Physical Fitness and Health

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Understanding Health & Wellness

The term “health” has been defined in many ways, and even today, not everyone agrees on a universally accepted meaning. Traditionally, the concept of health has applied to a person’s susceptibility for disease. If a person did not have any diagnostic criteria for disease or present any known health problems, they were considered “healthy.” Health professionals determined health status based on specific, quantifiable health measurements, such as blood pressure, and any self-reported problems. The problem with viewing health from this narrow diagnostic perspective is that, 1) it considers disease or symptomatic criteria, which may not be known to the individual, and 2) it does not consider the person’s overall well-being as a defining characteristic. During the late seventies and early eighties, a broadened philosophy of health emerged that suggested viewing the person holistically, rather than by independent physiological measures. The term “wellness” evolved to reflect the combination of physical, mental, emotional, intellectual, social, and environmental health. The rationale was that each health-related component of wellness had potential implications for overall well-being. When individuals have control over these physiological and psychological areas, the negative impact each may have on health is reduced. For instance, good social health entails meaningful interrelationships and confident social interaction. Both are linked with reduced stress and a decreased risk for depression.

The concept of wellness is fairly mainstream among fitness professionals, but it is not a clearly understood term by the average population. Rarely will the term wellness be applied in conversation. Instead, people more often use the term healthy. Therefore, the term health is better understood as both the physical state of a person, and the assortment of lifestyle behaviors that affect that state, rather than simply being free from disease.

It is well-known and documented that health is affected by what enters the body, what the body is exposed to, and what the body is required to do each day. Therefore, lifestyle is the largest determinant to the outcome of these collectively-applied factors. Healthy lifestyle is defined as a group of actions and behaviors which positively affect a person’s overall well-being. A person who lives a healthy lifestyle avoids stress, eats nutritionally appropriate foods, avoids behaviors that may negatively impact health, and engages in routine physical activity. The U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion, has listed objectives to encourage healthy lifestyles by Americans in the Healthy People 2010 initiative. Through this initiative, Americans are being asked to take personal responsibility for their health through lifestyle management.

An important part of the plan to improve one’s health is to routinely engage in physical activity. For most people, the term physical activity is synonymous with exercise. However, from a health standpoint, exercise and physical activity have two distinctly different meanings. Physical activity is defined as a period of time physical acts are performed. The definition is independent of the quantity of work, oxygen demand, and resultant energy expenditure. Examples of physical activity include gardening, walking the dog, and cleaning the house. Exercise, on the other hand, is defined as planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness. Thus, exercise is physical activity, but physical activity may not be exercise. All types of physical activity can improve overall health, but exercise is physical activity with specific parameters that allow an individual to achieve defined outcomes when applied correctly.

Physical Fitness

Physical fitness is broken down into two categories: health-related physical fitness and performance-related physical fitness. The first category encompasses factors that quantifiably affect health, while the second category affects performance. The health-related components include cardiorespiratory fitness, muscular strength, muscular endurance, flexibility, and body composition. In some cases, metabolic fitness also qualifies as a health related component because it affects risk for metabolic disease including obesity and diabetes. The performance components of physical fitness include power, speed, coordination, balance, and agility. Each plays an important role in human performance and should be considered a secondary health component.

Health Related Components of Fitness

Health related components of fitness are fundamental to a person’s overall well-being. They reflect quantifiable measures of efficiency and proper functionality of the movement systems of the body. Appropriate values or improvements in each of the respective components will promote positive health, while high score values in these categories of fitness will benefit the individual beyond that of basic health attainment. Although high rankings in some categories may be desirable for certain goal-related outcomes, it is important to maintain an acceptable level of fitness within each of the five areas.
**Hyperlipidemia** – An excess of fats or lipids circulating in the blood.

**Cardiorespiratory Fitness (CRF)** - Refers to the ability and efficiency of the circulatory and respiratory systems to supply oxygen to working muscles during sustained activity.

**Coordination** - The harmonious adjustment or interaction of parts.

**Agility** - The ability of the body to change direction.

Individuals who score very well in one or two components of fitness may be less healthy than a person who maintains a moderate level of fitness in all the health categories.

**Cardiorespiratory Fitness**
Cardiorespiratory fitness (CRF) includes several synonymous terms: aerobic fitness or endurance, cardiovascular efficiency or endurance, and cardiorespiratory efficiency. These all represent the same thing: the body’s ability to consume and utilize oxygen. CRF is a factor of synergistic efficiency of the body’s systems, as it includes the cardiopulmonary system, cardiovascular system, and the muscular system. CRF is the single most important health-related component of fitness because it links to risk for disease and death. Low measures of total-body oxygen efficiency are a risk factor for heart disease, diabetes, and obesity (198). On the contrary, high levels of CRF are associated with positive health, including improved self-reported quality of life (43).

**Muscular Fitness**
Muscular fitness is the body’s ability to produce and sustain force output. It encompasses both muscular strength and muscular endurance. Muscular strength is defined as the body’s ability to exert a single maximal contractile force, whereas muscular endurance is the ability of muscle tissue to sustain force output or apply force for an extended period of time. Muscular fitness is essential for health because it determines movement capabilities, affects joint health, and is responsible for posture and stability. Low levels of muscular fitness are linked to functional decline and loss of independence (20). Beyond functional demands, the actual amount of strength and endurance needed by an individual is specific to the types of activities he or she participates in on a routine basis.

~Quick Insight~

Many people believe that health and fitness are synonymous, but this may not always be the case. Health is a disease-free state of well-being that allows an individual to experience improved quality of life and independence. Fitness is a criterion-based measure of physical performance. A person does not have to be fit to be healthy, nor is a person guaranteed health because they are fit. Certainly, the two are interrelated, but distinct differences exist. An example of the differences can be seen in emotional, psychological, and physical assessment. A person who scores satisfactorily in the health-related components of fitness may be deemed fit by defined criteria, but experience high stress on the job, eat a diet high in saturated fats, and have hypertension and hyperlipidemia. The person is fit, but not necessarily healthy. On the other hand, a person may not score well on the assessments of physical fitness, but eat a very healthy diet, get enough physical activity to maintain functional performance levels, have low blood pressure, and a reasonable lipid profile. In this case, the person is classified as healthy but not physically fit.

In measures of skill or performance-related fitness, this difference can be even more significant. A person may show respectable scores in agility or on a vertical jump test but not be healthy by several categorical measures. Performance-related fitness is affected by genetics, exercise, and physical activity, but the activities that improve performance may not necessarily improve health. A weightlifter may exhibit high levels of power and low levels of cardiorespiratory fitness. Likewise, a person may have excellent balance and coordination, but be measured as obese. Skill measures are poor indicators of health, although people who score well on them often do so because they participate in sports and related physical activities.

When the level of physical activity is assessed in relation to health and fitness, there are two different criteria used to define acceptable values. Health simply requires routine physical activity of appropriate frequency and duration. Fitness requires a regimented program, designed to emphasize the specific components of health-related physical fitness. In general, moderate fitness may be attained from exercise performed 3 days a week at an intensity level of 60-70% of maximum. High level fitness however, often requires 4-6 days a week at 75-90% intensities.
Flexibility
Flexibility is probably the most undervalued and least-emphasized component of health-related fitness by most physically active adults. Anecdotally, this is likely due to three factors: 1) there is no vanity associated with improvements in flexibility; 2) high levels of flexibility are not needed to participate in most activities; and 3) the training is often viewed as time-consuming, boring, and uncomfortable. This being said, flexibility is actually one of the most important components of physical fitness. Flexibility is tied into joint function, movement capabilities, risk for injury, and chronic pain. More importantly, it is associated with functional decline and is both a direct and indirect variable of health problems that can lead to disability in older adults (37; 160).

Body Composition
Body composition is defined as the ratio of fat mass to fat-free, or lean mass. Most people incorrectly view body composition as the amount of fat individuals maintain on their bodies. Although it is often expressed as a percentage of body fat, the important factor is the ratio. For example, a person measured at 20% body fat would see a decline in the percentage of fat by adding muscle. This occurs without actually changing the quantity of fat on the body because it is expressed as a percentage. However, individuals who lose muscle mass without changing body-fat mass will show an increase in fatness when expressed as a percentage. When analyzed for health risk, the percentile relationship is evaluated, not the actual pounds of fat on the body. Body composition is tightly linked with metabolic fitness and health (165; 218). The more lean mass a person maintains, the better their overall ability to manage caloric balance and the lower their respective body composition will be when expressed as a fat percentage (175). Body composition directly correlates to risk for disease (197). Individuals who maintain high levels of body fat dramatically elevate their risk for disease and premature mortality.

Performance Related Fitness
Performance related fitness components have classically been the emphasis of sports-related conditioning for obvious reasons. Individuals looking to excel in competitive sports often train to improve nervous system function to enhance these particular components. In more recent years, an emphasis on the performance components has been placed on training for improved overall function. Power, speed, balance, coordination, and agility all have implications for health because they indirectly affect the health-related components. Without power, a person cannot rise from a chair; poor balance and coordination increases the risk of falls; gait speed decline correlates to functional decline (36; 159). Personal trainers should recognize the importance of integrating the performance components of fitness into exercise prescriptions for improved health, even in those clients who are not training for a particular sport. This is not to suggest training all clients with power cleans and high-speed pro agilities, but rather emphasizes utilizing activities that encourage improvements in neural contribution to these areas of human performance.
Power
Power is the speed at which work is performed. In performance enhancement, the focus is on acceleration. When power is emphasized in conditioning programs for athletes, the ability to move resistance at high speeds is fundamental. The Olympic lifts, plyometrics, and weighted throws all emphasize acceleration by calling on recruitment patterns which elicit the fastest development of force. This is necessary to improve jumping distance, forward drive, and speed. When power is viewed from a functional standpoint, it suggests the ability to generate adequate force velocity to allow body segments to effectively utilize momentum forces. For instance, getting up from a seated position requires powerful movements by the hip extensors to move the trunk anteriorly to assist in hip and knee extension. Individuals who lose this ability also increase risk of losing independence (35; 158). Many older adults find it difficult to get out of chairs or their car because of sarcopenic (muscular atrophy) decline. Thus, personal trainers should encourage power development in their exercise programs.

Speed
Speed is the ability to move the body or body parts (rate of positional change) over a distance in a period of time. Speed of movement also depends upon neural recruitment patterns and adequate muscle capabilities. Speed is crucial to successful athletic performance and is often considered to be the most valued performance measure in many sports. When speed capabilities are applied to the faculties of function, there is a noticeable age-related decline in older adults (206). The rate of decline is contingent on several health-related factors. Individuals who maintain higher levels of activity experience a slower rate of decline compared to their non-active counterparts. Movement speed should be appropriately addressed in activities designed for improved bodily function.

Balance
Balance can be described as the ability to manage forces which act to disrupt stability. Consistent with the other performance components, the nervous system plays the largest role in manipulating muscle tension to accommodate demand. Balance is needed in many occasions for sport and daily life activities in order to appropriately manage forces encountered in unstable environments and varying conditions. The stabilizing function of the muscles is used for efficient posture, movement, and body control during more dynamic applications. To improve balance, adequate strength, synergy of force and neural familiarity must be attained. When the body is appropriately challenged, the applied stress promotes improved neuromuscular coordination, which, in turn, enhances balance. Employing balance training across population segments encourages improved function and performance on several levels (11; 84). For the athlete, this means better management of force at higher speeds; for the general public, this suggests reduced risk of injury from falls or related accidents.

Coordination
Coordination is synonymous with neural efficiency. The better force is managed, the easier the body performs tasks. Webster’s dictionary definition implies that coordination is the regulation of diverse elements into an integrated and harmonious operation. Coordination means integrating or linking together different parts of an organization to accomplish a collective set of tasks. For instance, hand-eye coordination suggests combining visual data with neuromuscular control. High levels of coordination associate with execution proficiency, which is integral to sports performance. Adequate levels of coordination are needed to perform tasks safely and in a controlled manner. Although coordination is required for all physical activities, high levels are not necessary for health improvement.
Agility

Agility is the ability of the body to change direction and implies the quantifiable capability of being nimble. In object-based sports, agility allows the athlete to physically pursue the ball, puck, or other object that is constantly changing direction. Agility is often a defining quality in athletic pursuits and is necessary for effective contribution to success in many sports. The average person does not experience the same need for agility as a football running back or a point guard on a basketball team, but all people need to be able to manage direction change without losing balance, or to manage forces to avoid falls and injury from offsetting forces. Agility suggests quickness; therefore it applies most in situations where movement speeds are fast. Individuals who have low levels of agility have difficulty changing direction when faster movement velocities are present.

Factors that Affect Baseline Measures

Several factors affect a person’s baseline measures on the fitness components. In untrained individuals, the strongest independent factor is genetic predisposition. Although genetics alone do not fully account for a person’s physical fitness, they certainly cannot be overlooked. In addition to genetics, environmental factors, individual interest, and activity-related physical conditioning all contribute to the overall physical fitness of an individual.

Genetics, or heredity, contributes to the measurable components of physical fitness at any given time during a person’s lifespan and determines the potential capabilities of the body. It is estimated that a person’s genetics can determine up to 40% of uncontrolled factors that affect physical fitness (2; 78). With this being said, that leaves at least 60% of controllable or somewhat-controllable factors that can be manipulated and improved. Almost everyone has the ability to improve his or her health or performance by engaging in activities and behaviors that act positively upon the body, regardless of genetic makeup.

The environmental factors that affect physical fitness are fairly numerous, and each primary factor carries a number of sub-factors. These factors may be social, such as the family one is born into and its respective values, personal attitudes, financial means, societal environments and opportunities, or physical, such as climate, altitude, or exposure to pollutants. Early learned behaviors yield very powerful influences on the lifestyles of adults. Individuals born into families that place little value on healthy behaviors, or are not educated to those behaviors, are less likely to ever engage in them. On the contrary, families that emphasize health through activity promotion, proper nutrition, and the avoidance of negative influences are more likely to transfer those values to their children and encourage the continuation of those behaviors into adulthood.

Interest also plays a key role in the types of behaviors in which people partake. Individual use of discretionary time is often connected with personal responsibility and feelings of enjoyment. Few people will voluntarily engage in activities that they find unpleasant. Fun activities are often preferably selected for participation over those that do not have a positive association to them. Exposure to a variety of activities during youth allows individuals to evaluate their interests and make decisions about adopting them into their lifestyle habits. In some cases, knowledge of the benefits from certain activities or behaviors influences participation, even when certain activities are viewed as less pleasurable. A sense of responsibility for one’s health may cause people to exercise or eat right, even though they might prefer to make other decisions should consequences not exist. Education is an important factor in this decision making process. Individuals who understand that quality of life outcomes closely link to health are more
likely to participate in healthy behaviors. For example, a person looking to have an active retirement may emphasize healthy behaviors so as to be able to accomplish his or her retirement goals.

Physical Activity & Life Quality
The World Health Organization has acknowledged health-related quality of life (HRQL) as an important outcome from wellness behaviors. In 1982, Kaplan and Bush coined this multidimensional concept that acknowledges the influences that health status has on tangible and perceived measures of life quality. Clinical data has shown that physical activity has significant potential to positively influence a person’s HRQL (18; 39; 55; 82; 193). The areas that seem to be most directly affected include physical and psychological well-being, perceived physical function, and stress reduction (127). Additionally, a positive association exists between physical activity and self-esteem in people of all ages.

One important effect of physical activity is the perception of improved physical function in daily activities. Although most people can perform daily tasks, the ease or proficiency of accomplishing physical work seems to improve with regular activity. Individuals suffering from maladies, such as heart disease and arthritis, who participate in physical activity report the highest rate of perceived improvement in daily functional capabilities (4; 97; 164; 226). In clinical trials, self-reported outcomes identified improvements in physical function and health in subjects who engaged in physical activity (aerobic training) compared to controls (3). Again, the individuals who were diagnosed with disease presented the greatest magnitude of positive effects in both physical and psychological measures.

Physical Activity & Risk for Injury
Research clearly demonstrates that exercise can help most people improve quality of life (17; 39; 81; 192). This holds true for both apparently healthy individuals and those diagnosed with disease. Exercise, though, also offers the potential for negative outcomes. Individuals who increase physical activity should be familiar with the inherent risk of injury. Several types of common injuries are associated with exercise and sports participation. New exercisers are at particular risk for soft tissue strains, tears, and even bone fracture from inappropriately applied stress and repetitive motions. Progressing intensity too aggressively is associated with greater risk for multiple cause injury. Lower extremity injuries seem to be reported most commonly; in particular the articulation sites of the ankle, knee, and foot (62; 74; 156).

Metabolic abnormality is also a possibility with exercise participation. Although rare and mainly associated with prolonged duration, pre-existing exercise condition, or environmental influences, metabolic injury can be life threatening. Conditions such as hyperthermia, hypothermia, electrolyte imbalance, hypoglycemia, and rhabdomyolysis all may present acute emergency situations. Appropriate fluid consumption, acclimation to stress, and pre-exercise screening can help prevent incidents related to the aforementioned metabolic abnormalities.

Pre-Exercise Screening
Importantly, pre-exercise screening can also help reduce cardiac events during exercise. For some individuals suffering from cardiovascular pathology, exercise may cause more harm than good. Individuals may incite arrhythmia (abnormal heart rate or rhythm) triggers when exercising with compromised coronary circulation. Arrhythmias, acute angina, and myocardial infarction (heart attacks) may be precipitated by the combination of physical exertion and disease. Sudden death is not common but a definite possibility for high cardiac risk exercisers. It is important to recognize that the risk occurs not just during participation in the activity but also immediately following exercise. However, from a risk vs. benefit perspective, regular activity for medically cleared participants yields more protective effects from disease than the risk for injury from an exercise-related cardiovascular incident.

Other health concerns related to exercise may warrant attention as well. Overtraining increases risk for infection from immuno-suppression and can cause stress-related injuries (61). Likewise, pre-existing conditions, including asthma, musculoskeletal injury,
Osteoporosis, and arthritis can lead to additional problems during exercise participation. Studies show that previous injury and existing conditions strongly predict subsequent injury related to physical activity (106; 229). Although a myriad of adverse events are associated with physical activity, the risk of participation is still outweighed by the problems associated with a sedentary lifestyle. Taking steps to identify risk factors and high risk environments and situations, screening participants, providing structured and appropriate acclimation to the physical stress, prescribing exercise within individual capabilities, avoiding activity when injury or risk is elevated, and having an emergency plan, all contribute to reduced risk and consequence of physical activity-related injury.

~Key Terms~

Olympic lifts – Clean, jerk, and snatch exercises.

Plyometrics – Exercises that use explosive movements to develop muscular power.

Genetics - The science of biological inheritance which contributes to the measurable components of physical fitness during a person’s lifespan and also helps to determine the potential capabilities of the body.

Tendonitis - Inflammation of a tendon.

Plantar fasciitis - An inflammatory condition caused by excessive wear on the plantar fascia (bottom of the foot).

Ulnar nerve palsies - Paralysis caused by damage, compression, or trapping of the ulnar nerve.

Ischial bursitis - Inflammation of the bursa that separates the gluteus maximus from the underlying ischial tuberosity.

Epicondylitis - Inflammation of the muscles and soft tissues around an epicondyle.

Hyperthermia - Unusually high body temperature.

Hypothermia - Abnormally low body temperature.

Hypoglycemia - An abnormally low level of glucose in the blood.

Rhabdomyolysis - An acute, potentially fatal disease that destroys skeletal muscle and is often accompanied by the excretion of myoglobin in the urine.

Physical Activity & Risk for Disease

The rate of physical inactivity in the United States constitutes a societal health burden. The lack of participation in daily physical activity is, in part, blamed for elevated incidence of the Western Culture Diseases. The CDC estimates that the number of deaths associated with sedentary lifestyles is approximately 200,000 annually when viewed as an independent risk factor. Linked with poor diet, that estimate jumps to 300,000. It is likely that other risk factors associated with a sedentary lifestyle also contribute to these values, which speaks to the relevance of overall health accountability, rather than emphasis on any single factor (28; 53; 166).

Physical activity is associated with a reduction in risk of all-cause mortality, as well as mortality from all cardiovascular disease combined, coronary heart disease, hypertension, colon cancer, and non-insulin dependent diabetes mellitus (28; 45; 52; 167). Research presented in this chapter identifies the relationship of physical activity and cardiorespiratory fitness (CRF) to a variety of health consequences. Data collection results of epidemiological studies have identified the association of physical activity and health problems, the respective magnitude or strength of such relationships, and the biological mechanisms for the onset of the diseases in question.

Individuals regularly engaging in physical activity or those with high levels of CRF have a lower mortality rate than those classified as sedentary or those individuals who maintain low CRF (29; 45). The cited risk for dying from all-cause mortality is 1.2- to 2-times higher for sedentary individuals and those with low CRF (46; 215). In addition to a reduction in death rates associated with activity participation, a correlation also exists between lifespan and the level of physical fitness (46). Individuals who engage in activities of longer duration and higher intensity tend to live longer regardless of the age that they begin participation (121; 169).

Studies show that changes from low-level fitness to moderate fitness yield the greatest impact on death rates (44; 120; 168). In other words, a sedentary individual who trains to modest levels of fitness condition will have a greater impact on his or her risk for disease than someone who already has a modest degree of CRF who attains a higher level. In longitudinal studies, improvement from low CRF to moderate levels caused a 44% lower death rate compared to those who remained at low fitness levels. After adjusting for other
factors, that difference jumped to a 64% reduction in risk compared to those that remained sedentary (178). This information suggests that individuals who engage in physical activity reduce their risk for all-cause mortality. Regular physical activity is a strong indicator for overall mortality rates and shows a significant dose-response relationship (177). Adjusting lifestyle habits to include regular physical activity is an important part of taking control of one’s health and risk for death. Further increasing the level of fitness through training at higher intensities and for longer durations adds to the marked effects on mortality risk (45).

**Physical Activity & Cardiovascular Disease**

The Center for Disease Control (CDC) identifies heart disease and stroke as the most common cardiovascular diseases, representing the first and third leading causes of death in the United States, respectively (27). Research suggests that these diseases account for 40% of all annual deaths, which equates to 1 death every 35 seconds from CVD (128). Although these largely preventable diseases are more common in older individuals, the risk of sudden death has increased in individuals less than 35 years of age (71; 222; 223). CVD in the form of coronary artery disease is also the leading cause of premature, permanent disability among United States workers (68). Additionally, over 1 million Americans are disabled from stroke alone. Collectively, CVD forces the hospitalization of over 6 million Americans (54; 221). Estimates suggest that more than 70 million Americans currently live with some form of heart disease, and the cost associated with CVD was projected at $403 billion dollars in 2006 (224).

Physical activity has a dramatic effect on reducing risk for developing CVD (12). Several studies have shown that a dose-response gradient exists, further supporting the need for regular physical activity (191; 201; 219). As stated, lower CRF increases risk for mortality, which is consistent with its relationship with CVD-related death. Individuals with the highest levels of fitness show the greatest reduction of risk (139). The dose-response relationship suggests that benefits begin at moderate levels and increase consistently with activity intensity and duration. Therefore, physical activity strongly and inversely relates to CVD risk (138). Numerous studies have analyzed the impact of physical activity on risk for specific forms of CVD. The following text reviews the epidemiological literature related to the measured outcomes.

**Coronary Heart Disease (CHD)**

Earlier text acknowledged the transient risk of an acute coronary event with exercise participation by those with advanced coronary pathology. This being said, numerous studies have indicated a strong inverse relationship between physical activity and CHD (7; 42; 140; 196). In fact, active people have a significantly lower risk for coronary events compared to sedentary persons or those with low CRF (220). Participation in moderate to high intensity (60-80% VO₂) aerobic exercise has been shown to improve CRF and dramatically reduce the risk of CHD (141). Appropriate diet and lifestyle habits that reduce negative blood lipid profiles and stress enhances this benefit (100).

Although CHD is rare in children, enough evidence suggests that physical activity in childhood helps to prevent CHD in adulthood (182). The presence of CHD in adulthood is related to coronary plaque, and data shows atherosclerosis begins during childhood (173). Of particular relevance is that childhood behaviors linked to the initial development of coronary plaque persist into adulthood. Likewise, physical inactivity is linked to contributing factors for heart disease, including obesity, diabetes, hypertension, and hyperlipidemia (199).

The reduction in risk for CHD associated with aerobic activity and CRF is likely attained through several physiological mechanisms. Aerobic exercise demonstrates a positive effect on several factors that influence risk for CVD. These include reductions in
body fat, blood pressure, myocardial ischemia, blood clotting (thrombosis), and heart rhythm disturbances (cardiac arrhythmias), as well as improvements in plasma lipid profile (16; 41; 92; 142).

CHD is caused by occlusion of the coronary arteries due to vascular wall damage, which leads to atherosclerosis. Coronary plaque or atherosclerosis occurs when the arterial walls are injured from turbulent blood flow and high vascular pressure. Resultant lesions on the vessel wall cause fatty deposits in the lining of the artery. Circulating low density lipoproteins deliver cholesterol into the artery wall at the area of the initial insult. An inflammatory reaction then occurs, attracting macrophages, or immune cells, to accumulate in the cell wall, where they ingest the fatty deposits. These macrophages cause a proliferation of smooth muscle cells around the area, which are eventually replaced with collagen. A protective fibrous cap then forms between the fatty deposits and the artery lining. This process is commonly referred to as hardening of the arteries. At this point the lumen of the artery is not narrowed. However, over the course of years the plaque can form an aneurysm (an abnormal dilation) of the vessel inner wall, which can rupture. When a plaque ruptures in the wall, a clot can form, which can narrow or even occlude the artery so that little to no blood passes through. The inner wall damage is subject to additional build-up of fatty deposits, platelets, and other circulatory elements. With this decrease in blood flow through the artery, the tissue being fed by the vessel becomes ischemic and can die from lack of oxygen.

Exercise & Atherosclerosis
Exercise and physical activity reduce the risk of atherosclerosis by lowering blood pressure, as well as circulating LDL cholesterol, a prime instigator in plaque formation. Extensive review has shown that high density lipoprotein (HDL) increases via liver production in response to aerobic exercise (15; 91; 99). This lipid scavenger picks up circulating LDL cholesterol and transports it back to the liver, where it is reabsorbed and the cholesterol is used for bile. A dose-response relationship has been shown between the amount of regular physical activity and plasma levels of HDL (6; 98). Endurance-trained athletes have demonstrated 20% to 30% more circulating HDL cholesterol than same-aged sedentary healthy subjects (174). Moderate intensity activity seems to yield the same benefits in HDL production as high intensity exercise as long as one reaches an appropriate weekly energy expenditure value (1200-1600 kcal/week) (79). In addition, regular exercise reduces triglycerides and increases lipoprotein lipase, the enzyme responsible for removing fatty acids and cholesterol from the blood (67). Complementing the reduction in hazardous circulatory lipids, exercise also reduces platelet adhesion by influencing the stress response. Stress can increase circulatory lipids and make particles in the blood “sticky.” (217) Aerobic exercise offers a protective effect against this phenomenon.

Myocardial Ischemia
When the heart requires an amount of oxygen that cannot be met via functional mechanisms, it becomes ischemic. Oxygen supply does not meet demand. When this occurs repeatedly over time the condition becomes symptomatic. Exertion and consequential ischemia causes angina pectoris or chest pains and may cause irregularities in heart rhythm. Endurance activities have been shown to cause adaptations in coronary circulation that can reduce ischemia (129). Routine aerobic exercise leads to improved coronary blood flow and oxygen utilization by the cardiac tissue. Adaptations to exercise that account for the improved efficiency include improved blood flow dynamics, the promotion of oxygen transfer, and remodeling of the vascular structures that augment oxygen delivery. The vascular structures increase in diameter, allowing more blood to pass, while new capillaries and arterioles are formed to enhance the myocardial vascular network. Improved blood flow is further promoted by vascular reactivity and subsequent distribution in conjunction with increased vascular compliance. Together, these adaptations to training cause a relative reduction in peripheral resistance, thereby reducing the oxygen demand of the myocardium by lowering its workload.

Cardiac events related to coronary heart disease
are often triggered by heart arrhythmias or by thrombosis. Arrhythmias are heart rhythm disturbances that often occur in the presence of heart disease. Although they may occur in healthy individuals from artery spasm, electrolyte imbalances, responses to certain medications or drugs, and states of dehydration, they are more common in individuals with myocardial ischemia. The largest threat from arrhythmias occurs with ventricular fibrillation, where blockage causes the heart conduction system to malfunction. With ventricular fibrillation the heart's electrical activity becomes disordered. When this happens, the heart's lower chambers contract in a rapid, unsynchronized manner and the heart pumps little or no blood. If the heart is not defibrillated, the person will die from the phenomenon known as sudden death, due to heart attack. Exercise reduces the risk of cardiac arrhythmias by increasing blood flow to the tissue, thereby better satisfying the myocardial oxygen demand while suppressing sympathetic nervous system activity. This combined effect reduces the risk of sudden death in both healthy persons and those diagnosed with disease by mediating the two primary triggers, ischemia and neural stimulus.

**Thrombosis**

A thrombus, or blood clot, may also trigger a heart attack by occluding a coronary artery which, in turn, cuts off the oxygen supply to a portion of the heart. The initiation of an acute thrombotic event often starts with a disruption or rupture of an atherosclerotic plaque, tearing the inner wall of the vessel. Platelets accumulate at the injury site, causing the aforementioned process of obstruction. The formation of a clot, or thrombosis, around the injury site creates a major obstruction to blood flow. Even without full occlusion, the ischemic catalyst can cause lethal disturbances in the heart rhythm, resulting in a heart attack.

This process does not occur as rapidly as it may sound. It generally follows the slow progression of atherosclerosis, but the thrombosis is the acute precipitating event that sets the course into action. This development of blockage is the transition between silent coronary artery disease, where the lumen of the vessel is not disrupted and often asymptomatic, to significant occlusion and onset of symptoms. At this point, the individual may experience recurring chest pains called unstable angina, cardiac arrhythmias, acute myocardial infarction, or sudden death. Aerobic training reduces the threat of thrombosis by enhancing the enzymatic activity at the site. The enzymes produced from endurance training break down the blood clots and decrease platelet adhesion and aggregation, helping to reduce and prevent clot formation.

**Hypertension & Physical Activity**

High blood pressure has been implicated as a major underlying cause of cardiovascular pathology. It is linked with cardiovascular complications and mortality. Currently, about one in every three persons in the United States is classifiably hypertensive.

**Development of a Thrombosis**

Phase One

Phase Two

Phase Three
Several large cohort studies have identified a relationship between physical activity and risk for hypertension (51). Physical activity, measured through sport and structured aerobic exercise, has shown an inverse relationship between hours per week of participation and risk for the development of high blood pressure (76; 208; 214). Epidemiological cohort studies have consistently demonstrated that sedentary, unfit persons have a 20% to 50% higher prospective risk of hypertension, as compared to exercising, physically fit persons (123). Following adjustments for age, sex, baseline blood pressure, and BMI, low cardiorespiratory fitness was identified as an independent risk factor for the development of hypertension. Low CRF was linked to a 52% higher risk of later development of the disease. Consistent with other studies, a dose-response relationship exists between the amount of activity and the degree of protection from hypertension (5; 170; 185). Individuals who are the least active were shown to have a 30% increase in risk compared to those who were highly active. It should be noted that none of these studies analyzed higher-risk minorities.

Conclusions of several meta-analyses suggest that aerobic exercise has a significant effect on both diastolic and systolic blood pressure response (49). Participation in aerobic training 30-60 minutes a day, 3-4 days per week, at intensity ranges of 60-70% VO₂ Max caused a consistent decrease of approximately 6-7 mmHg in both diastolic and systolic measures (213). Different studies, lasting between 10 and 36 weeks, analyzed the intensity of the aerobic training to determine the dose-response implications of the training (50; 207; 212). Interestingly, lower-intensity training yielded more positive results (184). In the low intensity groups (50%, 53% of maximum intensity), a mean decrease of 6 mmHg and 11-12 mmHg diastolic blood pressure were found, and systolic reductions between measures were 9 mmHg and 20 mmHg, respectively. The high intensity groups (73%, 75% of maximum intensity) did not fare as well with diastolic reductions of 11-12 mmHg and 5 mmHg and systolic reductions of 8 mmHg and 3 mmHg, respectively. Based on these studies and others, moderate intensity may offer an even more pronounced effect at lowering blood pressure than high intensity training (95). The reason for these findings is unclear and more data is needed to conclusively confirm these results.

Blood pressure is the product of cardiac output and peripheral resistance in the blood vessels. Exercise has been shown to present a relaxation effect on vascular wall resistance (48). Acute response by the body to a bout of aerobic exercise causes an immediate and temporary reduction effect on vascular resistance through peripheral blood vessel dilation. This response has been measured several hours following a session of exercise. With chronic and appropriate exercise stress, peripheral resistance lowers via attenuation of sympathetic nervous system activity. Routine aerobic exercise may cause a reduction in renin-angiotensin system activity (hormones secreted from the kidney to control blood pressure), arterial vasodilation, and baroreceptor (the brain’s blood pressure monitoring system) adjustment (32). Additionally, the positive effect aerobic training has on circulating insulin levels contributes to a further enhancement in blood pressure reduction by decreasing insulin-mediated re-absorption of sodium by the kidneys (47).

### Obesity & Physical Activity

Obesity is a major issue facing the American population. It is a risk factor for diabetes, heart disease, hypertension, osteoarthritis, high cholesterol, various cancers, and all-cause mortality (56; 232). Documented increases in bodyweight have occurred in all race and sex groups and have led to concerns of epidemic proportion. The combination of high-calorie diets and low levels of physical activity has created an energy balance disturbance (positive caloric balance), leading to progressive weight gain. This weight increase is most pronounced between the third and sixth decade of life (23; 94). Recently, childhood obesity has also become a major concern facing the United States. Reductions in activity and poor diets have made children fatter than ever before. Childhood obesity

![](blood-pressure-categories.png)
is directly linked to adult obesity, and overweight children present an elevated risk for adult diseases later in life, including hypertension, diabetes, and CVD (181).

A common theme that links many diseases and chronic illness is uncontrolled cellular inflammation. It is a factor in diseases including cardiovascular disease, diabetes, cancer, arthritis and many autoimmune-related conditions. Obesity has recently been added to this group of diseases as it is now known to present a low grade inflammatory response within many of the body’s tissues, which cause deleterious effects, often leading to the development of cardiovascular and metabolic disease (115). It is well-known that being overweight is detrimental to one’s health, but until recently the known mechanisms were limited. Scientists over the last decade have started to unravel the mystery of why obesity leads to premature death.

Inflammation is, by design, a protective response leading to the repair of tissue. When inflammation becomes chronic, as is the case with obesity, chemical mediators derived from different cellular activities change their dynamics causing a progressive deterioration. Fat cells are now considered a dynamic immune organ that secretes numerous immune modulating chemicals (72; 119). Visceral fat, in particular, is associated with the low-grade inflammation that seems to be a contributing pathologic feature for metabolic disease through insulin resistance and the promotion of atherosclerotic build-up in circulatory vessels (33). When high levels of visceral fat are combined with physical inactivity, over-nutrition, and advancement in age, the effect becomes more pronounced. Visceral fat is highly metabolic and contributes to cytokine (a chemical signal used between cells) hyperactivity (10). Adipokines secreted from fat tissue influence the metabolic process and contribute to proper function (86). The consequent low-grade inflammation associated with obesity causes disturbance in the secretion and function of adipokines. Research has identified changes in adiponectin, leptin, and resistin that exhibit harmful effects upon the body in obese individuals (149).

Adiponectin is an antiatherogenic agent, meaning it helps prevent the development of atherosclerotic plaque in blood vessels and slows the progression of atherosclerosis in coronary vessels. It does this by acting directly upon the vessel wall, inhibiting adhesive molecules from contributing to plaque formation and acts as a blocking agent to the formation of foam cells. In the skeletal muscle and the liver, adiponectin serves to promote insulin sensitivity and a positive blood lipid profile. Visceral adiposity reduces adiponectin concentrations (155). Lowering the adiponectin concentrations lessens the cardioprotective effect, leading to increased cardiovascular risk.

Leptin regulates energy metabolism and balance in conjunction with the brain’s hypothalamus. Leptin is currently being touted as having cardioprotective benefits among its others roles in metabolism. Leptin concentrations adjust in response to obesity and contribute to insulin resistance (147). The changes in leptin concentration have also been recognized as a risk factor for coronary heart disease. Likewise, increased resistin concentrations correlate with obesity related inflammation and may be associated with the initiation and progression of atherosclerotic lesions (150). Resistin also promotes insulin resistance, although the actual mechanism is not known.

Insulin resistance due to adipokine dysfunction is further influenced by free fatty acids liberated directly into the liver from visceral fat tissue (112; 148). Visceral fat releases chemicals and fatty acids into the portal system, where they act on the connecting organs. The portal circulation system is a specialized network of blood vessels that connect the visceral organs to the liver. The excess fat in portal circulation has detrimental effects on insulin action, which is worsened by sympathetic hyperactivity in response to obesity. Sympathetic hyperactivity causes heightened lipolytic action resulting in excess free fatty acids in the blood. These actions, combined with beta cell hypersecretion and reduced insulin clearance resulting in hyperinsulinemia, lead to early stage diabetes (111).

Interleukin-6 (IL-6) is possibly another factor associated with obesity-related inflammatory detriment within the portal system. High levels of IL-6 are a marker for inflammation and vascular pathology (118). Obese subjects demonstrated a 50% greater portal vein IL-6 concentration, demonstrating again the profound effect visceral fat has on pathogenic indicators. Portal vein IL-6 correlates with systemic C-reactive protein concentrations (154). C-reactive protein is associated with cardio- and peripheral vascular disease. C-reactive protein and oxidative stress are now presumed to interact in the early inflammatory processes of atherosclerosis. This is significant for young obese individuals. Although more research is necessary for conclusive association, C-reactive protein may be a new risk factor for CAD in individuals under 25 years of age (93).

The imbalance between increased inflammatory stimuli with a concurrent reduction in anti-inflammatory activity may be the foundation for the accelerated endothelial dysfunction and insulin resistance.
associated with obesity and the comorbid disorders of metabolic disease. More research is needed to clearly delineate the particular relationships, but it seems evident that the low-grade inflammation caused by obesity and visceral adiposity lead to the premature development of disease. This, more so than ever before, identifies the importance of weight management during the developmental years and ongoing efforts to control weight throughout one’s lifespan. For individuals who are currently obese, there is still hope. Weight loss is related to a reduction of oxidative stress and inflammation, and these beneficial effects likely translate into reduction of cardiovascular risk in obese individuals (9). Likewise, exercise and dietary management, along with pharmacologic intervention, can lead to atherosclerotic reversal in the earlier stages of CAD (8; 13).

Exercise may provide some protection against the onset of obesity-related inflammation via heightened caloric expenditure and the attenuation of some of the side effects. It is assumed that individuals who engage in physical activity are more likely to be lean and experience a lower incidence of obesity than sedentary persons. These presumptions have not been conclusively backed by research. Physical activity has shown to be inversely related to risk of becoming overweight (83; 172). However, other research trials have not come to the same conclusion (40; 90). This suggests that an active lifestyle alone may not be enough to compensate for dietary intakes. Investigations comparing physical activity and childhood weight gain have shown higher activity levels in non-obese children and a reduction in BMI with increasing activity (14). However, inconsistent results have been seen in cross sectional studies examining physical activity and lower BMI and skinfold measures.

Studies examining the impact of exercise training on body weight and obesity have had more positive outcomes. Several reviews have concluded that exercise and physical activity positively affect weight by reducing fat mass and maintaining muscle. In addition, a dose-response gradient exists, based upon the frequency and duration of the activity (190). Most studies suggest that physical activity alone yields positive, but limited benefits for weight loss. When diet is factored in, the results become more favorable. The combination of caloric control and physical activity appears to be substantially more beneficial than either diet or physical activity alone. However, independently, physical activity seems to be an important factor in body fat distribution. Physical activity may favorably affect central storage through several measures to be discussed in the coming sections.

Weight gain is a factor of energy balance. When energy intake exceeds caloric expenditure, weight gain often results. Physical activity contributes most favorably to metabolic expenditure, and therefore is an important component in weight loss. Increasing physical activity contributes to greater caloric expenditure and consequently improves weight management. Exercise yields positive results for the maintenance of metabolic rate, whereas diet alone does not. Additionally, physical activity reduces the prevalence of central storage, which is important for lowering risk of metabolic disease.

It is suggested that decreases in physical activity may be a cause and consequence of weight gain. Adult weight gain has been linked with decreasing physical activity (189). As people reduce activity without appropriate adjustments in caloric intake, weight gain is likely to occur. When this occurs continuously over time risk for obesity increases significantly. To prevent creeping obesity, regular physical activity should be combined with caloric control.

**Body Mass Diagnostic Criteria**

<table>
<thead>
<tr>
<th>Condition</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overfat Bodyfat</td>
<td>21-24%</td>
<td>28-31%</td>
</tr>
<tr>
<td>Obesity Bodyfat</td>
<td>≥25%</td>
<td>≥32%</td>
</tr>
<tr>
<td>Obesity BMI</td>
<td>≥30</td>
<td>≥30</td>
</tr>
<tr>
<td>Obesity Height-Weight</td>
<td>&gt;20% mean</td>
<td>&gt;20% mean</td>
</tr>
<tr>
<td>Morbid Obesity/Bodyfat</td>
<td>≥30%</td>
<td>≥40%</td>
</tr>
</tbody>
</table>

**~Key Terms~**

- **Myocardial Ischemia** – Lack of oxygen to the myocardium
- **Cardiovascular disease (CVD)** - A general diagnostic category, consisting of several separate diseases of the heart and circulatory system.
- **Coronary heart disease (CHD)** - Progressive reduction of blood supply to the heart due to narrowing or blocking of the coronary arteries.
- **Arrhythmia** - An abnormal heart rhythm.
- **Thrombosis** - Formation of a blood clot in the heart or blood vessel.
a major problem in developed countries like the United States. A stroke is the sudden death of an area of brain cells caused by a lack of oxygen to the brain. The primary causes are vascular blockage, which impairs blood flow to the tissue (ischemic stroke) or an artery rupture (hemorrhagic stroke), causing bleeding within the brain. Ischemic stroke accounts for 80% of all stroke cases (134). In ischemic stroke, interruption of the blood supply to the brain results in tissue hypoperfusion, hypoxia, and eventual cell death. The main mechanisms involved in the development of ischemic stroke are associated with atherothrombotic and embolic disease.

In atherothrombotic disease, the pathophysiology resembles CAD in the heart (231). Lipid deposition leads to the formation of plaque, which narrows the vessel lumen and results in turbulent blood flow through the area of stenosis. The turbulence of the flow and the resultant alterations in flow velocities lead to vessel wall disruption or plaque rupture, both of which activate the clotting cascade. This process causes platelets to become activated and adhere to the plaque surface, where they eventually form a fibrin clot. As the lumen of the vessel becomes more occluded, ischemia develops distal to the obstruction and can eventually lead to infarction (death) of the tissue that relies on the parent vessel for oxygen delivery. Embolic stroke occurs when dislodged thrombi travel distally and occlude vessels downstream. One-half of all embolic strokes are caused by atrial fibrillation (an abnormal rhythm of the heart atria), while the rest are attributable to a variety of causes, including left ventricular dysfunction secondary to acute myocardial infarction or severe congestive heart failure, and atheroemboli. These latter emboli often arise from atherosclerotic lesions in the aortic arch, carotid arteries, and vertebral arteries, which break off and travel to the brain. Two of the most common risk factors for stroke include cigarette smoking and high blood pressure (75; 107; 108).

Hemorrhagic stroke, as indicated above, is caused by an intracerebral (within the brain) hemorrhage and results from the rupture of a vessel within the brain tissue. The primary cause of these ruptures is hypertension. Hypertension can cause an aneurysm (an abnormal ballooning of a vessel) to form in a brain artery. This aneurysm can burst, which causes bleeding into the brain. Although limited data exists to support the benefits of physical activity on stroke risk, no conclusive evidence has directly linked reduced risk of either type of stroke to physical activity participation (137). The CDC reported that one study attempted to distinguish the difference between stroke pathophysiology and physical activity participation (114). It suggested that inactive men were more likely than active men to have hemorrhagic stroke, and ischemic stroke risk was reduced in smokers, but not non-smokers. More research is necessary to unequivocally support the association between physical activity and stroke, but physical activity has been shown to reduce risk for hypertension, a leading cause of stroke.

**Diabetes & Physical Activity**

Diabetes mellitus, commonly referred to as diabetes, is a chronic disease involving abnormalities in the body's ability to use sugar. In healthy individuals, the hormone insulin is secreted by the pancreas in response to carbohydrates absorbed into the blood stream, usually in the form of glucose, through normal digestion. Insulin signals muscle and other cells to take up glucose, thereby lowering the blood
glucose level. The glucose taken up by cells is then used for normal metabolism, stored as glycogen, or converted into fat for later use. Diabetes is diagnosed when the body either has an inability to make insulin, or the cells have an inability to act in response to insulin (insulin insensitivity).

Diabetes is one of the largest threats to the health of the United States population. According to the American Diabetes Association, individuals born after the year 2000 have a 24% (males) to 33% (females) chance of developing diabetes in their lifetime (131). Of the estimated 16 million Americans with diabetes, only 8 million have been diagnosed. Diabetes is the 7th leading cause of death from direct means, but this statistic greatly underestimates the role diabetes plays in premature death and disability. When diabetes is analyzed as a secondary cause (the disease that precipitated the event) the number of deaths associated with the disease doubles (34). Diabetes usually kills through cardiovascular disease, including stroke, CHD, peripheral vascular disease, and congestive heart failure (205). Diabetes-related illness or injury accounts for 1 out of 10 hospital visits. Predictions suggest that by age 65, approximately 40% of Americans will have glucose tolerance impairment (an inability of the body to appropriately handle digested carbohydrates) (130).

Diabetes is classified into groups based on the cause of the metabolic disease. Insulin Dependent Diabetes Mellitus (IDDM), or type I as it is commonly known, is thought to be caused by a genetic autoimmune disorder that occurs in children. The beta cells in the pancreas responsible for the production of insulin are destroyed by the immune system, leading to a deficiency of circulating insulin. Non-Insulin Dependent Diabetes Mellitus (NIDDM), or type II diabetes, results from insulin insensitivity of muscle cells, a reduction of insulin due to impaired secretion or a combination of both. Diabetes may also occur during pregnancy due to metabolic disruption that occurs during the fetal development process.

NIDDM is the most common form of diabetes, representing more than 90% of all diagnosed cases. Although the most prevalent form of diabetes, NIDDM is also the most preventable. Even though strong genetic factors exist, and the disease is more common in older age, the primary causes of NIDDM are all modifiable. Physical inactivity, obesity (particularly android), and poor diet lead to the development of insulin resistance, glucose intolerance, and hyperinsulinemia (excessive secretion of insulin). When circulating glucose is not managed and remains elevated, it damages large and small vessels of the vascular system. Diabetic damage to blood vessels causes chronic complications and accounts for the significant morbidity and mortality related to the disease. As indicated above, these can be divided into large vessel (macrovascular) disorders, including coronary artery disease, stroke, and peripheral vascular disease, which are the main causes of death, and small vessel (microvascular) disorders including retinopathy, nephropathy, erectile dysfunction, and neuropathy which are the main causes of morbidity (decreased quality of life and disability). Diabetic macrovascular disease is caused by the acceleration of atherogenesis. However, how hyperglycemia causes small vessel disease is not clearly understood. Two predominant theories are the advanced glycation endproduct theory and the reactive oxygen species theory. The advanced glycation endproduct theory is based on the fact that hyperglycemia causes increased glycation of proteins (the attachment of sugar molecules to protein molecules). A variety of extracellular and intracellular products of glycation have been termed advanced glycation endproducts (AGE). Extracellular AGE may alter protein function, and intracellular AGE may alter gene expression, the net result being abnormal cellular and vascular function. Inhibitors of AGE have been used in animal studies, but their efficacy was limited by toxicity in clinical trials. Diabetes-induced oxidative stress is one of the oldest theories for hyperglycemia-induced microvascular damage. The oxidation of glucose releases free radicals, which may account for a number of cellular dysfunctions. Unfortunately, in recent human trials, the promise of antioxidants (such as vitamin C and vitamin E) in reducing diabetic complications has not materialized.

Inactive lifestyles are linked with the development of NIDDM. Considerable evidence exists which shows that sedentary lifestyle habits are a risk factor for NIDDM (30; 157; 230). Physical activity, to the contrary, has shown to both protect against and have a pronounced effect on NIDDM by reducing circulating
Exercise has demonstrated an improvement in carbohydrate metabolism and glucose tolerance by enhancing the cellular uptake of sugar. Contracting muscle tissue likely causes a synergistic effect between insulin and cellular sensitivity, increasing glucose transport into the cell. Single prolonged bouts of exercise increase cellular permeability for 24 hours, enabling better glucose management as the cells replenish the lost glycogen stores. The increased sensitivity to insulin prevents hyperinsulinemia and improves glucose tolerance, providing a protective effect from the onset of the disease.

Both endurance and resistance training have been shown to provide benefits (176; 233). Endurance athletes have demonstrated greater insulin sensitivity, allowing for lower insulin levels at relative glucose concentrations compared to sedentary subjects. Likewise, it has been reported that resistance-trained individuals experience similar glucose insulin dynamics (183). Physical activity has been shown to improve glucose management through muscle cell changes and fat cell response. Physical activity also leads to indirect benefits, including weight management, reduced central fat storage, and metabolic efficiency.

The combination of diet and exercise is recommended to prevent and treat diabetes. Individuals with mild disease not taking medication seem to experience the most benefit from the therapy. Individuals with advanced NIDDM may experience complications with excessive physical activity, including ketosis, an abnormality of the body’s metabolic process resulting in an increase of ketones in the blood, hyperglycemia (high blood sugar), and hypoglycemic (low blood sugar) response to vigorous exercise. Additionally, foot wounds, cardiovascular complications, and eye damage due to retinopathy are potential problems. Proper medical evaluation and screening can help identify individuals at greater risk and determine proper precautions.

**Diagnosing Diabetes**

**Pre-diabetes**
- Impaired Fasting Glucose 100-125 mg/dl, following over night fast
- Impaired Glucose Tolerance 140-199 mg/dl, following 2-hour glucose test

**Diabetes Diagnostic criteria**
- Fasting plasma glucose >126 mg/dl
- Casual plasma glucose >200 mg/dl
- Oral Glucose test >200 mg/dl

**Diabetes Risk Factors**
- Certain Medications
- Inactivity
- Race
- Pregnancy
- Hypertension
- Cholesterol
- Stress
- Obesity
- Family History
- Age

Diabetes in a process that causes insulin re-sensitivity in the cells. Physically inactive women ages 55-69 were found to have twice the risk for NIDDM as their physically active counterparts (31). Prospective cohort studies identified that physical activity provides a protective effect and is inversely related to the incidence of the disease (126; 179; 180). The highest risks identified in the studies were high BMI and/or family history of hypertension or diabetes. It is suggested that for each additional 500 kcal of expenditure per week from physical activity, risk for NIDDM is reduced 6% (225). Additionally, more vigorous activities were associated with the greatest benefit. A study of 34-59 year old women who reported engaging in vigorous physical activity at least once a week experienced a reduction in risk by 16% compared to women who did not participate in vigorous activities (122).
**Osteoarthritis & Physical Activity**

**Osteoarthritis**, the most common form of arthritis, is not a single disease but rather the end result of a variety of disorders leading to the structural or functional failure of one or more joints in the body. Osteoarthritis involves the entire joint, including the nearby muscles, underlying bone, ligaments, joint lining (synovium), and the joint cover (capsule). It is characterized by an advancing loss of cartilage. As the cartilage attempts to repair itself, the bone remodels, the underlying (subchondral) bone hardens, and bone cysts form. Age is a key risk factor for osteoarthritis, with the greatest prevalence in older adults. Osteoarthritis is credited with being the leading cause of activity limitation among many older adults. The actual cause of osteoarthritis is unknown. It seems to be more common in individuals who pursue competitive sports or engage in high-intensity activity (60). Competitive running, football, soccer, and weightlifting are all associated with increased risk for the development of the disease (116). The development of osteoarthritis seems to occur more frequently in joints used repetitively and excessively (24). In one study, a small sample of pitchers reported greater incidence in the shoulder and elbow of the throwing arm (200).

Osteoarthritis is linked with injury in sedentary and active persons alike. Researchers suggest that osteoarthritis may be more prevalent in athletes than non-athletes because of the high incidence of injury reported in competitive sports (59). Soccer players who did not experience injury during competition demonstrated no greater incident of arthritis than sedentary controls (171). It appears that physical activity is not the impetus for osteoarthritis but increases the risk of injury, which may be the underlying cause (26). Regular noncompetitive physical activity that is dose appropriate does not appear to be harmful to joints that have not been injured (101).

**Physical Activity & Osteoarthritis**

Physical activity using non-impact resistance and aerobic modalities, when performed at moderate levels, can improve function, reduce joint swelling, and relieve symptoms with both osteo- and rheumatoid arthritis (145). Increased levels of activity have been demonstrated to improve status in physical, psychosocial, and functional measures (146). In addition, self reports by subjects with osteoarthritis suggest moderate intensity activity raises pain threshold, improves energy levels, and self-efficacy (203).

The benefits of moderate intensity exercise are likely related to the mechanisms that naturally keep joints healthy. Joints require movement to receive nourishment. Nutrients diffuse through the cartilage matrix via pressure gradients that cause fluid to flow when compressed. When the joints are appropriately loaded through normal functional range of motion, proteoglycan synthesis is increased by the chondrocytes, increasing the cushioning effect. On the contrary, high impact, high intensity loading performed repeatedly disrupts this process, inhibiting cartilage matrix function. Inactivity also affects the cartilage matrix by reducing proteoglycan synthesis and cartilage turnover.

**Key Terms**

- **Insulin dependent diabetes mellitus (IDDM)** - Type I diabetes, is an autoimmune disorder in which the body’s own immune system attacks cells of the pancreas, sufficiently reducing insulin.

- **Non-insulin dependent diabetes mellitus (NIDDM)** - Type II diabetes is a metabolic disorder characterized by insulin resistance, insulin deficiency, and hyperglycemia.

- **Osteoarthritis** - A form of arthritis, occurring mainly in older individuals, that is characterized by chronic degradation of the cartilage in the joints.
integrity. Physical inactivity, particularly immobility, causes cartilage decline and makes the joint more susceptible to injury. Prolonged disuse associates with fibrous replacement and a loss of function. When comparing injured versus non-injured joints, running had a positive effect on healthy joint water content and proteoglycan synthesis but had negative outcomes on injured joints, ultimately leading to the development of osteoarthritis (25; 85).

**Osteoporosis & Physical Activity**

Osteoporosis is a progressive bone disease that occurs due to a loss of bone mass and structural deterioration of the bone tissue. The development of the disease is linked to three compounding factors: deficient level of peak bone mass, a reduction in bone mass after age thirty, and further loss of bone after age fifty. Osteoporosis causes the bone to become frail and brittle, increasing the risk for fracture. The vertebra, hip, and wrist experience the greatest risk of injury from the disease. Fractures in the vertebra are usually asymptomatic and lead to structural changes that often present as kyphotic disorders of the spine. Kyphosis, or hunchback, is associated with significant functional decline, gastrointestinal and abdominal problems, and chronic back pain. Injuries at the hip usually occur from falls. Hip fractures account for 16% of osteoporosis-related fractures each year (63; 228). Death or disabilities are expected outcomes from hip fractures related to osteoporosis, with 15-20% of sufferers dying within 12 months (227). Osteoporosis is more common in women than men due to lower peak bone mass, post-menopausal bone loss, and the fact that women live longer than men.

Physical activity is a vital part of bone health. Regular participation in physical activity increases peak bone mass during youth and maintains the mass into adulthood. Athletic young adults demonstrate greater bone mass than their sedentary counterparts. The strength of the attached musculature, amount and intensity of physical activity performed, and level of CRF correlate with the bone mineral density. This suggests that activities promoting the greatest bone stress have the largest magnitude of benefit for bone mass. Activities that encourage higher force outputs, such as resistance training, plyometrics, and weight-bearing endurance events have the greatest impact on bone maintenance. All persons should engage in routine weight-bearing physical activity to maintain appropriate bone health. This is particularly true for postmenopausal women due to the resultant reduction of estrogen experienced during menopause. Some evidence suggests that osteoporotic women may be able to reduce bone loss and facilitate improved bone mineral density with exercise. Other studies have found no such evidence (143). It is likely that the degree of bone stress determines the outcome. Resistance exercise seems to have a more pronounced effect compared with endurance exercise, which may be due to more muscle mass used and greater bone stress, particularly in the axial skeleton. Estrogen levels in both men and women seem to be an important component to bone improvement as well. In postmenopausal women, greater improvements have been demonstrated with the use of estrogen replacement therapy (113).

Bone stress from load-bearing activity is likely to be the most important factor in bone remodeling. Bone cell formation occurs in response to mechanical loading, which improves structural balance and density. The effects of the load placed upon the bone are mediated by glucose-6-phosphate, prostaglandins, and nitric oxide, all of which augment the adaptation response. Without appropriate stress, bone mass is compromised. In addition to mechanical factors, nutrition, medications, hormone concentrations, and age each have a relative contribution to bone health. Proper nutrition (in the form of calcium and vitamin D) and physical activity are necessary throughout a person’s lifespan to reduce the risk of osteoporosis.

In addition to the improvements and maintenance of bone that protect against osteoporosis, physical activity also reduces risk of fractures from falls. As previously mentioned, osteoporotic hip fractures account for a higher risk for premature death and disability than all the other fractures combined. Studies analyzing physical activity and hip fracture...
occurrence found a lower risk among more active adults (19; 202). The magnitude of the benefit seems to be related to the level of activity, although even exercise walking showed protective effects. A person’s risk for falls correlates to performance fitness scores and measures of functional task efficiency (132). Compromised gait, balance, reaction time, strength, range of motion, and impaired vision are all factors that affect fall risk. Exercise profoundly reduces risk by enhancing strength and balance. Additionally, improvements in functional capacity, gait efficiency, and speed and reaction time may positively impact risk. In measures of stair-climbing power, movement gait, and other functional tasks, frail elderly subjects suffering from chronic disease demonstrated improvements and reduced incidence of falls with weight training (77; 80). Individuals at high risk for falls should be encouraged to perform resistance training activities aimed at improving strength and balance to reduce risk of injury and hip fractures.

**Cancer & Physical Activity**

Cancer is reported to be the most feared of all diseases and is the second leading cause of death in the United States, accounting for one-fourth of all deaths (88). According to the American Cancer Society, the rate of new-case cancer is rising, with estimates of newly diagnosed cases well above one million per year (89). Cancer is actually several diseases, characterized by an abnormal and uncontrolled growth and spread of cells which have numerous forms and causes. Of all the cancers, colorectal cancer has been the most studied in relation to physical activity. Interestingly, there seem to be differences between the effects of physical activity on colon cancer and rectal cancer when viewed independently. Although two studies investigating colorectal adenomatous polyps (a pre-cancerous lesion) reported an inverse relationship between level of physical activity and risk for adenomas, other studies have not found the same association (64; 66; 87; 110; 117; 216).

Colon cancer seems to show more promise for physical activity as a preventive measure than rectal cancer (102). Although job title was the only criteria for physical activity status, numerous studies showed consistency, reporting an inverse relationship between cancer risk and physical activity related to job responsibilities (163; 194; 211). Five out of ten studies using two categories of physical activity for investigating the dose-response relationship found statistical significance with an inverse dose gradient (103; 135; 186; 188). Additionally, two studies found the same relationship when using leisure time activity as the measure of physical work (162; 209).

When diet is added as a measured factor the relationship becomes stronger. Studies that controlled for dietary intake found significant inverse relationships with various types of physical activity (161; 187; 204). The research suggests that physical activity, whether leisure, structured, or related to job responsibility reduces risk for colon cancer. The risk for rectal cancer seems to remain unchanged with activity participation, but recent studies show a possible link.
Depression, anxiety disorders, and subjective feelings of mental health & physical activity

Breast cancer may also possibly be affected by regular participation in activity, but little data exists to support this possibility. Two of five studies found strong significance between physical activities during youth and later development of breast cancer, whereas only 20% of the epidemiologic studies analyzing physical activity and breast cancer risk demonstrated significance (104; 210). The inconsistencies may be related to confounding factors not accounted for in the research trials. The benefits of physical activity for breast cancer may exist through the possible benefits of exercise on weight control (96). According to the National Cancer Institute, risk for cancers of the colon, breast, endometrium, kidney, and esophagus are linked to obesity (65; 73; 105; 109). Therefore, activity that reduces risk for weight gain may also indirectly help reduce the risk of these cancers.

For all other cancers, too little information exists to make inferences related to the effect physical activity has on risk. The probable cause for the effect seen in colon cancer is the alteration of local prostaglandin synthesis. When activities are performed at higher intensities, prostaglandin (F2 alpha) synthesis increases and prostaglandin (E2) may become suppressed. This leads to increased intestinal motility, which in theory reduces contact time between carcinogens (toxins that cause cancer), co-carcinogens, and related promoters with the intestine mucosa. Although inconsistent results have been demonstrated in research trials, scientists believe mechanisms for enhanced motility will likely help reduce risk of colon cancer.

**Mental Health & Physical Activity**

Depression, anxiety disorders, and subjective feelings of self-worth affect psychological well-being. These disorders affect millions of people and are linked to suicide, currently the nation’s ninth leading cause of death (136). Statistical reports suggest 1 out of 10 adults suffer from some type of depressive disorder, and approximately 15% of people experience anxiety disorders during any given year (125). One study found 25% of people ages 15-54 reported mental disorders during the previous year (1). Mental health and psychological well-being relate to mood, personality, cognition, and perception. Consequently, these factors are linked to physical health and perceived quality of life (153). Due to this relationship, it has been surmised that physical activity can improve mood, self-esteem, self-efficacy, and cognitive function.

Epidemiologic research demonstrates an association between physical activity and symptoms of depression, clinical depression, symptoms of anxiety, improvements in positive affect (disposition), and general well-being (69; 152). These trials suggest that improvements associated with physical activity occur in persons with diagnosed disorders and in the general public, among persons reporting mood disturbances (124). Studies using aerobic training have demonstrated a temporary change in mental state based on a single episode of physical activity (144). Subjects reported reduced anxiety, reduced muscle tension, and improvements in transient mood, lasting 2-6 hours post-exercise. For exercise to affect trait measures, it is suggested that participation must be routine. It is not known if chronic participation causes actual trait adjustments or simply results in “carry-over effect” of the transient state changes associated with the exercise bout. Adults who engaged in routine physical activity from exercise or sport experienced reduced symptoms of depression and anxiety compared to individuals reporting no physical activity (151). In a cross-sectional study involving over 46,000 individuals, physical activity was associated with improved mood and general well-being and fewer symptoms of anxiety and depression (70). On the contrary, studies analyzing the effects of physical inactivity on mental health found that individuals who engaged in little or no recreational physical activity had greater incidence of depressive symptoms.

The activity engaged in and frequency of participation may play a role in the mental shifts associated with physical activity (22). Women reported improvements in positive affect when the activity was recreational but did not show the same outcome when housework was a contributor to the physical activity measured by energy expenditure (21; 195). Men reported a 27% lower incidence of depression when engaged in activity 3 or more days per week (195). Additionally, individuals who expended 1,000-2,499 kcal per week showed a 17% reduction in risk, while those who exceeded 2500 kcal per week experienced a 28% reduction compared to those that expended less than 1,000 kcal in a one week period of time (38). In a similar study, an inverse dose-response relationship was found between energy expended and incidence of depression (58). Greater participation in activity seems to reduce risk for depression, consistent with the frequency and amount of work performed, up to a certain point. When individuals engage in strenuous or excessive activity, subjects reported negative mental health effects. No threshold of intensity or duration has been identified, nor has an optimal volume been demonstrated, but endurance athletes performing vigorous exercise have reported negative effects on mental health (57; 133). These included mood disturbances, increased fatigue, anxiety, and symptoms of depression. These negative effects are consistent with some of the symptoms identified in overtraining syndrome. It would seem that the deleterious effects from strenuous, high volume
exercise are related to overtraining, as mood improved when excessive work was tapered back.

The suggested biological mechanism for improved mental state with exercise relates to the concentration of brain neurotransmitters (chemicals that transmit signals from one brain nerve to another) and neuroreceptors. Dopamine, norepinephrine, and serotonin, as well as endorphins, enkephalins, and dynorphins have been proposed components in mood adjustments associated with activity. Additionally, the temperature changes and physiological adaptations associated with increased core temperature possibly explain the reduction in tension reported by subjects. It is also likely that some of the positive effects from exercise are psychosocial. Social interaction, healthy competitiveness, and social support that many people experience in environments associated with physical activity may be added factors to improved self-esteem, self-efficacy, and relief of daily stressors. No matter what the particular impetus for improvement in mental health and well-being, it seems physical activity performed at moderate levels throughout the week can improve mental health.

Chapter Twelve References


204. Tamakoshi K, Tokudome S, Kuriki K, Takekuma K and Toyoshima H. [Epidemiology and primary prevention


