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THE EFFECT OF STRENGTH TRAINING ON THE CARDIOVASCULAR SYSTEM

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Abstract

Aim: The purpose of this study was to review the current literature on the effects of exercise duration and intensity, physical fitness, and specific types of training/sport on long-term cardiovascular health.

Methods: A systematic review of recent studies was conducted using PubMed. Studies assessing fitness, exercise dose/type, and cardiovascular health were included as a priority.

Conclusion: Epidemiological studies have suggested that cardiorespiratory fitness is inversely associated with the risk of all-cause mortality, with no increased risk observed in the fittest cohort. Recent evidence suggests that high-intensity resistance training may be more effective than low-intensity training for promoting acute myofibrillar protein synthesis, triggering neural adaptations, and increasing long-term muscle strength. Additionally, several studies have shown that high-intensity resistance training has a lower impact on arterial blood pressure and cardiac output, potentially making it a safer option for individuals with cardiovascular conditions. Furthermore, strenuous exercise and weightlifting may not be ideal for optimizing longevity.

Keywords: Cardiovascular, Exercise, Strength Training, Rehabilitation

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Özet

Amaç: Bu çalışmanın amacı, egzersiz süresi ve yoğunluğu, fiziksel uygunluk ve belirli eğitim/spor türlerinin uzun vadeli kardiyovasküler sağlığı üzerindeki etkilerine ilişkin güncel literatürü incelemektir.

Yöntem: PubMed kullanılarak son çalışmaların sistematik bir incelemesi yapılmıştır. Uygunluğu, egzersiz dozunu/türünü ve kardiyovasküler sağlığını değerlendiren çalışmalar öncelikli olarak dahil edilmiştir.

Sonuç: Epidemiyolojik çalışmalar, kardiyorespiratuvar uygunluğun her türlü ölüm riskiyle ters orantılı olduğunu ve en uygun kohortta artmış bir risk gözlemlenmediğini ileri sürmüştür. Son kanıtlar, yüksek yoğunluklu direnç antrenmanının akut miyofibriler protein sentezini teşvik etmek, nöral adaptasyonları tetiklemek ve uzun vadeli kas gücünü artırmak için düşük yoğunluklu antrenmandan daha etkili olabileceğini ileri sürmektedir. Ek olarak, birkaç çalışma yüksek yoğunluklu direnç antrenmanının (intra) arteriyel kan basıncı ve kardiyak çıktı üzerinde daha düşük bir etkiye sahip olduğunu ve potansiyel olarak kardiyovasküler rahatsızlıkları olan bireyler için daha güvenli bir seçenek haline getirdiğini göstermiştir. Ayrıca, yorucu egzersiz ve halter uzun ömürlülüğü optimize etmek için ideal olmayabilir.

Anahtar kelimeler: Egzersiz, Kardiyovasküler, Kuvvet Antrenmanı, Rehabilitasyon

1. INTRODUCTION

Cardiovascular rehabilitation is a complex intervention that improves the functional capacity, well-being, and health-related quality of life of patients with heart disease. There is a solid evidence base showing that cardiac rehabilitation is a clinically effective and cost-effective intervention for patients with acute coronary syndrome or heart failure exhibiting reduced ejection fraction and heart failure after coronary revascularization (Taylor et al., 2022; Piepoli et al., 2016). Studies have shown that this intervention can significantly reduce fatal events in patients with coronary artery disease and cardiac hospitalizations in patients with heart failure (Rauch et al., 2016; Lewinter et al., 2015). Conversely, physical activity plays a critical role in improving lifespan and health (Thompson et al., 2022). However, studies on the optimal duration, intensity, and types of exercise to promote lifelong CV health, longevity, and overall health are scarce. To address this issue, a systematic review of studies published in this area was conducted using PubMed. Search terms included exercise, physical activity, CV fitness, sports, outdoor activity, longevity, health, CV events, and CV mortality.

2. EXERCISE DOSE AND INTENSITY AND MORTALITY REDUCTION

Lee et al. (2022) conducted a long-term prospective cohort study to evaluate the associations between the duration and intensity of leisure-time physical activity and all-cause and cause-specific mortality. Higher levels of vigorous and moderate-intensity leisure activities provide maximum benefit in reducing mortality. Although this study is arguably the best long-term prospective epidemiological study on exercise dose and mortality reduction, its results may be somewhat misleading due to overgeneralization.

The association between exercise dose and risk of death during follow-up were markedly different for vigorous physical activity (VPA) and moderate physical activity (MPA). First, very high levels of moderate-intensity physical activity reduced the risk of cardiovascular disease (CVD) death and all-cause mortality significantly better than very high levels of vigorous physical activity. Second, reductions in cardiovascular disease mortality and all-cause mortality were maximal at 150 min/week of vigorous physical activity; vigorous physical activity dose of 150 min/week was associated with a plateau in all-cause mortality and a modest but progressive reduction in cardiovascular disease mortality (slightly inverted J curve) at higher doses. Conversely, moderate-intensity physical activity reduced cardiovascular disease mortality and all-cause mortality in a dose-dependent, inverse association; the higher the dose of moderate physical activity, the lower the number of deaths during the study.

In a study conducted by the Harvard School of Public Health, 116,221 individuals were followed over a period of 30 years and assessed 15 times to determine the effects of exercise intensity on long-term cardiovascular health and overall longevity. These findings suggest that moderate-intensity exercise is more beneficial for those seeking to improve cardiovascular health and longevity. However, this does not apply to vigorous exercise, which has optimal benefits of approximately 150 min per week. Examples of moderate physical activities include walking, hiking, gardening, housework, dancing, shopping, golfing, double tennis, volleyball, and leisure biking. On the other hand, vigorous physical activity includes activities such as strenuous cycling, running, swimming, or high-intensity interval training (HIIT), singles tennis, basketball, or other activities that increase heart rate, sweating, and shortness of breath. This finding supports the hypothesis of overexertion cardiotoxicity/cardiac overuse injury, particularly in middle-aged and older adults (3-5). Although high-intensity vigorous exercise is necessary for peak physical performance, it may not be necessary to maximize life expectancy and cardiac endurance. Highly strenuous exercise can increase the risk of cardiovascular disease events, such as myocardial infarction and sudden cardiac arrest, especially in middle-aged and older individuals (Schnohr et al., 2015; Franklin et al., 2020). Admittedly, these catastrophic cardiovascular disease events are very rare, but more common problems, such as orthopedic injuries and overtraining, may force individuals to reduce or abandon their high-strength exercise regimens.

Moderate physical activity may reduce CVD risk and increase life expectancy. Survival Curves by Cardiorespiratory Fitness Categories, as measured by time on the Bruce protocol treadmill exercise test (Kokkinos et al., 2022). 13 Used with permission. Although chronically performing very high-dose vigorous physical activity may attenuate some of the benefits provided by less vigorous exertion, this effect was observed in only 2.5% of the adult population of the United States (US) (O'Keefe and Lavie, 2022). This finding does not mean that vigorous physical activity is harmful; compared with a sedentary lifestyle, vigorous physical activity significantly reduces all-cause mortality and cardiovascular disease mortality. However, the magnitude of the reduction in mortality and cardiovascular disease risk with high-intensity physical activity does not appear to be as significant as that with high-intensity moderate-intensity physical activity (Schnohr et al., 2018; Schnohr et al., 2021).

In the Lee study, very high-intensity chronic exercise reduced all risks. It was associated with at least twice as high mortality and cardiovascular disease mortality as extremely high-dose exercise.

At the other extreme, a sedentary lifestyle, which affects approximately half of the U.S. adult population, is associated with poorer health outcomes and reduced life expectancy (O'Keefe and Lavie, 2021; Dunstan et al., 2021). Blood sugar, triglyceride, and inflammatory marker levels begin to rise after sitting for >60 min (Dogra et al., 2019). Even light or moderate exercise mitigates the negative effects of sedentary behavior without significantly increasing the risk of orthopedic or cardiovascular injury.

Over the last three million years of hominin evolution, our ancestors' existence required a physically active lifestyle. Adults typically take between 14,000 and 16,000 steps per day, often walk 3–8 miles, and carry objects, such as firewood, food, water, and children (O'Keefe et al., 2010; Irimia et al., 2021). Daily subsistence in hunter-gatherer humans requires large amounts of vigorous physical activity interspersed with smaller doses of vigorous physical activity, an activity pattern genetically adapted to humans (O'Keefe & Lavie, 2021; O'Keefe et al., 2018). This evolutionary template provides a logical guide for creating ideal activity patterns that promote optimal health and longevity. The best survival rates among both men and women were those who achieved the highest exercise level of 14 metabolic equivalents (METs). An increased risk of premature death was not noted in the fittest cohort (Kokkinos et al., 2022; Lavie et al., 2022). Importantly, being in the least fit cohort had a greater risk of death, as did other traditional risk factors such as age, diabetes, smoking, chronic kidney disease, hypertension, atrial fibrillation, obesity, previous cardiovascular disease, and cancer.

3. HIGH-INTENSITY INTERVAL TRAINING

Clearly, there is an increased risk of cardiovascular events in patients with pre-existing cardiovascular diseases who undergo high-intensity strength training (HIST). However, it is important to note that these patients are typically under the direct supervision of trained clinicians during rehabilitation programs (Myers et al., 2009). Exercise training facilities are specifically designed and equipped to monitor and prevent adverse events during exercise (Myers et al., 2009). This may explain why the likelihood of experiencing adverse cardiovascular events during dynamic strength training in cardiovascular rehabilitation units is actually quite low, or at least not significantly higher than that during endurance training (Hollings et al., 2017; Marzolini et al., 2012). Furthermore, there is currently no established correlation between dynamic strength training intensity and the incidence of adverse cardiovascular events during rehabilitation (Hollings et al., 2017; Marzolini et al., 2012)

An alternative to maintaining a high CRF without engaging in large volumes of intense physical activity is high-intensity interval training, an effective exercise regimen characterized by short, repeated bouts of intense exercise (Ito, 2019). High-intensity interval training protocols lead to better improvements in maximal oxygen uptake than continuous moderate- or strenuous long-duration sessions, resulting in better fitness and a lower risk of injury.17 High-intensity interval training sessions performed once or twice per week may help achieve high-intensity fitness without the need for strenuous, prolonged exercise (Ito, 2019; Mendelson et al., 2022). This regimen maintains very high fitness levels but does not plateau in the longevity benefits that appear to occur with high-intensity physical activity.

Clearly, aerobic fitness as measured by treadmill performance is a strong predictor of life expectancy, but other dimensions of physical fitness, including strength, balance, flexibility, and body composition, have also been shown to be important for optimal functioning and well-being. These non-aerobic fitness parameters also exert significant independent effects on life expectancy and health.

4. J-SHAPED RISK REDUCTION AFTER STRENGTH TRAINING

A recent comprehensive meta-analysis reported that approximately 30–60 minutes of strength training (also referred to as resistance training) per week was associated with a significant 17% risk reduction in all-cause mortality, 18% in cardiovascular disease events, and 9% in cancer-related mortality (Momma et al. 19). The combined analysis of strength training and aerobic activities revealed greater benefits for all-cause mortality, cardiovascular disease mortality, and total cancer mortality when the two types of exercise were combined. This important finding of synergy between aerobic fitness and resistance training has been confirmed in previous meta-analyses and strongly suggests that adding muscle-strengthening activities to routine cardio activities may provide additional benefits in preventing disease and improving life expectancy (Momma et al. 2022; Saeidifard et al, 2019).

However, in a recent comprehensive meta-analysis by Momma et al. (2022), the survival curves were J-shaped; the benefits of resistance training lasting approximately 130–140 min per week were completely lost, with potential harms emerging at progressively higher doses (Momma et al., 2022). Another meta-analysis showed that resistance training sessions once or twice per week were associated with a reduced risk of all-cause mortality; however, increasing the frequency to three or more sessions per week did not have this effect. 20 In contrast, aerobic exercise follows an inverted J-curve, where some benefits for cardiovascular health and life expectancy may be lost during the most strenuous exercise, but even very high doses of vigorous physical activity do not increase the risk of premature death or cardiovascular disease compared with a sedentary lifestyle (Schnohr et al., 2021; O'Keefe et al., 2020).

Inactive adults lose 3%–8% of their total muscle mass per decade, accompanied by increased fat accumulation and decreased resting metabolic rate (Westcott, 2012). Strength training can reverse these abnormalities by increasing muscle mass and the resting metabolic rate, leading to a decrease in visceral fat (Westcott, 2012). Resistance training also improves physical performance, cognitive function/mood, blood pressure, insulin sensitivity, glucose metabolism, and lipid levels (Westcott, 2012; Lu et al. 2022). Additionally, strength training increases bone mineral density and functional independence and supports cardiovascular health (Westcott, 2012; Lu et al. 2022). The World Health Organization (WHO) recommends that muscle-strengthening activities be performed at least twice per week (Bull et al., 2020).

Grip strength is a useful biomarker of aging (Lu et al. 2022). Strong observational evidence suggests that grip strength can be used to assess current and future strength, physical functioning, bone mineral density, fracture risk, and hospitalization risk (Bohannon, 2019; Wu et al., 2017). Grip strength is also highly predictive of many health outcomes, including all-cause and disease-specific mortality and, surprisingly, cognitive function (Bohannon, 2019; Wu et al., 2017). Weightlifting, gardening, and competitive sports are all practical strategies for maintaining or improving grip strength.

5. OTHER FITNESS DIMENSIONS: BALANCE, FLEXIBILITY, AND BODY COMPOSITION

Balance is an aspect of fitness that declines rapidly from about age 50. A person's ability to balance the body can be assessed by standing on one leg alone. In a prospective study of 1,702 individuals who were followed-up for 7 years, the ability to successfully complete a 10-second one-leg stand test was independently associated with all-cause mortality (Araujo et al., 2022). In a multivariable-adjusted model that included age, sex, body mass index, and other comorbidities, the risk of all-cause mortality was 84% higher in the group that could not stand on one leg for 10 seconds without losing balance and having to put the other foot on the ground ($P<0.001$). 27 Furthermore, the ability to stand on one leg for 10 seconds provided incremental prognostic information beyond age, sex, and other relevant fitness and clinical variables (Marcori et al., 2022). The balance is highly trainable. Yoga and tai chi are forms of moderate-intensity physical activity performed in social settings that improve balance and flexibility (Welford et al., 2022).

Getting up from the floor is a fundamental task for autonomous functioning. The sit-to-stand test (SRT) is a simple and rapid assessment based on the ability to sit down on the floor and then get up (Araujo et al., 2020). Scores from 0 to 5 are awarded, with one point awarded for each sit-to-stand phase. Five points are subtracted for each used support (hand, forearm, and knee); two points are added, giving a maximum score of 10. The sit-to-stand test simultaneously assesses the basic non-aerobic components of physical fitness (flexibility, balance, muscle strength, and body composition), which are important for optimal functioning and survival.

A prospective study of 2,002 individuals aged 51 to 80 years showed that low Sit-to-Stand test scores were associated with a higher risk of all-cause mortality during follow-up (Brito et al., 2014). A low score on the Sit-to-stand test is associated with a sixfold higher risk of all-cause mortality; the majority of deaths in this study occurred in participants with low Sit-to-Stand test scores (Brito et al., 2014). In contrast, only two subjects with perfect Sit-to-Stand test scores of 10 (the ability to sit and stand without placing the hand or knee on the floor) died during the 1-year follow-up period (Franklin et al., 2020; Schnohr et al., 2018). The predictive power of this simple test, which does not require aerobic effort, was similar to that of cardiorespiratory fitness measured using the treadmill test.

6. POWER OF PLAY: EXPLORATORY STUDY OF THE POWER OF PLAY

The best forms of exercise for improving life expectancy and mental health are social sports such as tennis, golf, badminton, sicklebill, soccer, basketball, volleyball, softball, touch football, baseball, and group exercise. Activities that involve interactive physical play not only improve fitness but also enhance interpersonal bonding, and reduce stress. In the Copenhagen City Heart Study, adults who frequently participated in tennis, other racket sports, or team sports, such as soccer, lived significantly longer than those who were sedentary (Schnohr et al., 2018). After statistical adjustment for multiple potential confounders, people who participated in social sports also had longer life expectancies than those who regularly participated in other forms of exercise, some of which are strenuous but typically performed alone, such as running, swimming, and cycling (Schnohr et al., 2018). The finding that interactive social sports have a halo effect on health, well-being, and longevity has been confirmed in other large prospective registry studies (Chekroud et al., 2018; Oja et al., 2017). Approximately three in four adults in the United States participate in some form of sport during school and early adulthood, but unfortunately, after age 25, only one in four people still participates in sports regularly (Blendon et al., 2015).

Social support independent of exercise has strong positive effects on health, well-being, and life expectancy (Holt-Lunstad et al., 2010). Participating in team sports or group exercise not only provides the physical health benefits of exercise but also promotes interpersonal connection and tends to improve mood and reduce anxiety (Chekroud et al., 2018). Therefore, playing a sport that requires a partner or team or doing group exercise may result in different psychological and physiological effects that enhance the benefits of exercise (Schnohr et al., 2018). Furthermore, because interactive physical play is often perceived as fun, participants tend to engage in it more often than in an unenjoyable workout.

7. NATURE THERAPY

A growing body of evidence suggests a positive association between time spent in natural environments and good mental and physical health (White et al., 2016). A recent study assessed the dose-response relationship of "nature therapy" by focusing on the amount of time spent outdoors during a typical week among 19,806 adults, either in green spaces, such as parks, woodlands, and countryside or blue spaces such as lakes and beaches (White et al., 2019). Those who spent 120 min per week in nature were 59% more likely to report good health and 23% more likely to report not spending any time in nature. The authors concluded that spending at least two hours per week on outdoor recreation time may be a threshold for reaching the benefits of nature in terms of health and well-being.

In particular, exposure to nature has been shown to have numerous health and mood benefits, even when a person is not actively exercising in a natural environment (White et al., 2019). One popular therapy in Japan, known as Shinrin-yoku or forest bathing, has been found to have positive effects on both psychological and cardiovascular health. Studies have shown that being in natural environments such as forests, mountains, lakes, and streams can lead to reduced blood pressure and heart rate, as well as lower levels of cortisol and inflammatory markers (Park et al., 2010). Additionally, research suggests that engaging in physical activity in nature may have greater psychological benefits compared to exercising in other settings (Thompson et al., 2011). Gardening, a popular leisure activity worldwide, also offers a practical way to immerse oneself in nature and reap its benefits. This activity involves relaxation, multidirectional movement, exposure to potentially beneficial microbes, and sunlight, all of which have been consistently linked to physical and mental health benefits, as well as longevity (Soga et al., 2016).

Dog exercise is typically done outdoors. According to a study by Westgarth et al. (2019), individuals who own a dog are 14 times more likely to engage in recreational walking and four times more likely to meet the recommended 150 minutes of exercise per week compared to those who do not own a dog ($P < 0.001$). This

highlights the positive impact that dog ownership can have on physical activity levels. Furthermore, a nationwide study in Sweden with over 3 million participants and 12 years of follow-up found that owning a dog was associated with a 33% reduction in all-cause mortality and a 36% reduction in cardiovascular disease mortality for individuals living alone (Mubanga et al., 2017). Even those living in multi-person households saw a significant decrease in their risk of disease, with an 11% reduction in all-cause mortality and a 15% reduction in cardiovascular disease mortality. These findings demonstrate the potential health benefits of dog ownership for both individuals and families.

8. CONCLUSION

Moderate-intensity exercise is recommended for improving cardiovascular health and increasing life expectancy in the rehabilitation of various cardiovascular diseases. While vigorous exercise can also be beneficial, the maximum benefits are achieved at 150 minutes per week. The intensity of strength training is a topic of debate, with recent studies suggesting that high-intensity dynamic training may be more effective in increasing muscle strength while having lower cardiovascular demands. Additionally, regular participation in team sports or other physical activities can have positive effects on mental health and longevity. Spending at least two hours per week exercising outdoors in natural environments is highly beneficial, and activities such as gardening and owning a dog can help achieve this goal. It is recommended to aim for two sessions of strength training per week, totaling 40-60 minutes, and to also incorporate flexibility and balance training. Adequate rest, relaxation, and sleep should also be prioritized after strenuous exercise.

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