Cardiovascular Adaptation to Exercise

by

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Introduction:

Cardiovascular disease (CVD) is the leading cause of death worldwide. It encompasses disorders of the heart and blood vessels including coronary heart disease (CHD), aortic disease, peripheral arterial disease, and causing strokes, heart attacks, and clogged arteries. Due to the high prevalence of cardiovascular disease and related risk factors, it is important for individuals worldwide to recognize the potential risks as well as activities shown to minimize the risks of cardiovascular disease. CVD-related risk factors are associated with central and peripheral blood pressures, blood cholesterol, blood glucose, lipid profile, cardiorespiratory fitness, body composition, and muscular strength. Studies have shown that controlling blood glucose, consuming a healthy diet, and practicing healthy lifestyle habits can lower cardiovascular-related disease risks, though, the leading cause of cardiovascular disease is based on sedentary lifestyle habits. Evidence suggests that higher rates of fitness and physical activity can decrease the risks for cardiovascular disease and potentially reverse all-cause mortality rates (1). Physical activity is considered voluntary muscle movement resulting in energy expenditure, circulation, and an increased supply of oxygen (2). Variations can range from resistance training to aerobic exercises of different durations and intensities.

This review focuses on the effects of physical activity on cardiovascular adaptations. Primary research articles were analyzed for trends in the data, patterns in methods and results, contradictions, and gaps in the research. The main factors examined concern specific cardiac mechanisms, types of physical activity, cardiovascular disease risks, disease prevention, and the general quality of life associated with cardiovascular health.

Biological Mechanisms:

It is well-known that there are many benefits of exercise to cardiovascular health and wellness that lead to reductions in disease severity and longevity. In a randomized study designed to quantify the risk factors associated with cardiovascular disease concerning exercise, underlying mechanisms are assessed (3). Healthy female participants aged 45 and older and working as health care professionals were evaluated based on lifestyle factors, medical history, anthropometrics, and demographics. Health-related biomarkers were taken at the beginning and assessed throughout the study including hemoglobin A1C, homocysteine, traditional lipids, creatine, novel lipids, hemostatic biomarkers, and inflammatory biomarkers. Participants filled out questionnaires to self-report physical activity levels so total estimated energy expenditure could be determined. Participants were divided into groups based on relative risk for cardiovascular diseases such as potential confounders, activity level, and pathophysiological condition. The reference group participated in less than 200 kcal/week of activity, while test groups participated in more than 1500, 600-1499, and 200-599 kcal/week. After adjustments were made for randomization and age, the relative decrease in disease risks showed 41%, 32%, and 27% reductions, while a total of 59% of cardiovascular disease risk was associated with potential mediators. To determine associated physiological pathways, test groups with varying

risk factors were added one at a time. The data showed that CVD risk factors related to inflammation, hemostasis, and blood pressure showed the greatest improvements in cardiac function as a result of physical activity, and a linear relationship was determined between cardiovascular disease risks and physical activity. Higher rates of physical activity were associated with a lower incidence of cardiovascular disease and lower rates of physical activity were associated with higher rates of the disease. The study indicates that the association between the reduced incidence of cardiovascular disease in people with higher levels of physical activity can be explained by the presence and accumulation of potential mediators. The evidence suggests that higher rates of physical activity can alter the mechanisms underlying these mediators to reduce their chances of causing long-term, chronic cardiovascular disease. While previously attributed mostly to body weight, other pathways shown to be modified by physical activity include alterations in the insulin sensitivity pathway, effects on antioxidant and hemostatic activity in the coronary artery, and modified adipokine activity. Oxidative stress due to age and toll-like receptors associated with chronic inflammation was reduced with higher rates of physical activity as well.

Another study designed to evaluate the sub-cellular and molecular pathways in the body associated with training and cardiovascular function parallels these findings attributing the improvements of physical activity on cardiovascular health to the presence of potential risk factors and their underlying mechanisms (4). Though previous studies have shown the relationship between physical activity and changes in sodium and calcium activity, sarcoendoplasmic reticulum calcium transport ATPase, and phospholamban, findings are inconsistent. This study focused on the pathways involving calcium sensitivity and transport through the sarcoendoplasmic reticulum ATPase, and how it affects the strength of contractility, handling, and myofilament formation in cardiac muscle cells. Rats with failing and healthy heart function were analyzed and compared. Thirty-six female rats were divided into four groups based on the presence of infarction while training or sedentary, and sham surgery groups were also analyzed while training or sedentary. In order to study cardiac myocytes, rat hearts were removed, measured, and kept in a buffer solution. Cells were isolated from the myocardium left ventricular wall, centrifuged, and separated from the supernatant. Cell shape and length were analyzed and compared between the groups to determine differences between groups participating in aerobic interval training with sedentary groups. Calcium sensitivity was evaluated by corresponding cell length. Trained rats showed significantly increased cell shortening indicating greater strength of myofilament contractions. This is associated with improved cardiac function due to an improved ability of the heart to contract and pump blood throughout the body. Improvements also correlate with an increased stretch response, loading capacity to the heart, decreased peripheral resistance and increased endothelial function. Heart rate was monitored resulting in a lower heart rate, increased maximal uptake of oxygen, and a higher stroke volume in trained rats. Differences in gene expression appeared between trained and untrained groups such as in insulin-like growth factor, sarcoendoplasmic reticulum ATPase,

and atrial natriuretic peptide messenger RNA, attenuated in trained groups. This indicates improved cardiac function because it is associated with higher contractility of the cardiac muscle, higher sarcoendoplasmic reticulum ATPase activity, and less stress to ventricular walls of the heart.

Both studies showed significant improvements in cardiac function as a result of increased physical activity associated with the underlying biological mechanisms found to cause cardiovascular disease risk factors.

Types of Physical Activity:

It is well known that an active lifestyle benefits overall health and wellness as well as individual risks for disease. However, physical activity can encompass a wide range of different types of exercise. Physical activity is characterized by voluntary muscle movement resulting in energy expenditure, circulation, and an increased supply of oxygen. Many studies that address the implications of physical activity on cardiovascular function are centered specifically around aerobic exercise training. However, quantity, intensity, and type of exercise may alter the results. A study was designed to compare the effects of resistance training, moderate-intensity aerobic exercise, and a combination of the two types of exercise to evaluate changes in body weight, dietary intake, fat mass, fasting measures of glucose, insulin, and lipids, and cardiovascular risk in overweight and obese individuals (5). Since many physiological improvements in health parameters are not evident following short periods of treatment, participants were tested over the course of twelve weeks. Ninety-seven participants were randomized and divided into four groups based on training modalities. One group participated exclusively in resistance training, one group participated exclusively in aerobic exercise, one group participated in a combination of resistance and aerobic training, and the final group was used as a control. Although aerobic exercise correlates the strongest with visceral fat loss, the most significant improvements were seen in the group participating in a combination of both resistance training and aerobic exercise. Parameters including body weight, total body fat, abdominal fat, and cardiorespiratory fitness all showed the highest improvements due to combination training. Although fasting blood glucose, blood insulin, cholesterol, and triglyceride levels were not altered initially, results at the end of the study showed improvements in all of these parameters, with the combination training group showing the greatest improvements. This study concluded that compared to no exercise, any exercise, in general, will show significant benefits to various health parameters including cardiovascular health and fitness.

As well as types of exercise, physical activity can vary from low to high duration with different levels of physical exertion. Therefore, it is also important to consider the quantity and intensity of exercise (6). Surprisingly, one study found that higher intensity exercise did not necessarily correlate with increased cardiovascular health benefits, but that moderate-intensities of multiple types of resistance and aerobic training may be more ideal. In this study, middle to older aged

males were divided into multiple test groups based on the quantity of energy expended during physical activity. The group expending the lowest amount of energy per week expended less than 2,100 kilojoules per week. The group expending the most energy per week expended at least 12,600 kilojoules per week. The data showed a U-shaped curve associated with training intensity and relative risk for coronary heart disease with moderate intensity exercises showing the lowest risk for coronary heart disease. However, this study recognizes that these findings may be due to misclassifications in the data. Over longer periods of time, data may fluctuate. In terms of quantity, participants spending the lowest amounts of energy on physical activity (2,100 kilojoules per week) were associated with the highest risks for coronary heart disease. Test groups expending 2,100 to 4,199 kilojoules per week actually showed improvements in risk, but participants spending the highest amounts of energy on physical activity (12,600 kilojoules per week) showed the lowest risks for coronary heart disease. This study concluded an overall L-shaped curve in terms of both training intensity and quantity associated with the relative risk for coronary heart disease. Men should spend at least 4,200 kilojoules per week on physical activity to reduce their risk for coronary heart disease.

Both studies showed significant improvements in cardiac function as a result of increased physical activity. The most significant improvements to cardiovascular disease risk factors were associated with a combination of both resistance training and aerobic interval exercises, moderate-intensity training, and a total quantity of energy expended of at least 4,200 kilojoules per week.

CVD risks:

The individuals concerned and participants observed in studies involving cardiovascular disease risk factors are most often individuals already associated with one or multiple of these risk factors. Therefore, it is important to understand how results may be altered by individuals of different subgroups and disease states. In conjunction with cardiovascular disease prevention, studies observe cardiovascular disease management as well as prevention in individuals with diseases such as type 2 diabetes mellitus. Type 2 diabetes mellitus is a disease risk factor and in many cases often results in cardiovascular disease. A study designed to evaluate the mechanisms associated with cardiovascular disease in women with type 2 diabetes mellitus examines the effects of physical activity on vascular and left ventricular function in postmenopausal women (7). Twenty-eight subjects were divided into a control group and groups participating in ten weeks of physical activity regimens consisting of a combination of resistance training and aerobic exercises that increased in quantity and intensity every week. Carbon dioxide production and oxygen intake values were assessed at baseline and periodically during exercise and resting periods. Arterial compliance and vascular function were measured. Fasting blood glucose, insulin, triglycerides, hemoglobin A1C, and low and high-density lipoproteins were measured. The data suggests that the most significant findings were associated with improved cardiorespiratory fitness as well as large artery compliance in groups participating in physical

activity regimens, while cardiovascular disease risk factors and left ventricle filling dynamics remained unchanged. These findings imply the benefits of exercise even following the development of cardiovascular disease risk factors.

A study designed to evaluate the effects of fitness levels associated with cardiovascular disease risk examined individuals of varying body mass indices. Subjects participated in exercise tests and physical examinations assessing weight and height to calculate body mass indices. Cardiorespiratory fitness levels were measured by an estimation of maximal heart rate during treadmill training exercises while an electrocardiogram continuously measured blood pressure. The duration of exercise was factored in to calculate the total fitness of each individual. Participants were then divided into groups based on activity level and categorized as either very active, moderately active, or inactive. Annual follow-up assessments provided data on changes to physical examination parameters and mortality rates. The results concluded that although higher levels of fitness do not entirely reverse the mortality of cardiovascular disease in individuals previously considered overweight or obese, higher levels of fitness were associated with lower rates of all-cause mortality from cardiovascular disease.

Both studies indicate significant evidence concerning the extent to which increases in physical activity may still benefit cardiovascular disease and associated risk factors in individuals already exhibiting CVD risk factors.

Conclusion:

Due to the prevalence and severity of cardiovascular disease worldwide, it is essential to understand the potential risk factors, underlying mechanisms, and methods of improvement for cardiovascular disease. Physical activity is one of the most accessible lifestyle modifications that can be utilized for the purpose of cardiovascular disease prevention and management. The current studies discussed in this review indicate significant improvements in cardiac function as a result of increased physical activity associated with the underlying biological mechanisms found to cause cardiovascular disease risk factors. Significant evidence showed reductions in cardiovascular disease risk factors associated with a combination of both resistance training and aerobic interval exercises, moderate-intensity training, and a total quantity of energy expended of ideally fifty to sixty minutes each day.

Despite strong evidence in favor of even small amounts of physical activity for general health and wellness as well as disease management and prevention, most people still do not participate in physical activity but live very sedentary lifestyles (8). Further research might investigate the extent to which increases in physical activity later in life may still benefit cardiovascular disease and associated risk factors. A study designed to evaluate the ability of physical activity to improve cardiac function examined middle-aged sedentary males (9). Sixty-one healthy but previously sedentary subjects participated in high-intensity exercise consistent with health

recommendations for two years. The results indicated improved cardiac functioning through decreased cardiac stiffness and enhanced maximal oxygen uptake. This presents some evidence supporting the ability for cardiovascular systems to adapt and improve in middle-aged adults. However, previous investigations may present potential gaps in the research. For instance, one study examines the relationship between lifestyle habits and cardiovascular risk factors with coronary artery calcium scores (10). The study suggests higher coronary artery calcium scores are associated with coronary artery disease in marathon runners participating in very high levels of physical activity.

Although strong evidence suggests significant benefits associated with physical activity to cardiovascular health, research suggests a total of only 59% of cardiovascular disease risk is associated with potential risk factors. The additional 41% of cardiovascular disease cases remains unknown. Further research must be done to better understand the underlying mechanisms and implications.

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