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Aerobic Exercise Prescription for Older Population: A Short Review

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Abstract

Aerobic exercise can lower the susceptibility to certain preventable chronic diseases, decrease mortality and improve health in the older adults. The health benefits of aerobic exercise include prevention of cardiovascular and coronary heart diseases; lowering blood pressure and blood lipids; lowering the risk of type 2 diabetes mellitus, back pain, osteoarthritis, osteoporosis, falls and, to some extent, sarcopenia; and improving quality of life and independent living in older adults. Aerobic training should be continued in order to be beneficial. If it is professionally prescribed by a physiotherapist or clinical exercise specialist using the most current research evidence, aerobic exercise can be enjoyable and safe. Professional and medical supervision during aerobic training may be needed for the older population and those who are at a higher risk for cardiovascular disease, stroke, hypertension or who have diabetes mellitus, obesity, osteoarthritis, and osteoporosis. More research is still needed to identify the physiological and cellular mechanisms that show exercise can slow the aging process. This review article presents aerobic exercise-induced cardiovascular benefits and optimal exercise prescription for promoting cardiovascular-pulmonary-muscular health and preventing age-related diseases and mortality.

Keywords: Oxygen consumption; Aerobic exercise prescription; Cardiovascular pulmonary; Muscular health; Elderly population

Introduction

Physical health may be characterized as the ability to perform activities of daily living and other physical work such as walking around on campus or in a playground or playing tennis without experiencing any limitations or impairments such as undue muscular fatigue, chest pain or excessive dyspnea. For a healthy individual, under normal atmospheric conditions along with healthy functional respiratory, cardiovascular and muscular systems, exercise test results would be expected to show normal cardiac, pulmonary and muscular response to physical stress. Thus, with this assumption, oxygen is the major ingredient that supplies energy and changes levels of physical and metabolic activity during aerobic exercise. The process of aging and the preservation of healthy cardiovascular, pulmonary and muscular systems are working at different rates. These two dichotomies may be moving in two opposite directions. Accepting the fact that human's age at different rates, we must maximize the preservation process to preserve healthy organs. For elderly men and women, age between 65 and 85 years, participation in low-intensity aerobic exercise improved or retained postural balance, sit-to-stand muscular strength and muscular endurance, whole body reaction response as well as aerobic capacity [1,2]. For elderly postmenopausal women, low volume aerobic exercise consisted of walking 30-60 min a day, 2 days a week for 12 weeks significantly increased resting serum antioxidant potential concentration (e.g., attenuates oxidative stress) compared to baseline values [3]. However, report also suggests that the magnitude of positive health changes increases as exercise adherence and exercise dose increased [4]. To-date, pharmacologic invention of anti-aging drugs and gene therapeutic procedures are not available. We must rely on other resources that are currently available for slowing or reversing the aging process, which is to increase physical activity and exercise. Thus, this attractive and feasible undertaking is the basis for considering increased aerobic capacity or VO_{2max} as an important parameter in the preservation of health.

Aerobic Exercise and Oxygen Consumption

To unlock energy from metabolic subtracts, oxygen serves as the proton acceptor in the oxidative processes to split the phosphate anion bonds (~P) adenosine triphosphate (ATP) to ADP + Pi (ADP, adenosine diphosphate and Pi, inorganic phosphate) [5]. At the myofibril levels several enzymatic reactions control these oxidative processes. Once the energy is released it is transformed into mechanical energy for muscular contraction. However, the reserve of ~P in the muscle cell is quite small compared to ~P need during aerobic exercise [6]. In order to sustain external work, oxygen consumption (VO_2) at the cellular level must increase to meet the demands. The aerobic oxidation of substrates such as carbohydrates and fatty acids provide the majority of ATP regeneration during steady state moderate-intensity and long duration exercise such as 5-kilometer (k) and 10-k to marathon races. To complete a long-distance and moderate intensity race without exhaustion, cardiorespiratory response must continuously supply the needed oxygen to regenerate the ATP for that activity. Factors that limit or prevent an individual from continuing an exercise routine or road race include cardiorespiratory failure with its associated symptoms such as neuromuscular fatigue due to decreased levels of ATP, low cellular pH and increased Pi, impaired myofibrillar calcium sensitivity, and impaired calcium release from the sarcoplasmic reticulum [5]. The other factors are respiratory dyspnea and central cardiac distress (angina) or peripheral disturbances (claudication). Considering the central cardiac distress (angina) factor, acute myocardial ischemia induced by insufficient coronary blood flow is a reflection of an inadequate oxygen supply to the myocardium in response to increased myocardial oxygen demands during activity. In light of the ventilatory factor, it can be related to inefficient gas exchange due to ventilation-

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perfusion mismatching to eliminate CO_2-H^+ equivalence from the body, hypoxemia, or impaired ventilatory mechanics in response to exercise [7]. Exercise intolerance (e.g., reduced exercise capacity) can be determined using a cardiorespiratory exercise testing to detect the source of limitations whether it is due to cardiovascular, ventilatory or metabolic abnormality.

During steady-state exercise to exhaustion, cardiac output (e.g., stroke volume and heart rate) and pulmonary ventilation (VE) must increase at a rate that is adequate to meet cellular O_2 (Q_{O2}) demand. If respiratory VO_2 fails to increase at a rate appropriate to Q_{O2}, lactic acids and hydrogen ion (H^+) concentration will accumulate in the cells leading to work rate decrement. Under this condition, elimination of excess CO_2 via adequate ventilation must be accomplished quickly to regulate arterial pH at physiological levels. To accomplish this, the ventilatory control mechanism must increase ventilation (VE) at a rate closely matched with CO_2 elimination and exchange at the lungs as well as the degree of lactic acidosis. With regards to the ventilatory system, its function is linked to the CO_2-H^+ and lactic acid production during steady state exercise [7]. However, during incremental exercise to exhaustion the observed hyperventilation (e.g., increase VE) response is usually inadequate to reduce CO_2-H^+ production and arterial lactic acid accumulation and thus arterial acidemia develops, so that external work cannot be sustained. According to Wassermann et al. [5] inefficient coupling or failing of the interaction of physiological mechanisms that link gas exchange between the cells and the external environment is the primary course of impaired or limited work performance.

Increased Aerobic Capacity Can Influence Cardiovascular-Pulmonary-Muscular Health and Lower Disease Risk Factors

Individuals who have acquired a high level of Cardiorespiratory Fitness (CRF) are often associated with low risk for developing coronary heart disease [8]. There are many other positive health benefits associated with high level of CRF, such as an enhanced level of High-Density Lipoproteins (HDL), improved insulin sensitivity, prevention of the onset of type 2 diabetes mellitus, and increased stamina and ability to tolerate the routine activities of daily living (e.g., less fatigue). People who have a high risk of developing type-2 diabetes mellitus can lower their risk by engaging in lifestyle intervention, aerobic training and weight loss [9]. A very important component related to aerobic capacity is cardiorespiratory fitness which is a physiological characteristic for quantifying the ability of the body to transport and utilize oxygen in the exercising muscle. This physiological function is associated with maximal stroke volume and heart rate (e.g., the central factor) as well as maximal arterial and venous oxygen difference (e.g., the peripheral factor). Thus, people who regularly engage in aerobic exercise will enhance their cardiovascular and respiratory efficiency, increase muscular oxidative capacity, and lower sympathetic nervous reactivity in response to physical and/or psychological stress. It is well known that exercise stress and psychological stress act synergistically to intensify cardiovascular responses which may contribute to the increased risk of developing Cardiovascular Disease (CVD) [10]. Acute psychological stress contributes to the progression of CVD and can activate the sympathetic-adrenal-medullary axis, eliciting the release of catecholamines (e.g., norepinephrine and epinephrine) leading to chronic elevation of heart rate and blood pressure [10]. There are several studies reporting the association between aerobic capacity and CVD morbidity and mortality in older men and women [11-16].

The question is, does equivalent energy expenditure (e.g., similar training volume) of moderate–intensity (e.g., walking) versus vigorous–intensity exercise (e.g., running) provide similar health benefits? With vigorous-intensity aerobic exercise, Williams and Thompson [16] observed significantly decreased risks of developing hypertension by 10%, high cholesterol by 18%, type-2 diabetes mellitus by 25%, and coronary heart disease (CHD) by 35%. With moderate-intensity exercise, the percentages for lowering the risk of developing hypertension, high cholesterol, type-2 diabetes mellitus and CHD were 14%, 24%, 22%, and 38%, respectively [16]. Between the runners and walkers the risk reductions were not significantly different for diabetes mellitus, hypertension, or coronary heart disease, and only marginally greater for walking than running for hypercholesterolemia (p=0.04). In other words, whether one engaged in moderate or vigorous exercise with equivalent energy expenditures, risk reductions for hypertension, hypercholesterolemia, diabetes mellitus, and coronary heart disease are the same.

Concern about Excessive Aerobic Training and Cardiovascular Health Benefits

There is no doubt that the health benefits of aerobic exercise eventually reach a point of diminishing returns, according to the dose-response curve [13]. The dose-response curve is a term adapted from a pharmaceutical response to treatment of a health condition or illness. In the context of exercise prescription, for example, at the initial dose of exercise intervention or treatment, the curve exhibits a sharp gain in the outcome response. When the dose of exercise intervention increases, a greater gain in the treatment outcome occurs, followed by a lesser gain despite further increased doses of exercise intervention. Finally, this curve exhibits no additional gain: it reaches a plateau in the outcome response. Thus, the term "dose-response curve" means greater stimulus (dose) would induce greater response until the dose induces lesser or no response in the intervention outcomes. The term "no response" signifies an upper limit has been reached, and is sometimes expressed as a plateau curve. For instance, Figure 1 exhibits a dose-response curve for all-cause mortality reduction in percentage versus daily physical activity duration in minutes. This dose-response curve suggests that at the dose of 60 minutes of daily physical activity there was a 29% reduction in all-cause mortality and at 90 minutes of daily physical activity there was a 35% reduction in all-cause mortality [15].

Yet, no one really knows when you have reached this point of "diminishing returns". For example, do the health benefits begin to

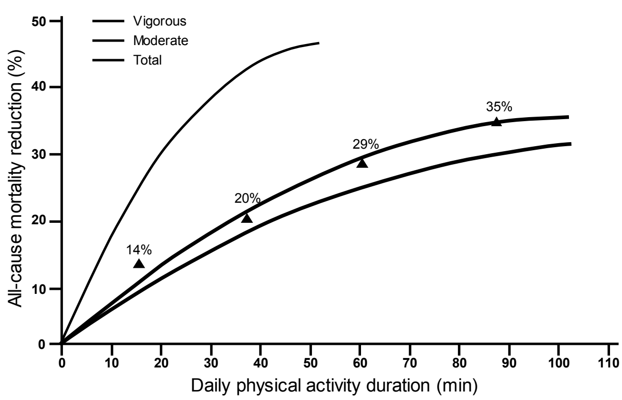

Figure 1: Shows regular daily physical activity benefits of lowering all-cause mortality reached at 60 min/day (29% reduction) and the beneficial effect continues at 90 min/day of daily physical activity (35% reduction). This dose-response curve suggests that there was no identifiable upper limit of moderate or vigorous daily physical activity beyond 60 min/day (with permission from the editors of the Lancet).

diminish as the time spent in vigorous aerobic exercise increases beyond one hour a day? Many people may nevertheless wonder whether excessive strenuous aerobic exercise such as running a Marathon race, would have an acute or long-term harmful effect on cardiovascular health. Wen et al. [15] showed that regular daily physical activity benefits of lowering mortality reached a peak at 50 min per day (a hazard ratio of 0.60). The beneficial effect continues past 70 min per day and by the 120th min of exercise per day, the hazard ratio for all-cause mortality was around 0.55, with even better hazard ratios for cardiovascular diseases [15]. Thus, the adverse effects of strenuous aerobic exercise with incremental efforts for more than an hour a day did not seem to outweigh the benefits. With regards to this, there was no identifiable upper limit of moderate or vigorous physical activity beyond 60 min per day [15]. In light of this, here are some of the concerns one must be aware of, for example, cardiovascular and musculoskeletal health benefits may be negatively affected, if a novel or experienced runner 1) does not adequately prepare for a long duration vigorous exercise such as the Marathon race, 2) does not have a cardiovascular health screening prior to running a Marathon, and 3) ignores the principle of over-training [17].

Aerobic Exercise Training and Preventable Chronic Diseases

Aerobic exercise has an inverse relationship for developing coronary heart disease, diabetes mellitus, certain cancers and depression as well as all-cause mortality [18-21]. In a most recent study on the impact of aerobic exercise and daytime blood pressure variability, a significant and independent contributor of cardiovascular disease and all-cause mortality, Pagonas et al. [22] observed that after aerobic training, daytime resting systolic and diastolic pressures were significantly decreased. Considering the dose-response relationship between aerobic exercise and blood pressure, Haul et al. [23] performed a meta-analysis study and observed that there was a significant inverse relationship between levels of recreational (non-occupational) physical activity and risk of developing hypertension in older adults. This relationship holds true for both genders. For example, in older women with hypertension moderate and vigorous intensity aerobic exercise lowered systolic and diastolic blood pressure, compared with exercise that is moderate-intensity [24]. In men and women with hypertension, low-to-moderate intensity aerobic training appears to be more beneficial for decreasing blood pressure, compared with higher-intensity aerobic training [25].

For sedentary older adults, researchers support the inclusion of non-vigorous physical activity [1,4,15,19] or moderate-intensity aerobic exercise for lowering the risk of developing hypertension and cardiovascular disease [20,21,24,25]. Chapman et al. [26] reported that one hour a day of moderate-intensity aerobic exercise, 3 sessions a week of shorter-term aerobic training (e.g., 12 weeks) can improve VO_{2max} and cognitive function. In light of this, the focus of exercise intensity for older adults should be placed on the dose-response relationship, which identified the amount (or exercise volume) of aerobic exercise below that is recommended. The exercise volume that would confer some protection against hypertension is 500 MET-min per week or 1.8 MET-hour per day [17]. The 1.8 MET-hour per day of aerobic exercise would be an equivalent to an exercise intensity of 3 METs, 30 minutes per day, 6 days per week or an equivalent to an exercise intensity of 6 METs, 30 minutes per day, 3 days per week. "MET" is an acronym for metabolic equivalent which is a standardized way of describing the absolute intensity of a variety of physical activities or exercise. Conventionally, one MET requires an average of 3.5 ml /kg/min of oxygen uptake at rest during quiet sitting. Accordingly, any physical activity or exercise at or less than 3 METs level (a level that is about 3-time higher than the resting energy expenditure such as walking) indicates "light" intensity; any physical activity or exercise between 3 and 6 METs level denotes "moderate" intensity such as brisk walking and jogging; and any physical activity or exercise at or higher than 6 METs level is considered "high" intensity [17]. For example, an endurance trained older man with a high aerobic capacity of 11 METs (or VO_{2max} of 38.5 ml/kg/min) may be able to do moderate- to high-intensity exercise at 70% of his aerobic capacity, which is at 7.7 METs level (11 METs × 0.7).

The Components of Aerobic Exercise Training Session

According to American College of Sports Medicine (ACSM) [17], a single session of aerobic exercise should include: 1) warm-up activities (5 min at a minimum of 40% - 60% oxygen uptake reserve [VO_2R]), 2) stretching exercises (5 min of dynamic or static neuromuscular stretching), 3) conditioning exercises (20-60 min of aerobic activities at ≥ 60% - 85% VO_2R), and 4) cool-down activities (5-10 min of low-intensity aerobic activities at 40% - 60% VO_2R). The conditioning exercises phase should follow the F.I.T.T principle of exercise training which is: Frequency of exercise (F), Intensity of exercise (I), duration of exercise (T), and Type of exercise (T) [17]. Thus, the volume of aerobic exercise is the combined function of frequency, intensity, and duration of the exercise completed in a single aerobic session. Based on the overload principle of training, aerobic exercise volume follows a "dose-response" relationship for achieving health benefits. In other words, a small increase in oxygen uptake or energy expenditure during daily aerobic exercise may improve health benefits.

Aerobic Exercise Prescription

ACSM [27] and American Heart Association [28] suggest that the number of days per week an individual is engaged in aerobic training (e.g., frequency of aerobic exercise) is very important for gaining health benefits and CRF. For example, for some people one to two sessions per week of aerobic training performed at moderate-to-high intensity (>60% VO2R) can achieve health benefits and improve CRF [13,28]. The Center for Disease Control and Prevention and the ACSM recommend that aerobic exercise should be performed on most days of the week (e.g., more than 5 days per week) [29]. Currently, ACSM recommends that 3 to 5 days per week of moderate- and vigorous-intensity exercise (≥ 60% VO2R) for most adults to accomplish and maintain health benefits and CRF [17]. There is a plateau period in CRF improvement according to the "dose-response" curve of exercise stimulus [13]. Accordingly, an individual should be aware of this and adopt a variety of exercise modalities to generate different stimuli for the cardiovascular, pulmonary and musculoskeletal system to achieve optimal health benefits and gain CRF.

Intensity of exercise should follow the "overload" principle of training, also known as progressive overloading the cardiorespiratory and musculoskeletal system to achieve optimal responses for gaining health benefits and CRF. The "overload" principle of training states that to improve CRF and gain greater health benefits one must train harder, by progressively increasing training intensity and/or duration of exercise. This concept is one of the major components of aerobic training. ACSM [17] recommends that a minimum threshold for most adults to achieve health benefits and CRF is an intensity of 40% to <60% maximal oxygen uptake reserve (VO2R) or heart rate reserve (HRR). On occasion, it is not possible to accurately determine resting and maximal heart rate or VO_2 of an individual. In light of this, the following equations can be used to estimate the rate of energy expenditure and exercise intensity during aerobic exercise. Age predicted maximum heart rate can be obtained by using the following equations: 1) predicted maximum heart rate (HR_{max}) = (220 – age in year), or 2) predicted HR_{max} = 207 – (0.7 × age in year) [30]. Heart rate reserve may be calculated using a target heart rate (THR) formula: THR = [(HR_{max} – HR_{rest}) X % intensity] + HR_{rest}, and VO2 reserve may be calculated using a target VO_2 (TVO2R) formula: TVO2R = [(VO_{2max} – VO_{2rest}) × % intensity] + $VO_{2rest.}$

Duration of exercise is the measurement of total amount of time spent in performing aerobic exercise or physical activity per session. The amount of time spent doing the aerobic exercise can be continued within one single session or accumulated over the course of a day through one or more sessions of exercise of at least 10 minutes in duration. Accumulating 150 minutes per week of jogging (e.g., 30 min a day at a 10 min-mile pace, 5 days a week) equals approximately 1,000 kcal of caloric expenditure. This duration of exercise may be recommended for older adults with some health limitations or poor CRF for achieving health benefits and gaining CRF. However, for most healthy adults a quantity of more than 2,000 kcal per week of caloric expenditure (but not higher than 3,500 kcal per week) may result in greater health benefits and CRF [17].

The modality of aerobic exercise should be rhythmic and repetitive in nature involving large muscle groups. By using large muscle group to perform aerobic exercise we can promote cardiorespiratory endurance and musculoskeletal health, and have a better overall quality of life. The modes of aerobic exercise include walking, stair climbing, hiking, jogging, running, social dancing, cycling, swimming, cross-country skiing, skating, rowing, tennis, racquet sports, basketball, soccer, volleyball, and Tai-Chi. Some of the listed modes of activity may require little sport skills and other may require a high degree of skills and appropriate level of CRF to perform. Keep in mind the principle of specificity of training suggests that optimal physiological adaptations to training are specific to the type of exercise performed. To lower the risk of over-exertion or injury, prescriptions should be individually tailored and professionally supervised.

Exercise Precautions and Specific Concerns

The following aerobic exercise precautions and specific concerns should be observed to promote optimal health and prevent injury.

1. Persons with low risk for cardiovascular disease such as high blood pressure, obesity, diabetes, and hyperlipidemia; musculoskeletal disorders; osteoporosis and falls may participate in aerobic training without supervision, especially those regular exercisers with an aerobic capacity greater than 7 METs.
2. Persons with high risk for cardiovascular disease, musculoskeletal problem, osteoporosis and falls may need a pre-participation health screening, medical evaluation or exercise stress testing to detect any contraindications to exercise.
3. Some high-risk older individuals with cardiovascular disorders, metabolic syndrome or family history of cardiovascular disease may need a medical clearance to begin an exercise program and clinical supervision during exercise (e.g., cardiac and pulmonary rehabilitation program).
4. Provide proper and adequate guidelines for fluid replacement because sustained and repeated aerobic exercise in a hot environment may induce moderate to severe dehydration causing heat cramps, heat exhaustion and heat stroke, especially when body weight loss during aerobic exercise is > 6% of initial body weight [17].
5. Wear well-cushioned exercise shoes during aerobic training and pay attention to daily foot hygiene.
6. Avoid exercise-induced hypoglycemia by consuming an extra 20-30 grams of carbohydrate during and after exercise. Also, be aware of an exercise-induced phenomenon in diabetic patients known as delayed-onset hypoglycemia (e.g. low blood glucose concentration 6 to 15 hours after exercise) [17]. You should eat meals of small portions and at greater frequency to avoid delayed-onset low blood glucose response after exercise.
7. Overweight or obese individuals may not be able to complete 50-60 min of continuous aerobic exercise and, therefore, should gradually increase the duration and frequency of exercise between 2 and 3 weeks.

Summary and Conclusion

Aerobic exercise can lower the susceptibility to certain preventable chronic diseases, decrease mortality and improve health. For sedentary older adults, non-vigorous physical activity or low- to moderate-intensity aerobic exercise may be prescribed for lowering the risk of developing hypertension, type-2 diabetes mellitus and cardiovascular disease. However, exercise training should be continued in order to be beneficial. If it is professionally prescribed by a physiotherapist or clinical exercise specialist using the most current research evidence, aerobic exercise can be enjoyable and safe. More research is warrant to identify the physiological and cellular mechanisms that show exercise can slow the aging process. In summary, to sustain aerobic work, oxygen consumption at the cellular level must increase to meet the demands of the working muscle. To achieve health benefits and optimal cardiorespiratory fitness, exercise prescriptions should be tailored to individual's needs and tolerance to the impact of exercise.

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