing bone mineral density has been suggested in many studies of children and adolescents. Peak bone mineral density is achieved during adulthood (Dunford & Doyle, 2014). Therefore, it is advisable for 18-24 years old to keep exercising to maximize gains in bone density. In addition to the ongoing physical development occurring after age 17, during the transition from adolescence to adult life one is often faced with many challenges and an increased amount of responsibility. This includes trying to begin a new independent life away from parents, dealing with schoolwork for college students, and handling a busy work schedule for those with jobs. The effects of increased freedom, responsibility, and stress can lead young adults to engage in high-risk behaviors that negatively influence their health such as, drug and substance abuse, excessive alcohol drinking, and cigarette smoking.

Regular PA has been shown to alleviate stress and improve mental health. For example, Burg et al. (2017) found an inverse relationship between stress and exercise among young adults. In addition, low PA is associated with psychological conditions such low self-esteem and self-worth. As such, PA may be a more adaptive, positive strategy for young adults to help them pass through this tough time with greater ease. In fact, a previous study examining undergraduate students reported that students who engaged in VPA were less likely to report poor mental health compared to their counterparts who did not (Vankim & Nelson, 2013). As such, it is clear that PA has a lot of potential value for young adults as they are going through intense social changes and achieving the optimal amount of PA might help them navigate this difficult period of life and support their long-term health. It is therefore important that the PA recommendation for this age group is correct, and as such, it is worth exploring the sudden change in the quantity of PA currently recommended for young adults, given that they are similar in age to adolescents who are encouraged to follow a very different PA guideline.

Furthermore, recent research suggests that higher intensity PA (VPA) has superior health benefits (compared to MPA) for children and adolescents. For example, Aadland, Kvalheim, et al. (2018) reported better metabolic health for those who engaged in VPA compared to those who reported lower intensities of PA. Similarly, a significant impact on psychological well-being among first-year college students was reported for those who did more VPA. In another study, VPA showed more influence on reducing body mass index (BMI) compared to MPA (Schwarzfischer et al., 2017). Collectively, these studies highlight the significance of VPA for improving health outcomes among young people. It is therefore reasonable to question how appropriate it is that young adults (18-24 years old) are encouraged to follow the adult PA guidelines, which do not stipulate the need for regular engagement in VPA.

In summary, the literature indicates that individuals who do more VPA are less likely to show poor health results. While these results are valuable, many of the studies were focusing on children, or adolescents, rather than young adults. Indeed, young adults are not much older than adolescents, and they might also benefit from regular VPA. However, it is not appropriate to speculate that the relationships among one age group will be the same for another. As a result, it would be helpful to review the available literature that has explored relationships between VPA and health outcomes among young adults in order to inform public health recommendations.

Need for Study

Young adulthood (18-24 years old) is a vulnerable life period where an individual is changing physically and mentally. Young people are more likely to have to make several adjustments in life plans, career plans, and social responsibilities. The role of high-intensity exercise appears to be effective in reducing negative health and well-being factors among youth, but less attention appears to have been paid to young adults. Young adults are not much older than adolescents but are encouraged to follow a very different set of PA guidelines (which do not stipulate the need for regular VPA), and which may not be optimal for their health and development. Therefore, there is need to carry out research to assess the association between VPA and health indicators among young adults.

Statement of Problem

This study will investigate the association between VPA and physical and mental health indicators among young adults (18-24 years old).

Research Question

Based on currently available evidence, what is the relationship between vigorous-intensity physical activity and (a) body mass index, (b) blood pressure, and (c) anxiety, in young adults (18-24 years)?

Hypothesis

Young adults who engage in more VPA will have a lower body mass index, lower blood pressure, and fewer anxiety symptoms when compared to those who engage in less VPA. (Moderate-intensity PAs are those that require 3-6 METs (metabolic equivalent) while vigorous-intensity PAs require 6 or more METs.)

Chapter 2: Literature Review

Importance of Health for Young People

The WHO (n.d.-a) has defined adolescence as being between the ages of 10 and 19 years, and youth as between 15 and 24 years. Globally, young people make up about one-fourth of the population (Gupta et al., 2014). Their health can be the foundation for global health improvement in a way that focusing on an individual's health in this early period sets a baseline for future adult health. For example, a negative behavior like smoking could develop into a very serious health issue, especially when smokers begin at young ages—it can become a lifelong habit that is increasingly difficult to change. In addition, when people in younger age groups engage in a positive behavior, it is an investment in their health for later in their life. The impact is not only on themselves but also on the future generation and their productivity in the community. Healthy people benefit their society in economic terms and by decreasing the spread of threatening diseases and protecting public health. As such, establishing healthy behaviors at a young age provides a great chance to improve health in both childhood and later life.

Compared to adults, young people are easier to influence and able to change (Gwon & Jeong, 2018). Indeed, this period of age is critical as it includes the developmental transition from childhood to adulthood. During this transition, young people go through intense periods of change, which include physical, sexual, psychological, and social developmental changes. Facing all of these simultaneous challenges may lead to issues with their health and well-being. According to the WHO (n.d.-d), 50% of lifelong mental disorders emerge by age 14, and 75% emerge by age 24.Youth is also a time of emotional lability, in which depression and anxiety can occur frequently, and as reports have shown, one in five adolescents suffers annually from psychological problems (Office of the Assistant Secretary for Planning and Evaluation, US

Department of Health and Human Services., 2016), with anxiety and depression being the most common (Office of Population Affairs, US Department of Health and Human Services., 2017).

In the United States (US), the average age of students when they start attending college is 18. This is a time of life when individuals experience significant changes physically and psychologically, which are reflected in behavioral changes. For example, research has provided a list of the most common negative behaviors among college students, which include eating an unhealthy diet, cigarette smoking, and physical inactivity (Calamidas & Crowell, 2018). Results of this study also demonstrated the leading factors that cause youth to engage in these unhealthy behaviors. Students who were more worried and under stress, had busy schedules at work or school, and lacked a network of supportive friends and families were more likely to be physically inactive, gain weight, and have poor eating habits. However, the study also mentioned the most common ways to break these bad habits, as identified by the students. All kinds of sport and exercise had the highest percentage rate of engagement for the students, followed by improved healthy eating habits (Calamidas & Crowell, 2018).

It is important to help young people to develop healthy behaviors and lifestyles for several reasons. First, a large portion of the population is comprised of young people. Second, they are vulnerable and amenable to change during this period of life. Therefore, factors and behaviors that can prevent the development of poor health must be identified.

Benefits of Physical Activity for Health

Low levels of PA in young people have been associated with increased risk for a range of chronic diseases such as obesity, cardiovascular diseases, certain cancers, and poor mental health (Centers for Disease Control and Prevention., 2019b). According to the WHO (n.d.-c), an adequate level of PA improves muscular and cardiovascular fitness, and reduces the risk of hypertension, coronary heart disease, diabetes, and depression. In addition, physical activity has been associated with psychological benefits in young people by reducing their anxiety and depression symptoms (Larun et al., 2006a). Thus, it is widely accepted that PA has significant health benefits among youth and adults. Further, physical activity interacts with the aging process and influences how physical function and health care needs change as people get older. Inadequate PA is associated with increasing health care expenditure (Carlson et al., 2015). Health care costs rise slowly throughout an individual's life and are related to lower PA and higher BMI. For example, when adults reported an inadequate level of PA, health care expenditure increased by an estimated 11.1% (Carlson et al., 2015). Therefore, PA is extremely important in reducing the risk of several health issues.

In addition, scientific evidence relates the effect of sedentary behavior to serious health consequences during young adulthood. For example, increased sedentary behaviors are associated with increased risks of obesity. According to the study was conducted by Laurson et al. (2008), adolescents who reported that more than 2 hours of daily screen time were almost two times more likely to be obese and overweight, while others have reported even higher odds of being overweight for those who do not follow the recommended amount of screen time. More health risks were reported in a study by Hancox et al. (2004) that demonstrated those who watched television for more than 2 hours in childhood and adolescence had a higher body mass index (BMI), lower cardiovascular fitness, and higher cholesterol levels (Hancox et al., 2004). In the US, obesity prevalence among 12-to 19-year-olds was 20.6% (Centers for Disease Control and Prevention., 2019a). Obesity is a complex health issue that increases young people's risk of multiple conditions such as high blood pressure and high cholesterol, which are risk factors for cardiovascular diseases, impaired glucose tolerance, respiratory problems, and cancer (Centers for Disease Control and Prevention., 2020c). In addition, overweight young people are more likely to experience low self-esteem, which is associated with poor self-image and could increase the incidence of mental health problems (Sans et al., 2018). Considering all these facts, young people should establish a healthy behavior pattern (sufficient PA and low sedentary behavior) to obtain an improvement in their life quality and protection from serious health conditions in adulthood.

With all that being said, replacing sedentary behavior with LPA can result in improved health and quality of life in for children, adolescents, and adults. Examples of light activity include walking, cooking, and washing dishes. Less time spent in sedentary behavior and more in low-intensity activity was associated with a lower BMI (Bann et al., 2015). Additionally, LPA has been shown to have beneficial effects on lowering cardiovascular risk factors (Khoja et al., 2016). As has been reported in prior research, those who reported higher engagement in LPA showed better levels of biological markers, such as insulin and triglycerides, than those whose sedentary behavior time exceeded time spent in LPA (Loprinzi et al., 2014).

Previous evidence supports the effects of regular PA on promoting health, which can be achieved from a reduction in sedentary behaviors and augmentation of different activity intensities. Physical and mental health benefits result from engaging in PA. In addition to promoting health, decreasing heath care expenditure in the US can result from people engaging in sufficient amounts of PA from a younger age. Therefore, it is essential for young people to choose the right lifestyle options. Developing good behaviors earlier is an important factor to promote health later in life.

Physical Activity Levels of Young People

According to the CDC (2017), only 23% of adults in the US (over 18 years old) meet national PA guidelines. However, it has been established that the pattern of PA dramatically declines with increasing age in men and women. This has been explored in several US surveys. For example, 39% of young adults aged 18-24 years did not achieve a sufficient level of PA, and the percentage of insufficiently active adults was higher among adults aged 25-34 years—it reached 46% (O'Dougherty et al., 2009). In addition, almost 50% of American youth aged between 12 and 21 years are not regularly engaging in VPA (CDC, 1999). Based on a National Health Interview Survey, the overall annual reduction trend from 2008-2018 in meeting the PA guidelines among adults over 18 years is 0.9% (Centers for Disease Control and Prevention., n.d.-b). In addition, inactivity was higher among females than males. Data from the 2007 National Health Interview Survey shows that 67% of women aged 18–24 years reported insufficient amounts of leisure time PA, compared to 59% of men (O'Dougherty et al., 2009). Over the past 10 years, 81% of adolescents aged 11-17 years across the world were classified as insufficiently active (World Health Organization., n.d.-f). In Europe, the level of PA in both genders declined with age, and girls were less likely to be engaged in PA than boys (Armstrong & Welsman, 2006). In addition, 78% of children and youth are not meeting the recommended amount of activity in the US (2018 Physical Activity Guidelines Advisory Committee, 2018). In addition, sedentary behavior in the young population has increased in recent years. In 2018, the American Heart Association estimated that youth spend an average of 6.6-8.6 hours engaged in sedentary behavior per day. As children progress into adolescence, they use computers more and engage in less MVPA (Nelson et al., 2006).

PA during adolescence may directly influence PA in adulthood. However, not many studies have investigated the association between PA in adolescence and adulthood, as it requires a long period of follow-up time. A cohort study that evaluated the associations between adolescent's participation and adult PA found that female participants who engaged in PA at least once a week were more likely to be active later in life (Tammeline et al., 2003). In addition, the findings of some studies suggest that the transition from childhood to adolescence, and then to young adulthood are associated with a decline in PA. For instance, a cohort study suggested that MVPA during adolescence was 30 minutes per day lower than during childhood, and MVPA during young adulthood was 13 minutes lower than in adolescence, with a larger drop found in boys than girls (Ortega et al., 2013). These results were also in line with another longitudinal study, which demonstrated that maintaining a specific type of PA significantly decreased between the ages of 13 and 23, with greater reduction seen among males than females (Kjønniksen et al., 2008). Similarly, in the Amsterdam Longitudinal Growth and Health Study, the time spent in PA dropped by 42% in males and 17% in females between the ages of 13 and 27 (Van Mechelen et al., 2000).

Global evidence suggests that the majority of young people are not sufficiently active and that PA levels decline through childhood, adolescence, and into young adulthood. The evidence for the difference in activity reduction among males and females is varied. Public health promotion efforts need to target young people, in order to support their healthy growth and development. Part of the PA promotion effort among young people should focus on increasing the proportion of them that meet national PA guidelines, which outline the volume of activity needed to optimize health.

Physical Activity Guidelines

National PA guidelines recommend that adults should engage in at least 150 minutes of moderate-intensity PA (MPA), or 75 minutes of vigorous-intensity PA (VPA) per week. At present, the youth PA guidelines specify that youth should engage in MVPA for 60 minutes daily and that they should engage in VPA on at least 3 days of the week (the duration component for VPA is not specified). As such, it is clear that the recommended amount of PA for individuals is different based on their age. Children are encouraged to (a) engage in more exercise than adults and (b) to regularly engage in VPA (whereas adults aren't), as PA and VPA enhance their development physically and mentally and increase the likelihood of better health as they get older. The PA guidelines for youth and adults are based on large bodies of evidence exploring the relationship between PA and various health outcomes. Some of the evidence that underpins the youth guidelines is outlined in the following paragraph.

Early engagement in MVPA has effects on bone health. This was successfully established as described by Janz et al. (2010), who found bone mass content increased by 4-14% at age 8-11 years in those who engaged more in MVPA at age 5. Further to this, some authors have specifically explored the relationship between bone development and engagement in higher intensity PA. Research has provided evidence that more time spent in VPA is associated with increasing bone strength (Herrmann et al., 2015). Daily engagement in VPA for 40 minutes in children significantly increased the strength of bone. In addition, bone stiffness increased by 2% for an additional 10 minutes of VPA per day (Herrmann et al., 2015). These results support the importance of high intensity PA for the health of children and to optimize their growth. Therefore, exercising during growth plays a fundamental role in the healthy bone development of young people.

Intensity, frequency, and duration are three descriptive components of the PA guidelines. The *intensity* of PA refers to how physiologically challenging/demanding the activity is, the *frequency* component refers to how many times per week PA is carried out, and *duration* refers to the length of each PA session/bout. Each of these components has been described in the guidelines established by the American College of Sports Medicine (2014). In an effort to identify the most appropriate public health recommendation, research studies have attempted to identify the role that each of the descriptive components has on health–for example, when total volume of PA held constant, greater health benefits were found among those who accumulated PA on 3 or more days per week than who accumulated a same volume on 1 or 2 days per week (2018 Physical Activity Guidelines Advisory Committee, 2018). Wang et al. (2018) reported that a reduction in depression prevalence for those who exercise three times per week compared to their counterpart who exercise in lower frequency (one or two times per week). Moreover, some studies have reported that intermittent physical exercise elicits better health outcomes than a continuous bout. A study by Park et al. (2006) found that four 10-minute intervals of PA at a moderate intensity (50% VO_2max) were more effective in reducing blood pressure (BP) than those who did single sessions of 40 minutes of PA among prehypertensive people. Similarly, a greater effect on blood lipids was achieved through accumulated bouts of exercise compared to a single continuous session of similar intensity (Mestek et al., 2006).

An individual's weekly volume of PA is calculated by multiplying the PA frequency and duration by MET values (an indicator of activity intensity). Performing activities of a higher intensity will result in an individual achieving the recommended volume of PA faster. According to current evidence base, total volume of PA achieved is the key determinant of health outcomes–regardless of how the activity volume was achieved (all on one day or spread across the week, at a high or moderate intensity). For example, among adults several studies assert that 30 minutes of MVPA on 5 days per week is acceptable to get health benefits. Splitting these 30 minutes into three 10-minutes sessions per day was found to have similar results to a single continuous 30-minute episode. However, a consideration is that acute health benefits can be driven by a single session of PA. For example, anxiety attacks might be relieved immediately following exercise (Boutcher & Landers, 1988). Therefore, a greater frequency would be more beneficial.

The current PA guidelines for youth and adults are based on the highest quality available evidence. However, the evidence base is far from complete–the Physical Activity Guidelines Advisory Committee (2018) recently identified many areas where further research was needed in order to better inform the PA guidelines. It is important that researchers continue to answer questions regarding the optimal volume, frequency, intensity, duration, and type of PA for health benefits for both adults and youth.

Youth vs. Adult Physical Activity Guidelines

As it has been highlighted, the recommended volume of PA differs for adolescents and adults. The PA recommendation for adults (18 years and older) is 150 min per week of MPA or 75 min per week of VPA. Thus, the daily adult recommendation for PA is 20 min of MPA or 10 min of VPA (if the weekly recommendation is divided equally across 7 days of the week). This amount is much lower than the 60 minutes of MVPA per day, which is the amount that youth (5-17 years) should accomplish in order to gain optimum health benefits. As such, when an individual's age changes from 17 to 18 years, the required amount of MVPA suddenly (i.e., overnight) decreases to less than half of the youth recommendation. In addition, the adult guidelines do not stipulate the need to engage in VPA regularly. As previously highlighted, young adults (18-24 years old) face a number of psychological and social challenges and ongoing physical development. For example, peak bone mass is achieved between mid-20's late 30's, and in general, higher bone mineral density is seen in young adults who are physically active at high intensities than in sedentary adults. PA can support the ongoing physical and psycho-social development of young adults, so it seems reasonable to question the appropriateness of the substantial change in recommended PA intensity and duration for this demographic.

The positive influence of VPA for adolescents' health has been mentioned in several studies; these findings may extend to the young adult demographic, given their proximity in age to adolescents. For example, researchers found greater improvement in blood lipids and waist circumference in obese adolescents after 12 weeks of high intensity interval training (HIIT) compared to moderate-intensity interval training (Racil et al., 2013). Also, adolescents who engaged in high-intensity exercise reported less stress and fewer depressive symptoms than those who engaged in moderate-intensity exercise (Norris et al., 1992). To my knowledge, there are few published studies that explore the benefits of VPA on mental health among young adults which is quite surprising as mental health is an important aspect to consider for young adults. However, based on the findings of previous studies, the beneficial effects of VPA for youth and adolescents suggest that we might expect young adults to experience similar benefits (since young adults are slightly older than adolescents)–even though the current PA guidelines do not recommend regular engagement in VPA.

Vigorous Physical Activity

The most common unit used to report the rate of energy consumption needed to perform any PA is the metabolic equivalent (MET). One MET equals 3.5 milliliters of oxygen uptake per kilogram per min—for most people, this is the rate of oxygen consumption while sitting at rest (Jetté et al., 1990). As the intensity of any activity increases, the number of METs (i.e., the oxygen consumption required to support that activity) also increases. Moderate-intensity PAs are those that require 3-6 METs while vigorous-intensity PAs require six or more METs. Percentage of maximal oxygen consumption (VO_2max) is another method for describing the intensity of PA. Moderate-intensity exercises refers to activities that elicit a VO_2 between 40% and 60% of VO_2max, whereas vigorous-intensity exercise elicits a VO_2 that is $\geq$ 65% of VO_2max. Because people are not familiar with MET units and don't typically have equipment to measure VO_2max, a simpler tool has been used to help individuals self-assess activity intensity, which is called the "sing-talk test." During moderate-intensity PA most people able to talk but not sing while during activities of vigorous-intensity they are not able even to talk. In summary, vigorous-intensity PA requires more energy and more aerobic capacity (2018 Physical Activity Guidelines Advisory Committee Scientific Report, 2018).

Even though moderate- and vigorous-intensity physical activities are beneficial for overall health, several studies suggest that VPA might afford superior health benefits to MPA. For example, higher intensity PA has been associated with greater improvements in cardiorespiratory fitness (Drenowatz et al., 2016). There are various physiological factors involved in this improvement such as increases in muscle mitochondria capacity and GLUT 4 (glucose transport protein) which are unlikely to happen with MPA (Little et al., 2010). Regarding metabolic function, high-intensity activity is efficient at enhancing lipid and glucose metabolism and consequently insulin sensitivity (Racil et al., 2013) and blood lipid profile (Kemmler et al., 2014). It has also been found that the risk of cardiovascular disease and all-cause mortality are reduced by 8-17% with every one MET increase of aerobic capacity

(Drenowatz et al., 2016). As VPA provides a greater stimulus for physiological adaptation, it elicits superior health outcomes.

The importance of VPA for children and adolescents has been highlighted in several research papers and is stipulated in their PA guidelines. For example, a review by Hay et al. (2012) suggests that only VPA was consistently associated with lower waist circumference, BMI, and systolic blood pressure (SBP), and increased cardiorespiratory fitness in youth (Hay et al., 2012). In addition, VPA might be essential in decreasing the possibility of being obese. This was explored in a recent study by Martinez-Gomez et al. (2010) which found that 10-20 minutes per day of VPA might have a major benefit in reducing body fat during adolescence. In contrast, a study by (Gutin et al., 2002) did not have evidence to support the effectiveness of high-intensity training over moderate-intensity training in enhancing body composition when they compared both intensities in 13 to 16 years old obese individuals. However, they found that cardiovascular fitness was significantly increased by high-intensity training (Gutin et al., 2002). Also, no difference between the two intensities was found with regard to improving insulin sensitivity and hepatic triglycerides in overweight adolescents (Hay et al., 2016). The importance of VPA in children and adolescents is evident, but less attention has focused on whether VPA provides pertinent health benefits to young adults (18-24 years old), given that their age is similar to that of adolescents.

Some examples of research exploring the health benefits of VPA among young adults come from work carried out on university/college students. Most of these studies focus on the impact of PA on psychological health among undergraduate students. For example, first-year university students have been examined to assess the relationship between VPA with psychological health and illness. The result was that students who did more VPA had better psychological well-being (Bray & Kwan, 2006). In addition, students who spent more time in vigorous exercise were less likely to have poor mental health (Vankim & Nelson, 2013). These findings support the potential value of encouraging young adults to engage in regular VPA. However, only one in every four college students aged 18-20 years meet the PA recommendation of 150 minutes of MPA every week (Grasdalsmoen et al., 2019).

In summary, young adults are only slightly older than the age range addressed by the youth PA guidelines, but their PA recommendation is much lower. Evidence suggests that VPA may provide potent health benefits to young adults (as it does for children and adolescents), but there is limited research exploring whether VPA is particularly beneficial for them. It would be helpful to identify and summarize literature that has examined the relationship between VPA and health outcomes in young adults, so that we can ensure we are providing the appropriate public health recommendations.

Vigorous Physical Activity and Specific Health Outcomes

There are many important health outcomes that can be explored in relation to VPA–it is not feasible to examine all of them within this thesis. To ensure I can complete this project in a reasonable time frame, I will be focusing on three important health indicators and their relationship with VPA among young adults: BMI, BP, and anxiety. Below I have provided a summary of some of the existing literature exploring the relationship between VPA and these three selected health outcomes.

Vigorous Physical Activity and Blood Pressure

Hypertension, defined as systolic blood pressure (SBP) of 130 mmHg or higher, or diastolic blood pressure (DBP) of 80 mmHg or higher, affects more than 1 in 7 youth aged 12 to 19 years in the USA (CDC, 2020a). It is expected that the number of people who will be diagnosed with hypertension in the future is going to increase. Childhood obesity prevalence is increasing (World Health Organization., n.d.-e) and obesity is a risk factor for hypertension (Jiang et al., 2016). When a risk factor shows up at younger age, most probably it will carry over to adulthood (Shrestha & Copenhaver, 2015). Therefore, the presence of childhood hypertension increases the risk of adult hypertension (Tsioufis et al., 2011). Many people only know that they have high blood pressure when they develop symptoms with their heart, kidneys, or brain. Hypertension is the most common chronic disease (Kitaoka et al., 2016) and associated with increased risk of coronary artery disease, renal failure, heart failure, and stroke (World Health Organization., n.d.-b).

Even though there is no cure for hypertension, medications and healthy lifestyles are possible ways to reduce the risk of high blood pressure and prevent health problems related to hypertension. Half of hypertensive people who only use drugs to manage their BP do not have their hypertension under control (CDC, 2020a). Healthy lifestyles support the effectiveness of BP medication (Nicoll & Henein, 2010), delay the development of hypertension (American Heart Association, 2017) and reduce risk of heart disease, renal failure, and stroke (American Heart Association, 2017). Quitting smoking, eating a healthy diet, losing weight, limiting alcohol consumption, and exercise are all examples of healthy behaviors. According to the American Heart Association (2017), these lifestyle modifications reduce BP in hypertensive people by approximately 4 to 11 mmHg. British Hypertension Society (BHS) guidelines state that lifestyle modification can reduce BP by at least the same amount as one antihypertension drug (Nicoll & Henein, 2010). Changing PA and diet in particular have been shown to be effective (Whelton et al., 2018).

Due to the inverse relationship between BP and cardiovascular health, many scholars investigated the effectiveness of increasing PA on high blood pressure. According to the WHO, exercise on a regular basis plays an important role in protecting individuals against hypertension and all-cause mortality (Organisation mondiale de la santé, 2014). It is the first choice recommended by health care providers to people with hypertension (Pescatello et al., 2015). In addition, it can lower BP in pre-hypertensive people (Pescatello et al., 2019). A number of authors have explored BP responses to various exercise characteristics such as different exercise frequencies, durations, and intensities. For example, youth showed greater cardiovascular benefits when they engaged in MVPA and VPA, as compared to lighter intensities (Carson et al., 2014). A recent cross-sectional study conducted in 6-17 years old reported that SBP significantly reduced by 4.11 mmHg for youth who spent 13% of accelerometer wear time in MVPA (accumulating an average of 1,154 counts per minute; Jenkins et al., 2017). Similarly, a cohort study found a significant reduction of SBP by 1.15 mmHg for every 100 metabolic equivalent (MET) hours of PA (Gidding et al., 2006). VPA demonstrates an inverse relationship with elevated blood pressure in children with cerebral palsy (Ryan et al., 2014). In addition, another study reported that the odds of elevated SBP declined by 36% when children achieved more than 7 minutes of daily VPA, but no relationship was found between BP and light or moderate PA in adolescents (Hay et al., 2012). Interestingly, Tsioufis et al. (2011) found that VPA was directly related to elevated blood pressure and even to the prevalence of hypertension among 12-17 years old Greek students. Tsioufis and colleagues concluded that MPA each day would avoid increased BP among participants. Very few studies have examined engagement in different intensities of PA and BP among young adults. However, the available literature for younger youth demonstrates the benefits of VPA.

An increasingly common way to engage in VPA is through high-intensity interval training (HIIT). HIIT is defined as "alternating periods of brief, very high-intensity aerobic exercise separated by recovery periods of lower intensity exercise or rest" (Pescatello et al., 2015,p. 5). Several studies have supported the superior benefits of HIIT over moderate-intensity continuous training (MICT) for decreasing BP. For example, a study was conducted on 28 male participants aged between 18-45 years who had BMI higher than 25 kg/m^2; the aim was to investigate the effect of a six weeks exercise intervention on BP. One group of participants took part in moderate-intensity exercise (MICT), and another group took part in high-intensity exercise (HIIT). The main findings were that a 3-5 mmHg greater reduction was observed in overweight and obese individuals in the HIIT group compared to the MICT group. The reduction was more noticeable in those with a higher baseline BP (Clark et al., 2020). However, these findings were not matched with other studies that found no statistically significant differences between HIIT and MICT for DBP. Moreover, a greater reduction in SBP was found for MICT when compared to HIIT (Arboleda-Serna et al., 2019). It is possible that methodological differences between Clark et al. (2020) and Arboleda-Serna et al. (2019) contributed to the different findings. For example, the length of the intervention and the duration of each training session were different. In the study by Clark and colleagues, the HIIT intervention lasted 6 weeks and each session was comprised of 10 minutes intervals at 90-100% peak heart rate, while the MICT group completed 30 minutes of exercise at 65-75% peak heart rate. However, the intervention duration in Arboleda-Serna et al. (2019) was 8 weeks and involved a lower volume of HIIT (15 bouts, each lasting 30 seconds), and an additional 10 minutes per session in the MICT group. In addition, even though the participants in both studies were in the same age group, they were healthy in the Arboleda-Serna et al. (2019) study, with normal BMI and normal

BP, compared to the participants in the Clark et al. (2020) study, who were overweight or obese. Also, the exercise mode in the two studies was different—cycling was used in the Clark et al. (2020) study and treadmill exercise was used in the Arboleda-Serna et al. (2019) study. Therefore, maybe these differences are reasons for the differences in the findings of the two studies.

Consistent with the results of previous studies, Farah et al. (2014) also conducted a study with 43 obese adolescents aged between 13 and 18 years to compare the effects of various exercise intensities on BP and heart rate. The subjects were randomized into two groups, high-intensity aerobic exercise training (HIT) and low-intensity aerobic exercise training, three days per week for a period of 6 months. By the end of the intervention, it was found that both groups had the same reduction in BP, but that HIT showed more beneficial effects than lower intensity exercise.

Based on ACSM (2019), individuals who were more willing to engage in vigorous physical intensity had greater reduction in BP. However, not many studies specifically compared VPA and other intensities when assessing the relationship between VPA and BP among young adults. This is the case even though some studies support the superiority of HIT to MICT in lowering BP among younger youth.

Vigorous Physical Activity and BMI

Screening an individual's height and weight provide indications of health and wellbeing. One way to assess someone's body fatness is by calculating their BMI—which is defined as a person's weight in kilograms divided by the square of height in meters (CDC, 2019). Overweight is defined as BMI of 25 kg/m^2 or higher, while obesity is defined as BMI of 30 kg/m^2 or higher according to the CDC. Globally, obesity is an epidemic and the number of cases is predicted to rise steadily in the future. In 2016, the number of overweight cases around the world was around 2 billion among adults over the age of 18 years, and more than 500 millions of those cases were obese. In the USA, the prevalence of obesity is 40% among young adults aged 20 to 39 years (CDC, 2020c). Unfortunately, children and adolescents are not far away from what has been reported among adults. The prevalence of obesity and overweight among children and adolescents aged 5 to 19 years has significantly increased from 4% to more than 18% between 1975 and 2016. The proportion of obese adolescents in the US was around 20.6% among 12-to-19-year-olds. The probability of obesity in adulthood is higher when it is diagnosed during childhood or adolescence (Lee & Yoon, 2018).

Many risks have been associated with obesity that affect organs that are essential for living. For example, the kidneys can be affected because of the excessive fat in overweight/obese individuals. Also, the heart can be damaged, as it has to pump harder to supply a larger body with required blood. Together the heart and kidneys are essential for regulating BP. Therefore, the prevalence of hypertension is higher among people with a high BMI. Other health issues associated with obesity including high cholesterol, high blood sugar, and some types of cancer (National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK]., 2018).

The risk of becoming overweight is significantly increased by spending more time in sedentary behaviors (Schwarzfischer et al., 2017). Three hours of screen time per day increased the likelihood of gaining weight among girls aged 13 years (Hume et al., 2009), and this risk was five-fold higher when screen time increased to more than three hours. In contrast, PA is associated with weight loss and obesity prevention; many studies have shown successful prevention of weight gain through exercise adherence. The Department of Health and Human Services in the USA report that PA is divided into two parts: baseline activity and health enhancing activity. Sedentary behaviors and LPA are considered baseline activity and many of an individual's waking activities such as standing or walking slowly are considered LPA. Compared to engaging in sedentary behaviors, engaging in LPA shows small health benefits, including a minor effect on BMI (Schwarzfischer et al., 2017). While LPA is associated with gaining less weight, sedentary behaviors are more positively related with overweight/obesity. This was successfully established by Schwarzfischer et al. (2017), who explored the effect of different intensities and durations of PA on BMI. Participants who performed 60 minutes per day of LPA, 15 minutes per day of MPA, or 5 minutes per day of VPA had similar changes in BMI. Similarly, those who performed 60 minutes of MVPA or MPA, or 15 minutes of VPA each day experienced similar changes in their BMI. Additionally, a healthy BMI in children aged 4 to 7 years is associated with daily engagement in MVPA (Schaefer, 2015). These findings suggest that PA of all intensities has a favorable effect on weight.

The influence of PA in adolescence on adult weight status had been examined in a cohort study. Participants in this study were in Grades 8 to 12. Their BMI were collected at baseline and 5 years later. The results indicated that the participants who engaged in PA more than two times per week may offset a BMI increase as they progress into adulthood. Accordingly, PA was noted as having a prevention effect on BMI rather than being a treatment for obesity. In addition, PA contributed more weight maintenance than excess weight loss (Menschik et al., 2008). Another cohort study showed the significant association between PA and change in BMI after 9 years of follow-up in participants aged 9-10 years (Kimm et al., 2005). The result was consistent with the finding of (Menschik et al., 2008) in that PA in adolescence played a preventive role in weight change during adulthood. Therefore, engaging in PA early in life can be a contributing factor of weight management years later.

Even though being physically active at any intensity plays a role in maintaining weight, VPA has been shown to have better results than activity at lower intensities. Schwarzfischer et al., (2017) provide support for this notion; their findings indicated that 15-20 min/day of VPA was an appropriate amount to reduce risk of obesity. Collings et al. (2013) concluded that every 15 min/day of VPA was associated with 0.36 reduction in body fat percentage. Consistent with the previous study, 12 minutes of daily VPA significantly predicted a lower body fat percentage among 8-11 years old boys and girls (Dencker et al., 2006). Collectively, these findings supported the significance of VPA in reduce the risk of obesity.

Other studies further support the effectiveness of VPA in reducing BMI. Hay et al. (2012) found an inverse association between VPA (but not MPA) and BMI in youth aged 9–17 years. In addition, Patrick et al. (2004) recruited a sample of 878 adolescents aged between 11 and 15 years to evaluate the relationship between VPA and BMI. Participants who engaged in an insufficient amount of VPA recorded a higher BMI than their counterparts. Additionally, Chiu et al. (2017) investigated the effectiveness of different exercise intensities in modulating body weight among 48 obese young adults. Participants were equally randomized into four groups: light-intensity training group, moderate-intensity training group, High-intensity training group, and control group. The researchers concluded that high-intensity training was more effective in changing body weight than lower intensity exercise. Similarly, Sijie et al. (2012) reported inverse association between high-intensity exercise and BMI. Using a sample of 60 female university students aged between 19 and 20, participants engaging in high-intensity training recorded better outcomes than their counterparts who engaged in moderate-intensity exercise as part of a program for treating young women who were overweight.

While VPA shows a positive impact on the management of body weight status, most of studies involving young adults in this topic investigated on the effectiveness of MVPA. A cohort study involving young adults aged 18-25 years examined the relationship between self-reported PA and body composition measured by dual-energy X-ray absorptiometry (DXA). The study found that the participants in the highest quartile of PA had a lower percentage of body fat, lower fat mass, and higher lean tissue mass compared with those in the least active quartile. In addition, a decline in exercise frequency with age was noticed in a study composed of college students aged 18 to 35 years. Compared to age 18 to 20 years, exercise frequency reduced by 18% in students above 29 years. This reduction in PA was associated with a significant increase in BMI. Students who had less frequent days of MVPA were more likely to have high BMI (Grasdalsmoen et al., 2019).

Evidence supports the effectiveness of VPA in preventing obesity and maintaining weight status among youth. While these studies are valuable, most of them involved children and adolescents. The relationship between VPA and BMI among young adults has not been fully explored as the available studies on this age group tend to focus on MVPA.

Vigorous Physical Activity and Anxiety

Students attending college may experience some level of anxiety. The large life change and new responsibilities that accompany the first year of enrollment at a university are a big challenge for some students. Bayram and Bilgel (2008) found that students in their first year and second year were more anxious than others. Mental health problems among this group of age have been increased year over year (Pedrelli et al., 2015). Anxiety and depression are the most common (Heckman, 2019; American Psychology Association, 2013). It has been reported that three out of four students experience overwhelming anxiety at some time (Heckman, 2019).

Body image perceptions have been studied in relation to anxiety among college students. Females at this age are more concerned with their body weight and appearance, and males are interested in increasing muscular tone and losing weight. Therefore, anxiety and body dissatisfaction and how PA can help to attenuate them have been discussed by several of authors. Korn et al. (2013) examined the relationship between PA and self and body perceptions among undergraduate students and found a positive influence of PA on self-esteem. PA is predicted to be associated with better mental health. It is generally believed that exercise can improve mood among healthy individuals (Szabo et al. 2013) and increase their mental health such that active people are least liable to develop psychological issues such as anxiety and depression (Sharma et al., 2006). Szabo et al., (2013) reported that people who engaged in VPA experienced a 50% improvement in mood. Also, the advantages of exercise were analyzed among patients with an alcohol disorder. Subjects who completed 12 weeks of moderate-intensity exercise had an improvement in mood and a reduction in anxiety compared to control group (Brown et al., 2016). Additionally, in a study that examined anxiety responses to an acute bout of exercise in adult participants aged 18 to 30 years, the beneficial effects of exercise on anxiety were shown in highly anxious individuals (Lucibello et al., 2019). Participants were randomized into a moderate-intensity exercise group and a control group for a period of 9 weeks. By the end of the intervention, a significant reduction in anxiety after exercise training was found, with a greater response in those who reported a high anxiety status at baseline (Lucibello et al., 2019). In addition, a study on non-clinically anxious college students reported similar results. Hale and Raglin (2002) compared the anxiety response to resistance and aerobic exercise following 8 weeks of training. No significant differences in the amount of anxiety reduction were found between both ways of training. However, the reduction in the anxiety after resistance training was only observed in students who had high-state anxiety, whereas students with high or low anxiety demonstrated a response to the aerobic exercise training.

The positive impact of VPA on the management of anxiety has been reported by several studies. Bray and Kwan (2006) investigated this relationship using a sample of 175 first-year university students. Participants who were involved in VPA recorded more positive psychological well-being than their counterparts. The importance of VPA on reduced levels of anxiety was further affirmed by VanKim and Nelson (2013). The researchers undertook a national cross-sectional survey involving 95 college students in the USA to examine the association between VPA and mental health. An in-depth analysis of the data showed that students who met the VPA criteria were less likely to register poor psychological health outcomes, including anxiety, stress, and depression. Morgan (1985) concluded that VPA was effective in reducing anxiety. The likelihood of developing anxiety is suggested to reduce by 25% for those who engage in VPA (Anxiety and Depression Association of America, n.d.)

Although regular PA has been found to reduce risk of anxiety, some studies showed no significant effect of exercise preventing anxiety. A meta-analysis of randomized trials investigated the effect of exercise as a therapeutic intervention for psychological health, including anxiety, among children and adolescents aged up to 20 years. The anxiety scores were not significantly different between those who engaged in VPA and those who did not. Similar outcomes were also found in a study by Larun et al. (2006), which indicated that participants who engaged in VPA showed no better results than those engaged in exercise at lower intensities. The same results were found among college students in China—no association was found between high-intensity PA and anxiety (Feng et al., 2014).

Among the available studies focused on relationship between PA and psychological health, especially in managing anxiety levels, findings turned out to be heterogenous. In particular, some of the studies suggested that VPA had the potential to address psychological challenges such as anxiety and stress, whereas other studies found no additional benefits of VPA in reducing risk of anxiety. The mixed findings between these studies indicate the need for an extensive literature search to clarify the relationship between VPA and anxiety among young adults.

Research Question

Based on currently available evidence, what is the relationship between vigorous-intensity physical activity and (a) body mass index, (b) blood pressure, and (c) anxiety in young adults?

Chapter 3: Methods

Literature Search Strategy

We performed a comprehensive computerized search of published literature using three databases (PubMed, CINHAL, and MEDLINE). Searching three databases is a recommended practice when carrying out a systematic review, to ensure as many relevant articles are identified as possible (Harris et al., 2014). In each database, we carried out three different literature searches—one to address each of our three questions (relating to (a) BMI, (b) blood pressure, and (c) anxiety). In addition to sourcing articles through the databases, the reference lists of included articles were reviewed and any relevant articles not sourced through the database searches were included.

Search Terms

The PICOS criteria (Participants, Interventions, Comparisons, Outcomes, and Study design) were used to guide the selection of search terms and inclusion criteria (Harris et al., 2014).The search terms are outlined in Table 1. The search terms (with alternative phrasings) were (a) “vigorous physical activity” (vigorous physical activity, vigorous exercise, high-intensity physical activity, high-intensity exercise, high-intensity interval training, high-intensity aerobic training), (b) “young adult” (youth, teenage, adolescent, college, university, young adult, adult), (c) blood pressure (hypertensi*, blood pressure), (d) body mass index (BMI, body mass index, obesity, overweight, weight status), and (e) anxiety (anxiety, stress, anxious, tense, tension).

Included studies focused on VPA, but finding articles that isolate the influence of VPA separately from MVPA was challenging—articles that explore the independent effects of VPA were likely to reference “MVPA” somewhere in their document. As the term v*igorous physical* *activity* is part of the term *moderate-to-vigorous physical activity*, we could not use the phrase "NOT moderate vigorous physical activity" in our searches, as the ones that focus only on VPA were likely be excluded too. To try and find the articles that focus on just VPA, we specified that our search terms need to be mentioned in the title or abstract of the article.

Inclusion Criteria

Each study needed to meet the following criteria in order to be eligible for inclusion (see Table 2 for database filters):

- one of the following article types: observational, longitudinal, cross-sectional, randomized control trial, any phase of clinical trial, multicenter study, comparative study, controlled clinical trial, journal article, pragmatic clinical trial;
- human participants;
- participants aged between 13 to 18 years, 19 to 24 years, or 19 to 44 years (depending on the database's available filters); and
- published in English or Arabic.

When possible, we used search filters to ensure all returned results met the inclusion criteria.

Data Extraction and Reliability

Two individuals (Catherine Gammon and Fatimah Aldarwish) independently carried out the literature searches on the same day. The online search results were exported and saved. Each individual independently screened the titles and abstracts of the returned articles and decided whether each article should be included in the review pool. Upon completion, the two individuals cross-referenced their lists and resolved any inconsistencies in article selection.

Following the compilation of the final search results, the information from each article was extracted and recorded in a table, including details such as the author, title, sample size, target population, article type, method, and main outcome.

Reporting

It is recommended that the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram is used in systematic review reports (to demonstrate the selection process of studies (Liberati et al., 2009). In general, three stages were used for screening articles, as shown in Figure 1. In stage 1, the number of identified articles were reported after both reviewers exclude irrelevant articles through reading article titles. In stage 2, abstracts were screened and excluded according to the eligible criteria listed above. In the final stage, the full text of articles were read and screened for inclusion before reaching the final set of articles.

Table 1.

Search Strategy in Database

Database	Search Strategy
PubMed	((vigorous physical activity[Title/Abstract] OR vigorous exercise[Title/Abstract] OR high intensity physical activity[Title/Abstract] OR high intensity exercise[Title/Abstract] OR high intensity interval training[Title/Abstract] OR high intensity aerobic training[Title/Abstract]) AND (youth[Title/Abstract] OR teenage[Title/Abstract] OR adolescent[Title/Abstract] OR college[Title/Abstract] OR university[Title/Abstract] OR young adult[Title/Abstract] OR adult[Title/Abstract])) AND (hypertensi*[Title/Abstract] OR blood pressure[Title/Abstract])
	((vigorous physical activity[Title/Abstract] OR vigorous exercise[Title/Abstract] OR high intensity physical activity[Title/Abstract] OR high intensity exercise[Title/Abstract] OR high intensity interval training[Title/Abstract] OR high intensity aerobic training[Title/Abstract]) AND (youth[Title/Abstract] OR teenage[Title/Abstract] OR adolescent[Title/Abstract] OR college[Title/Abstract] OR university[Title/Abstract] OR young adult[Title/Abstract] OR adult[Title/Abstract])) AND (BMI[Title/Abstract] OR body mass index[Title/Abstract] OR obesity[Title/Abstract] OR overweight[Title/Abstract] OR weight status[Title/Abstract])

Table 1 *continued*

Database	Search Strategy
CINAHL	(vigorous physical activity OR vigorous exercise OR high intensity physical activity OR high intensity exercise OR high intensity interval training OR high intensity aerobic training) AND (youth OR teenage OR adolescent OR college OR university OR young adult OR adult) AND (hypertensi* OR blood pressure)
	(vigorous physical activity OR vigorous exercise OR high intensity physical activity OR high intensity exercise OR high intensity interval training OR high intensity aerobic training) AND AB (youth OR teenage OR adolescent OR college OR university OR young adult OR adult) AND AB (BMI OR body mass index OR obesity OR overweight OR weight status)
	vigorous physical activity OR vigorous exercise OR high intensity physical activity OR high intensity exercise OR high intensity interval training OR high intensity aerobic training) AND AB (youth OR teenage OR adolescent OR college OR university OR young adult OR adult) AND AB (Anxiety OR stress OR anxious OR tense OR tension)
MEDLINE	(TS=("vigorous physical activity" OR "vigorous exercise" OR "high intensity physical activity" OR "high intensity exercise" OR "high intensity interval training" OR "high intensity aerobic training") AND TS=("youth" OR "teenage" OR "adolescent" OR "college" OR " university" OR "young adult" OR adult) AND TS=(hypertensi* OR "blood press ure")) AND LANGUAGE: (English OR Arabic) AND DOCUMENT TYPES: (Clinical Trial OR Clinical Trial Phase I

Table 1 *continued*

Database	Search Strategy
	OR Clinical Trial Phase II OR Clinical Trial Phase III OR Clinical Trial Phase IV OR Comparative Study OR Controlled Clinical Trial OR Journal Article OR Multicenter Study OR Observational Study OR Pragmatic Clinical Trial OR Randomized Controlled Trial) AND AGE GROUP: (Adolescent OR Adult) AND SPECIES: (Humans)
	TS=("vigorous physical activity" OR "vigorous exercise" OR "high intensity physical activity" OR "high intensity exercise" OR "high intensity interval training" OR "high intensity aerobic training") AND TS=("youth" OR "teenage" OR "adolescent" OR "college" OR " university" OR "young adult" OR adult) AND TS=(BMI OR body mass index O R obesity OR overweight OR weight status)) AND LANGUAGE: (English OR Arabic) AND DOCUMENT TYPES: (Clinical Trial OR Clinical Trial Phase I OR Clinical Trial Phase II OR Clinical Trial Phase III OR Clinical Trial Phase IV OR Comparative Study OR Controlled Clinical Trial OR Journal Article OR Multicenter Study OR Observational Study OR Pragmatic Clinical Trial OR Randomized Controlled Trial) AND AGE GROUP: (Adolescent OR Adult) AND SPECIES: (Humans)
	TS=("vigorous physical activity" OR "vigorous exercise" OR "high intensity physical activity" OR "high intensity exercise" OR "high intensity interval training" OR "high intensity aerobic training") AND TS=("youth" OR "teenage" OR "adolescent" OR "college" OR "

Table 1 *continued*

Database	Search Strategy
	university" OR "young adult" OR adult) AND TS=(Anxiety OR stress OR anxious OR tense OR tension)

Table 2.

Search Filters in Database

Database	Limits
PubMed	Document Types: Clinical Trial, Clinical Trial Protocol, Clinical Trial, Phase I, Clinical Trial, Phase II, Clinical Trial, Phase III, Clinical Trial, Phase IV, Multicenter Study, Observational Study, Randomized Controlled Trial, Species: Humans Languages: Arabic, English, Age Groups: Adolescent: 13-18 years, Young Adult: 19-24 years, Adult: 19-44 years.

Table 2 *continued*

Database	Limits
MEDLINE	Document Types: (Clinical Trial OR Clinical Trial Phase I OR Clinical Trial Phase II OR Clinical Trial Phase III OR Clinical Trial Phase IV OR Comparative Study OR Controlled Clinical Trial OR Journal Article OR Multicenter Study OR Observational Study OR Pragmatic Clinical Trial OR Randomized Controlled Trial) Age Groups: Adolescent OR Adult Species: Humans

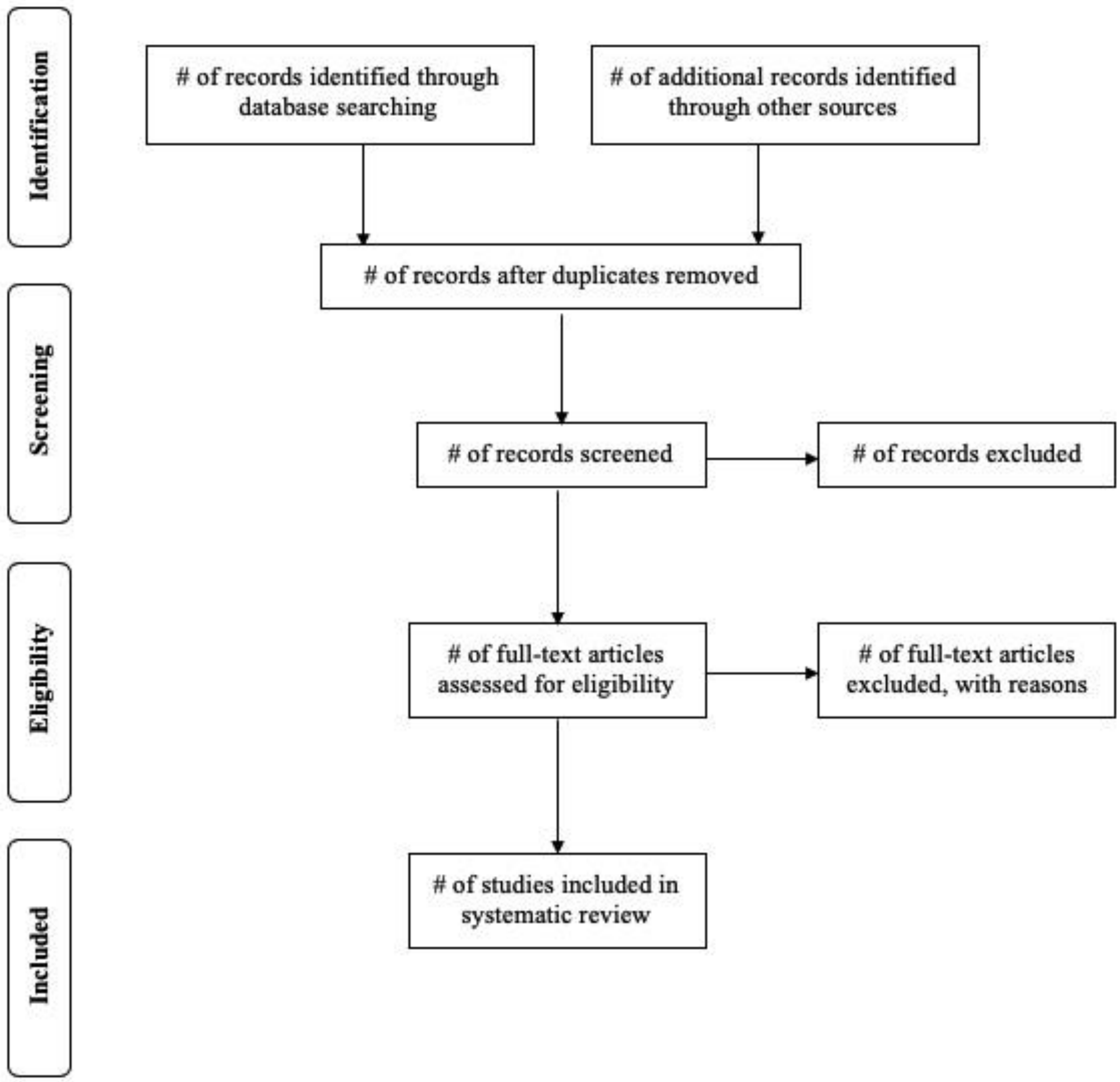

Figure 1.

Paper Selection Process

Chapter 4: Results

Study Selection

Figure 2 shows the PRISMA flow chart of the literature screening. Tables 3, 4, and 5 summarize the characteristics and major findings of all the studies included in this review. Data was collected from 320 articles as secondary sources of information for this work. It was determined that 239 studies were ineligible due to titles and abstracts screening. Of the remaining 81 articles, 14 were duplicates, which were removed. From the remaining 67 articles, 21 met the inclusion criteria. Among the 21 eligible studies, 10 studies assessed the relationship between VPA and BMI, eight studies evaluated the relationship between VPA and BP, and six studies assessed the relationship between VPA and anxiety. Three of these included studies evaluated more than one of the health indicators of interest. Reasons for excluding full text articles included: ineligible age (n = 37), non-English or non-Arabic language (n = 1), not original research study (n = 1), only protocol paper (i.e., no result; n = 3), did not evaluate the association between PA and health outcome of interest (n = 1), not relevant to the research of interest (n = 1), the intensity of PA was not controlled (n = 1), and intervention did not exclusively design to assess physical activity (n = 2).

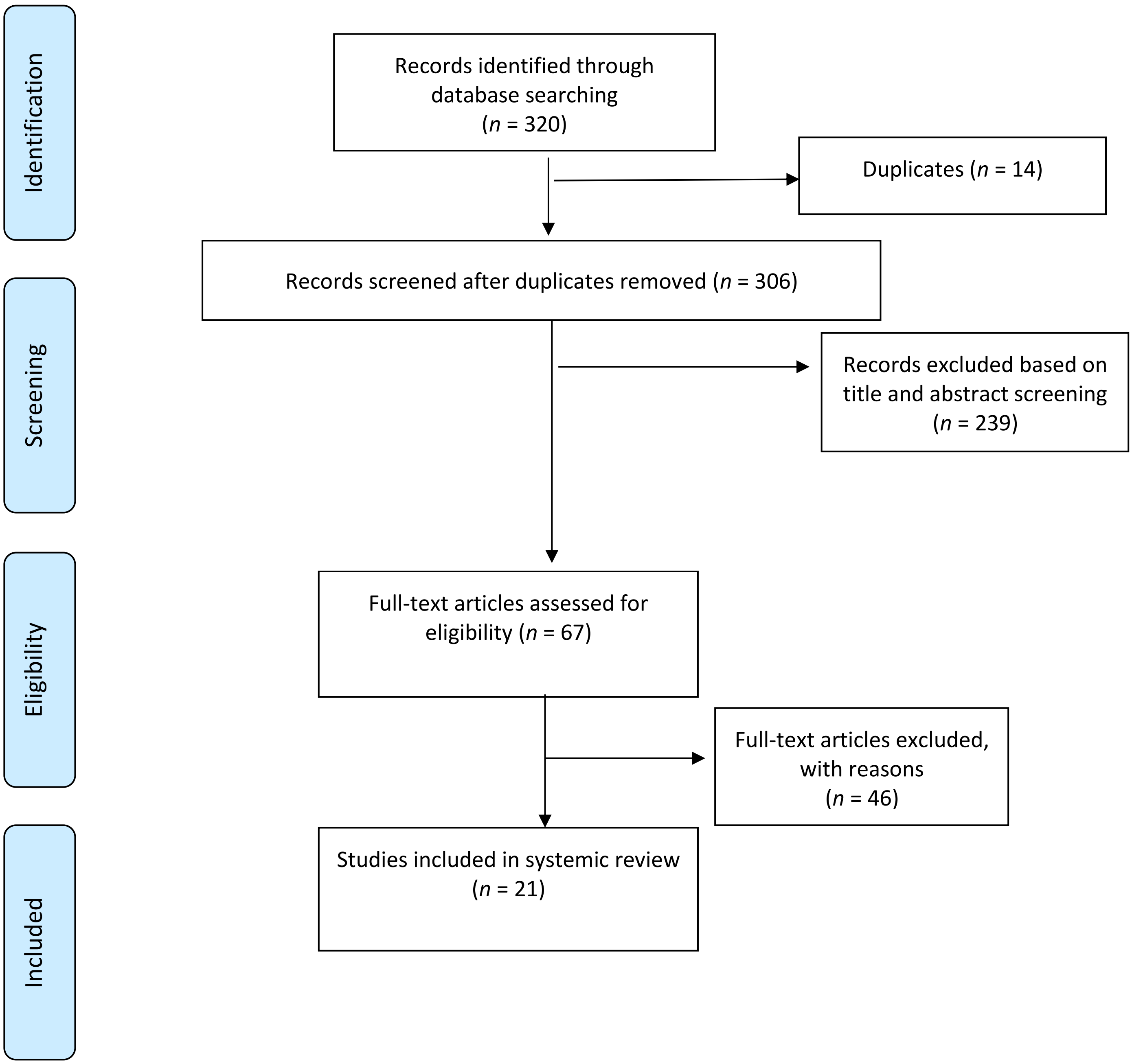

Figure 2.

Completed PRISMA Diagram of Included Articles

Table 3.

Included Articles for VPA and Anxiety

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of Anxiety	# of participants	Age	Overall findings
da Silva et al. (2019)	RCT	USA	3 exercise trials on treadmill 1) continuous AE at 40% VO2peak 2) continuous AE at 40% VO2peak with 50% of BFR 3) HIIT 6*90 s of running at 80% VO2peak with 90 s rest interval at 40% VO2peak. All testing conditions lasted for 18 min.	BRUMS immediately before exercise, post, and 1-h post-exercise.	22 Male	Mean Age = 24.2 ± 2.8	Tension level increased and elevated up to 1-hour post HIIT.

Table 3 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of Anxiety	# of participants	Age	Overall findings
Broman-Fulks et al. (2004)	between group experiment study	USA	Two groups (high-intensity or low-intensity). Treadmill exercise session at 60%-90% of HRmax for high-intensity group. Each exercise session lasted 20 min, 2–4 times per week for a total of 6 sessions across 2 weeks.	ASI, BSQ, STAI. Immediately before the first exercise session, after a five-minute cool down period following the final exercise session, and at a one-week follow-up session	54 with elevated anxiety sensitivity	18-51 (Mean age = 21.17)	Both low and high exercise intensities reduced anxiety sensitivity.
Bass et al. (2002)	nonrandomized controlled trial	USA	Eight weeks training program (3 days/week) . weight-training course at 60 to 80% of 1-RM. Aerobic dance group: 45-min. control group: enrolled in Fitness Concepts course.	The Survey of Recent Life Experiences during the first week of classes and eight weeks later.	114	17-29	Stress reduction among lower intensity exercises

Table 3 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of Anxiety	# of participants	Age	Overall findings
Bartholomew & Linder (1998)	within group experimental design	USA	EXPERIMENT1: three 20 min bouts of resistance exercise at varying intensities set as function of perceived exertion. Experiment 2: exercise intensity set as submaximal lift until exhaustion. Low-intensity session was at 40-50% of predicted 1 RM, and high-intensity session was at 75-85% of predicted 1 RM.	Experiment1: Prior to and following each exercise session participants completed Spielberger's State Anxiety Inventory (STAI). Experiment2: Prior to and following each exercise session participants completed the STAI, the PANAS, and Spielberger's State Anger Scale	Experiment1: 19 Experiment2: 20	Undergraduate students	Experiment1: males reported an increase in anxiety immediately following high-intensity exercise, but Females reported no significant change. Experiment 2: Both males and females reported increases in anxiety high-intensity exercise. Significant decreases in anxiety following low-intensity exercise.

Table 3 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of Anxiety	# of participants	Age	Overall findings
May et al. (2019)	RCT	USA	The HIIT protocol involved 3 cycling sessions per week over 4 weeks. Each session comprised 10 × 60s cycling bouts interspersed with 60-s recovery.	STAI	90	Mean Age = 18.55	No significant change after HIIT training.
Steptoe et al. (1993)	RCT	UK	20 min of exercise at high-intensity 70% Vo2max or moderate-intensity 50% Vo2max or control (light exercise).	POMS	72 men	20-35	No significant difference

Note. PA: Physical Activity; AE: Aerobic Exercise; BFR: Blood Flow Restriction; BRUMS: Brunel Mood Scale; HIIT: High-Intensity Interval Training; ASI: Anxiety Sensitivity Index BSQ: Body Sensations Questionnaire; STAI: State–Trait Anxiety Inventory; HRmax: Heart Rate Max; PRF: Function of Perceived Exertion; RM: repetition maximum; BP: Blood Pressure; POMS: Modified Version of the Profile of Mood States; VO2max: Maximal Oxygen Consumption.

Table 4.

Included Articles for VPA and Body Mass Index

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BMI	# of participants	Age	Overall findings
Heinrich et al. (2014)	A stratified, randomized two-group pre-test posttest intervention	USA	The HIFT group utilized CrossFit training for 60 minute sessions over 8 weeks. The Aerobic training: 50 minutes of moderate aerobic exercise at 40-50% HRR for weeks 1–4 and 50-60% HRR for weeks 5–8 and full-body resistance exercises on 2 sessions per week.	Detecto scale	23	Mean Age = 26.8 ± 5.9	BMI did not significantly change for either group

Table 4 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BMI	# of participants	Age	Overall findings
Chiu et al. (2009)	RCT	China, Taiwan	Three 60-min sessions weekly for 12 weeks. The LITG performed walking treadmill exercise test at 40%–50% HRR. The MITG performed at 40%–50% HRR throughout first 6 weeks, increasing to 50%–70% HRR throughout the last 6 weeks. The HITG performed at 40%–50% HRR throughout first 6 weeks, increasing to 70%–80% HRR during weeks 7–12.	weight scale. BMI was calculated using the following formula: BMI = body weight (in kg)/ [height (in m)]2 .	48 obese sedentary college students	18-26	Body weight significantly improved in the HITG and MITG compared to LITG and CG.
Plavsic et al. (2020)	randomized two-group pre-test posttest intervention	Serbia	Two groups (dietary advise only and dietary advice + HIIT). HIIT was performed on a treadmill 4x4 min intervals at 85-90% of HRmax with a 3 min active recovery at	Body height was measured using stadiometer, BMI was calculated using standard formula [body mass (kg)/height(m2)].	44 Adolescent girls with obesity	Mean Age = 15.8 ± 1.6	Both groups had significant improvements in BMI.

Table 4 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BMI	# of participants	Age	Overall findings
			70% of HRmax between each interval for a total of 43 min.				
Racil et al. (2016)	RCT	Tunisia	Three groups (HIIT, Plyometric exercise +HIIT, control). 12 weeks training program (3 days/weeks). HIIT: 2 blocks of 6 or 8 bouts of 30-s runs at 100% VO2peak, with 30 s of active recovery between bouts at 50%VO2peak. The 2 blocks were separated by a 4-min passive recovery period.	BMI was calculated from the following equation: BMI (kg·m−2) = body mass (kg)/height2(m)	75 obese females	Mean Age = 6.6 ± 1.3	Significant decreases were noted in body mass and BMI score in both groups.
Dionne et al. (2000)	nonrandomized controlled trial	Canada	Subjective measure by PA diary for 3 days.	was not mentioned	373 males	Mean Age = 14.5 ± 3.3	Greater amount of time spent doing VPA was associated with lower BMI
Chin et al. (2020)	single-blind randomized controlled trial	China	4 groups (control, HIIT 3 times/wk, MICT 3 times/wk, HIIT 2 times/wk,	BIA	590 males	Mean Age =	HIIT once weekly showed more favorable BMI changes

Table 4 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BMI	# of participants	Age	Overall findings
			HIIT once/wk). Each HIIT session performed on 30 m shuttle run and consisted of 12 min exercise at 90% of heart rate reserved and was interspersed with 11 bouts of active recovery at 70% of HRR. MICT consisted of 30 min of continuous running exercise at 60% of HRR.			22.8 ± 3.1	than MICT 3 times per week.
Hagovska et al. (2019)	RCT	Slovak Republi	Participants were split into two groups, as follows: Group 1 (high intensity) 3 times a week for 60–90 minutes and group 2 (low intensity) once a week for 60–90 minutes.	BIA	77 overweight women with overactive bladder symptoms	Mean Age = 26.2	High-intensity group lost body weight and showed a reduction in Body Fat Percentage of more than 5%, whereas low-intensity group did not.

Table 4 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BMI	# of participants	Age	Overall findings
Kong, Sun, et al. (2016)	randomized two-group pre-test posttest intervention	China	Five weeks training program (4 sessions/wk). HIIT group performed 60*8 s cycling and 12 s passive recovery on a cycle ergometer for 20 min. Participants in the MICT group performed a continuous cycling at 65% VȮ2peak for 40 min.	Stadiometer and an electronic scale. BMI was calculated by dividing weight (kg) by height (m) squared	18 overweight women	Mean Age = 19.8 ± 0.8	No significant changes in weight and BMI for both groups.
Kong, Fan, et al. (2016)	RCT	CHINA	Five weeks training programs (4 days/week). Participants in HIIT performed 20 min of 60*8 s cycling interspersed with 12 s rest intervals, and those in MVCT cycled at 60-80% VO2peak for 40 min.	Stadiometer and an electronic scale. BMI was calculated by dividing weight (kg) by height (m) squared	31 obese females	18–30	HIIT did not lead to any beneficial changes in weight loss.
Duval et al. (2017)	one group pretest-posttest design	Canada	Two weeks training program (14 days). HIIT program was	dual energy X-ray absorptiometry.	16 male	18-30	No significant differences were observed.

Table 4 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BMI	# of participants	Age	Overall findings
			performed on treadmill. 15 × 60 sec sprint intervals at 90% of maximal heart rate and interchanged with 60 sec active recovery.	Standing height was measured using a wall stadiometer. BMI = Body weight (kg)/Height (m2) was then calculated			

Note. PA: Physical Activity; HIFT: High-Intensity Functional Training; HRR: Heart Rate Reserve; BMI: Body Mass Index; LITG: Light-Intensity Training Group; MITG: Moderate-Intensity Training Group; HITG: High-Intensity Training Group; , WC: Waist Circumference; WHR: Waist to Hip Ratio: WHtR: Waist to Height Ratio; CG: Control Group; SBP: Systolic Blood Pressure; HRmax: Heart Rate Max; HIIT: High-Intensity Interval Training; P: Plyometric Exercise; VPA: Vigorous Physical Activity; MICT: Moderate-Intensity Continues Training; BFP: Body Fat Percentage; VFA: Visceral Fat Area; MVCT: Moderate to Vigorous Continuous Training; FM: Fat Mass; BP: Blood Pressure; VO2max: Maximal Oxygen Consumption; BIA: Bioelectric impedance analyzer

Table 5.

Included Articles for VPA and Blood Pressure

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BP	# of participants	Age	Overall findings
Faria et al. (2020)	RCT	Brazil	12 weeks training program (twice/wk). HIIT on the treadmill 1 and 2 min at 90% Vmax followed by 2-3 min at 40%-50% Vmax. MICT: walking/running, at 55% to 65% Vmax. RT took place immediately following the MICT or HIIT. Control Group.	digital device.	75	Mean Age = 16.1	Both the HIIT + RT and MICT + RT groups significantly reduced SBP and DBP compared with the baseline.
Chin et al. (2020)	single-blind randomized controlled trial	China	4 groups (control, HIIT 3 times/wk, MICT 3 times/wk, HIIT 2 times/wk, HIIT once/wk). Each HIIT session performed on 30 m shuttle run and consisted of 12 min exercise at 90% HRR and was interspersed with 11 bouts of active recovery at 70% of HRR. MICT consisted of 30 min of continuous running exercise at 60% of heart rate reserved	Electronic Sphygmomanometer	590 males	Mean Age = 22.8 ± 3.1	All exercise frequencies of HIIT showed reduction in BP. One session of HIIT per week was effective for lowering BP.

Table 5 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BP	# of participants	Age	Overall findings
May et al. (2019)	RCT	USA	The HIIT protocol involved 3 cycling sessions per week over 4 weeks. Each session comprised 10 × 60s cycling bouts interspersed with 60-s recovery.	SphygmoCor XCEL pulse wave analysis system.	90	Mean Age = 18.55	No statistically significant reduction in BP after HIIT.
Holloway et al. (2018)	Non-randomized controlled trial	UK	Six weeks training program involved HIIT and control group. HIIT involved 5*60 sec cycling bouts at 90% VO2max, interspersed with 2 min recovery.	SphygmoCor System.	21	Mean Age = 21±2	SBP reduced compared to control group
Fisher et al. (2015)	RCT	USA	Six weeks training program. HIIT involved 4*30 sec cycling bouts at 85% MAX-AP, interspersed with 4 min recovery, 3 sessions/week. MIT performed 45–60 min of continuous cycling at 55–65% of VO2peak, 5 sessions/ week.	automatic sphygmomanometer machine	28 sedentary overweight or obese men	17–22 (Mean Age = 20 ± 1.5)	Significant decrease in DBP in the MIT compared to the HIIT group.

Table 5 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BP	# of participants	Age	Overall findings
Steptoe et al. (1993)	RCT	UK	20 min of exercise at high-intensity 70% Vo2max, moderate-intensity 50% Vo2max, control.	electronic sphygmomanometer.	72 men	20-35	Sportsmen had higher baseline SBP than inactive men. Hypotensive response was observed immediately following both high intensity interval training and moderate continuous exercise.
Duval et al. (2017)	one group pretest-posttest design	Canada	Two weeks training program (14 days). HIIT program was performed on treadmill. 15 × 60 sec sprint intervals at 90% of maximal heart rate and interchanged with 60 sec active recovery.	automatic sphygmomanometer machine	16 male	18-30	No significant differences were observed in BP.
Costa et al. (2016)	experiment design (randomized	Brazil	HIIE involved 10*60S at 90% Vmax interspersed with 60 s of active recovery at 30% Vmax.	automatic sphygmomanometer machine	14 normotensive males	Mean Age = 24.5 ± 4.2	Hypotensive response was observed following both

Table 5 *continued*

1st Author (Year of publication)	Study Design	Country	Measurement of PA	Measurement of BP	# of participants	Age	Overall findings
	counterbalance study design)		CE consisted of 20 min at 60% Vmax.				high-intensity interval training and moderate continuous exercise.

Note. PA: Physical Activity; HIIT: High-Intensity Interval Training; Vmax: Maximal Treadmill Velocity; MICT: Moderate-Intensity Continues Training; RT: Resistance Training; SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BIA: Bioelectrical Impedance Analyzer; HRR: Heart Rate Reserve; BMI: Body Mass Index; CG: Control Group; MIT: Moderate-Intensity Training; MAX-AP: Maximal Anaerobic Power; CE: Continuous Exercise; PEH: Post Exercise Hypotension; VO2max: Maximal Oxygen Consumption.

Study Characteristics of VPA and Anxiety

The association between high-intensity PA and anxiety was evaluated in six studies that fit the inclusion criteria for this systemic review. Two of these studies assessed state anxiety by taking anxiety measurements immediately post exercise, whereas the other four studies assessed trait anxiety by taking anxiety measurements post-intervention when the intervention lasted for several weeks (ranging between 4 to 8 weeks). In addition, nine of the included studies focused on males and five on females.

An experimental study design was used in all these studies, including RCT (*n* = 3), nonrandomized controlled trial (*n* = 1), between group trial (n=1), and within group trial (*n* = 1). All included studies were performed in the USA, except one performed in the UK, and all were published between the years 1993 and 2019. Different types of high-intensity activities, including biking, weight-bearing exercise, jogging, walking, aerobic exercise, and dance were measured objectively in the selected studies.

Trait anxiety was assessed by Broman-Fulks and colleagues (2004), who reported that both low and high exercise intensities reduced anxiety sensitivity with a more rapid reduction among participants who performed high-intensity activity. Conversely, Bass and colleagues (2002) reported greater stress reduction among freshmen students who performed lower intensity exercises compared to those who performed higher intensity exercises after 8 weeks of intervention. May and colleagues (2019) reported no significant change in trait anxiety following 4 weeks of high-intensity exercise. Steptoe et al. (1993) reported no significant differences in stress levels between sportsmen and inactive men. The study by Broman-Fulks et al. (2004) was the only one that, in addition to an immediate post-intervention anxiety measurement, conducted a follow-up measurement of anxiety one week after the intervention. The findings indicated an improvement in anxiety sensitivity score following high-intensity exercises at one-week follow-up, but not immediately post exercise or at one hour after the intervention.

The findings on state anxiety was reported by da Silva and colleagues (2019), who found that compared to moderate aerobic exercise, tension level was greater immediately following HIIT among athlete participants. In addition, Bartholomew and Linder (1998) examined state anxiety responses to different exercise intensities among male and female participants in a two-part study. In the first part of the study, anxiety was reduced after low-intensity exercise and increased after moderate- and high-intensity exercises among males with no change in anxiety reported by females. In the second part of the study, both men and women reported an increase in anxiety after high-intensity exercise and a reduction in anxiety following low-intensity exercise.

Study Characteristics of VPA and BMI

Ten studies examined the influence of high-intensity exercises on BMI. Of these eligible studies, eight were published between the years 2010 and 2020, and the remaining two studies were published between the years 2000 and 2009. Four studies were performed in China, two in Canada, two in Europe, one in the USA, and one in Tunisia. The design of these studies was experimental and included RCT (*n* = 5), randomized two groups pretest posttest intervention design (*n* = 3), pretest posttest design (*n* = 1), and a non-randomized controlled trial (*n* = 1). BMI was calculated by dividing weight (kg) by height (m^2) in all of the included studies. Among the 10 studies, the intensity of PA was determined objectively by measuring maximal heart rate (*n* = 3), heart rate reserve (*n* = 3), and VO_2 peak (*n* = 3). Only one study used a subjective measure through using a PA diary to estimate the amount of time subjects engaged in VPA.

The results from four studies indicated that high-intensity exercises were not effective in reducing BMI, although two studies suggested that high-intensity exercises might be effective in the maintenance of body weight (Heinrich et al., 2014; Kong, Sun, et al., 2016; Kong, Fan, et al., 2016; Duval et al., 2017). These four studies lasted between 2 and 8 weeks, and involved between three and seven sessions per week. All of them lacked a control group, the participants were mostly overweight inactive women (except in the study that was conducted by Duval et al., 2017), and the high-intensity exercise modality varied across studies, including treadmill, cycling, and CrossFit.

In contrast, some studies reported beneficial effects of high-intensity exercise on BMI. Chiu and colleagues (2017) reported that BMI was significantly lower following a 12-week intervention of high-intensity exercises when compared to a control group. Similar results were reported by Chin and colleagues in 2020; they reported that overweight participants who performed HIIT once weekly demonstrated more favorable BMI changes than participants who engaged in moderate-intensity continuous training (MICT) three times per week. In addition, Hagovska and colleagues (2019) report that, compared to low-intensity exercise, engagement in high-intensity exercise reduced body weight to a greater extent in overweight women. Finally, Dionne et al. (2000) reported that a greater amount of time spent doing VPA was associated with lower BMI and had the important effect of preventing weight gain.

Study Characteristics of VPA and BP

Eight studies assessed the influence of high-intensity PA on BP. Two studies were from the USA, two from the UK, two from Canada, and two from Brazil. Five of these studies were RCT's, one was a non-randomized controlled trial, one used a pretest-posttest design, and one used a randomized counterbalance design. All of these studies were published between 2015 and

2020, except one published in 1993. In addition, most of these studies assessed the chronic effect of exercise on BP, but the timing of assessment for BP was varied between the studies. One study assessed BP following 2 weeks of an exercise intervention, one study assessed BP after 4 weeks, one study assessed BP after 4 and 8 weeks, two studies assessed BP after 6 weeks, one study assessed BP after 12 weeks. The acute effects of exercise on BP were documented in two studies; BP was measured at baseline and immediately following one session of high-intensity exercise.

Acute responses

In the study by Costa et al. (2016), an acute hypotensive response was observed following both HIIT and moderate continuous exercise. However, a greater systolic BP reduction was observed in the participants who performed moderate continuous exercise. Similar results were documented by Steptoe et al. (1993), who found post-exercise hypotension following both high-intensity and moderate-intensity exercises, but with a greater systolic BP reduction following the high-intensity exercise trial than the moderate exercise trial.

Chronic responses

Three of the included studies reported a reduction in BP following several weeks of high-intensity training. Faria et al. (2020) assessed the effect of combined exercise programs: HIIT+ resistance exercise, and moderate-intensity continuous training + resistance exercise on BP. Following a 12-week intervention period, both combined exercise programs reduced SBP and DBP. Consistent with these findings, Holloway et al. (2018) reported that participants who engaged in 6-weeks of HIIT exhibited a reduction in peripheral SBP compared to those who did not engage in any kind of activity. In another study, Chin et al. (2020) reported that one session of HIIT per week was effective for lowering BP of overweight individuals. In contrast, Steptoe and colleagues (1993) compared the BP of sportsmen and inactive men, and found that sportsmen had significantly higher SBP than inactive men. Three studies found no significant change in systolic BP and diastolic BP following high-intensity exercise interventions (May et al., 2019; Fisher et al., 2015; Duval et al., 2017).

Chapter 5: Discussion

This systemic review summarized evidence from 21 articles regarding the influence of high-intensity PA on anxiety, BMI, and BP in young adults. The studies examining each health indicator varied in their conclusions regarding whether high-intensity exercise had a beneficial effect, a detrimental effect, or no effect on the health indicator.

Anxiety and VPA

A number of studies have documented the state and trait anxiety responses following vigorous exercise. Two of the included studies showed that a bout of high-intensity PA was not associated with a reduction in stress and state anxiety. It was shown that anxiety scores were elevated immediately following high-intensity exercise (Bartholomew & Linder, 1998) and elevated up to 1 hour post exercise (da Silva et al., 2019). A number of hypotheses have been suggested to explain the increase in state anxiety with a bout of VPA. Vigorous exercise leads to metabolic and physiological changes which could increase sensations of pain sensitivity and potentially contribute to peripheral fatigue, therefore negatively affecting state anxiety. These factors might cause the participants to feel that they failed to achieve their desired goals of exercise which could consequently increase the participants' feelings of anxiety. Trait anxiety on the other hand did not change significantly from pre- to post-exercise intervention (May et al., 2019; Bass et al., 2002) but reduced following two weeks of high-intensity intervention (Broman-Fulks et al., 2004). In addition, sportsmen and inactive men had no significant differences in stress levels (Steptoe et al., 1993). The findings across these studies are heterogenous, which make it hard to decide whether our hypothesis that young adults who engage in VPA will have fewer anxiety symptoms was supported or not.

From the included six studies, it appears that lower intensity exercises reduce state and trait anxiety, whereas high-intensity exercises increase state anxiety and reduce or have no effect on trait anxiety. The small number of included studies differed in some key methodological ways, so it is difficult to make comparisons between them and draw an overall conclusion about the relationship between VPA and anxiety in young adults. Further research is necessary to explore this relationship among young adults in the effort to determine whether specific PA guidelines are needed for young adults. Future research studies on this topic should include larger sample sizes, and if the age range of participants is wide, authors should report findings separately for smaller age intervals so that age-specific relationships can be assessed. It would also be helpful for studies to use longer follow-up periods to determine any chronic anxiety responses to VPA.

There are a number of reasons that might explain why studies reported different results. For example, da Silva et al. (2019) reported that the baseline anxiety score might have an effect on the extent to which anxiety score decreases following exercise. In this study, the participants doing low-intensity exercises had higher baseline anxiety values than participants in the moderate-intensity and high-intensity exercise groups. Consequently, the improvement in anxiety was higher in the low-intensity exercise group than in the moderate- and high-intensity groups. On the other hand, 54 participants with elevated anxiety sensitivity scores at baseline all reported reduced anxiety sensitivity following a two-week intervention of either high-intensity exercise or low-intensity exercise, although a more rapid reduction in anxiety was observed in participants in the high-intensity exercise condition (Broman-Fulks et al., 2004). These observations imply the influence of baseline anxiety scores on research findings and could account for some of the differences between studies' results.

Another reason for inconsistencies in the results across studies could be related to differences in how males and females responded to the manipulation of exercise intensity. A study conducted by Bartholomew and Linder (1998) reported different post-exercise anxiety responses for males and females (males demonstrated a post-exercise change in anxiety, whereas females did not). The authors suggested that these differences could be due to different interpretations of the RPE (perceived exertion) scale between males and females. The researchers attempted to address this interpretation factor in a second study—they duplicated the experiment and found that both males and females reported reduced anxiety following low-intensity exercise and an increase in anxiety following high-intensity exercise. It was interesting to note that gender may play a role in influencing exercise intensity and/or anxiety scores and therefore the effectiveness of some interventions.

In addition, the influence of high-intensity exercises on anxiety might vary based on exercise modality—e.g., aerobic exercise or weight training. Bass et al. (2002) reported a greater stress reduction in a weight training group that performed exercise at lower intensity than an aerobic dance group in a study that included 144 freshmen students. An explanation for these different levels of stress reduction following different exercise modes could be related to the participants in the weight training group feeling a greater sense of control and ability to monitor their progress – for example, they are able to increase the heaviness of weight they lift when they do resistance training. Thus, the influence of high-intensity exercise on anxiety may be dependent on exercise mode.

The timing of anxiety assessment post intervention could also contribute to the mixed results that were observed between the studies. Several studies report an acute increase in anxiety after vigorous exercise. Most of them showed the effect of VPA on anxiety immediately after exercise exposure or at one-hour after exercise. Only one study used a longer period of follow-up (one week), and this study reported an improvement in anxiety sensitivity score following a high-intensity exercise intervention at 1 week after the intervention, but not immediately after the intervention.

The population of interest in this systematic review is young adults in the 18-24 years age range. Even though some of the included studies had a wider range of ages in their sample, the age average of the participants was within our target. It was difficult to ascertain findings for only young adults because many studies present results for a wide range of adults of adolescents and do not split the results by age group. A previous systematic review in a child population found no difference in anxiety score following VPA as compared to low-intensity activity (Larun et al., 2006b).

BMI and VPA

Results regarding the relationship between high-intensity PA and BMI are consistent with our hypothesis. Most of the studies included in this review suggested that high-intensity PA was more beneficial in reducing BMI and maintaining body weight than lower intensity activities or no activity at all. This finding is consistent with a recent meta-analysis among overweight and obese children that suggested the effectiveness of HIIT in improving BMI and body composition (Liu et al., 2020).

It is difficult to draw a conclusion about the specific amount, duration, or frequency of VPA that is needed for a better BMI/adiposity outcome because of the variety of PA protocols were used in the included studies. Despite this, there is some indication from the included studies that a greater volume of VPA is better. Whilst the results of the included studies are not completely consistent, most authors observed that VPA was associated with favorable changes in BMI.

There are some factors that might influence the ability to draw a definite conclusion regarding to the relationship between VPA and BMI. For instance, differences between the findings of the studies might be attributed to the variation in intervention duration. The period range in four studies that showed a negative or no significant changes in BMI after high-intensity PA intervention was 5 to 8 weeks. In contrast, other studies reporting positive results involved 12 weeks of intervention. Thus, it seems that longer term interventions are recommended for eliciting beneficial effects on BMI.

Additional factors include the influence of dietary intake and daily PA on weight loss. It is important to eliminate or minimize their effect during the experimental period of a research study. For that reason, four of the included studies used 3 days-diet recall ensuring their participants maintained their diets. Also, seven studies used either questionnaire or a pedometer to ensure maintenance of daily PA among their participants. In contrast, the rest of the studies had either instructed their participants to maintain their daily diets and PA, or these factors were not assessed at all. In this systematic review, two studies evaluated the effect of high-intensity PA and diet on BMI. Plavsic et al. (2020) studied BMI in 44 obese girls who were randomized into two groups. The authors of this study compared individuals who had a low caloric diet alone to individuals who combined low caloric diet with high-intensity PA. By the end of the 12-week intervention period, improvements in body weight and BMI were observed in both groups. On the other hand, Duval et al. (2017) investigated the effect of HIIT during two weeks of fast food diet (high caloric diet) in 15 healthy, physically active men. The outcome measurements of BMI were taken at baseline and post intervention. There were no significant changes in BMI and body weight after the intervention. This suggests that diet, if not controlled, can play a very significant role in changing the intervention outcome. Therefore, a detailed dietary intake record and daily PA record should be used in the future studies to control for these potential confounding factors.

Although most of the included studies recruited sedentary and overweight participants, we could not eliminate the possibility of participant’s weight change being due to other factors that were not VPA. This is a particular concern in studies that had no control group. For example, menstrual cycle and changes in hormonal levels of female subjects might be factors that have an influence on eating behaviors which can affect weight change. Menstrual cycle should therefore be taken into consideration in future studies examining the influence of VPA on BMI of young adults.

Another factor that might also influence the ability to make conclusion is the accuracy of the VPA assessment. Across all of the included studies, Dionne et al. (2000) was the only study that used self-reported PA. Self-reported PA has reliability and validity concerns. The self-report method often has an issue with inaccurate recalls and response bias from the participants. Therefore, we could not rule out the possibility of the overestimation of the reported amount of time participants spent in VPA. Additionally, Heinrich et al. (2014) monitored the effect of high-intensity functional training (HIFT) on the reduction of BMI. They analyzed 32 sedentary and overweight/obese participants with an average age of 28 years for a duration of 8 weeks. They found that changes in BMI was not significant after HIFT workouts. Despite their finding, the intensity was not measured during HIFT, and it was self-selected intensity level. For that reason, participants may not have reached vigorous-intensity level and therefore the findings may need to be interpreted with caution. As such, future studies should correctly measure and control PA intensity and use objective measures when possible.

BP and VPA

The evidence regarding VPA and BP was contradictory. While a reduction in BP was observed following high-intensity PA in some of the included studies, three articles found no significant change.

Previous evidence has indicated the effectiveness of high-intensity training on BP in populations other than young adults. For instance, a systematic review suggested that HIIT might have a preventative effect against cardiometabolic diseases in overweight and obese youth and that it induced a reduction in systolic and diastolic blood pressure ([-1.370 to -0.683]; [-1.628 to -0.304], respectively; (Thivel et al., 2019). It is important to note that overweight and obese individuals have higher risk of developing hypertension and other chronic diseases. This evidence is in agreement with some of the findings in our review, which indicates the potential of HIIT for modifying health in young adults which, therefore, may have a positive effect on preventing hypertension in older age.

The differences between the findings of the studies in this review might be attributed to several factors. Exercise modality may have influenced the results related to BP. The influence of a combination of both aerobic and resistance training exercise has been reported in just one study. The findings of both aerobic and combination training showed a beneficial effect on reducing BP; however, aerobic workouts have been the most commonly used in the reported studies. Comparing the effect of different VPA exercise modalities on BP should therefore be determined in future studies of young adults.

Differences in findings among the studies included in this review might be attributed to the time when BP responses were measured. For instance, post-exercise hypotension has been observed in two studies that involved normotensive men (Costa et al., 2016; Steptoe et al., 1993), while all other studies examined the chronic response of BP to VPA. Fisher et al. (2015) reported no change in systolic and diastolic BP following 6 weeks of HIIT when BP was assessed 48 hours following the last session of exercise. Likewise, Duval et al. (2017) did not find any favorable changes in BP measured 48 hours after the end of the experiment. However, differences in resting BP have been observed between athlete men and inactive men. In one of the studies in this review, sportsmen had higher baseline BP values than inactive men (Steptoe et al., 1993). This finding is inconsistent with research examining the influence relationship between BP and MVPA among adults. The chronic effect of VPA on BP remains questionable and requires further investigation.

Another reason for differences in findings across the included studies could be the absence of a control group in some of the studies. Control groups are important because maintaining diets and daily PA during the whole intervention period is necessary to be able to exclude their effect on the final result. Plavsic et al. (2020) reported that only the combined group of VPA and low caloric diet had a significant reduction in both SBP and DBP, while the diet only group improved SBP. On the other hand, Duval et al. (2017) found no significant changes in SBP following a combination of VPA and high caloric diet. Control of daily diets and PA is therefore recommended in future studies since they might have influenced the end results regarding the relationship between VPA and BP.

In addition, it is important to investigate the impact of high-intensity PA on BP in normotensive and hypertensive subjects. However, the included studies were all conducted on healthy normotensive individuals. As such, the findings of this review may not generalize to hypertensive individuals. The mechanism behind the effect of VPA on BP is still unclear.

However, the acute response of BP in the post-exercise period is likely to be attributed to changes in cardiac output and total peripheral resistance.

Strengths and Limitations

The discussion has already emphasized several gaps and limitations that need to be address in the future research; however, there are additional limitations in this systematic review that demand attention. Some limitations are associated with our search strategies. The search was restricted to three selected databases (e.g., PubMed, CINAHL, MEDLINE). In addition, we only looked at articles that were written in English or Arabic. Thus, articles in other languages were not included, and this could have resulted in the omission of relevant articles.

The nature of the studies included in this review also has some limitations. Most of the articles had small sample sizes and were limited to only one gender, which might limit generalization of their results. Moreover, no study assessed the changes of health indicators by socioeconomic status.

Across all studies in the present review, HIIT was the major type of exercise used to evaluate high-intensity PA. Only a few studies included continuous high-intensity activities of resistance or aerobic exercises. For example, Bass et al. (2002) found different results related to anxiety between resistance exercise and aerobic dance. Faria et al. (2020) investigated the effect of combined exercise training (aerobic and resistance training) on cardiometabolic risks. Very limited sources have compared the effect of a single exercise intervention and a combination of aerobic and resistance exercises on health outcomes. Future research should examine other types of high-intensity exercises.

Despite the limitations, this systematic review is useful to help identify where further research is needed and extends knowledge of the relationship between VPA and health-related outcomes of anxiety, BMI, and BP in young adults. Strengths of our systematic review include using objective ways to measure PA in all of the reported studies, except one utilized self-report PA measurement. Moreover, most of the studies compared high-intensity activities to lower intensity so we can infer the beneficial effect of higher intensity exercises.

Future Research Directions

Only two of the included studies compared the effectiveness of different frequencies of high-intensity PA on the health indicators (Chin et al., 2020; Dionne et al., 2000). It has been suggested that more sessions per week of high-intensity exercises are more beneficial than lower frequencies. On the other hand, only one session of HIIT per week was shown to have similar benefits to moderate-intensity exercises completed three days per week. These findings indicate that HIIT is more time efficient than moderate-intensity exercises. However, limited published research has examined how much VPA is needed to get a beneficial effect. Thus, we recommend authors of future studies investigate the optimal frequency and duration of VPA in young adults. In addition, we were only able to find 21 studies for our review because we wanted studies that looked at a specific young adult age range. More studies are therefore needed on this age group, or larger population studies should report results for smaller age groups to help us in understanding whether VPA should be specifically recommended to young adults.

Conclusion

In summary, the findings regarding the relationship between VPA and anxiety, BMI, and BP in young adults demonstrate some inconsistency but appear to indicate that high-intensity exercises are effective in reducing BMI and BP in young adults. The findings suggest that VPA is not consistently successful at decreasing anxiety after exercise. HIIT is considered protective behavior against cardiometabolic diseases. However, the current evidence base for VPA among young adults is not sufficient to support the development of a new set of national PA guidelines that specifically recommend VPA to young adults. In the future, research studies on this topic should involve longer duration interventions, longer follow-up periods, larger sample sizes of both genders, and evaluate different types of high-intensity exercises in young adults.

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