

## The Effect of Resistance Exercise on Aerobic Capacity for Old Adults and CAD Patients

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Aerobic capacity is an important health indicator which is related to the probability of disease, disability, and mortality. Typically, endurance exercise is known as the primary method of improving aerobic capacity. Although most of resistance exercises are not considered for a good method increasing aerobic capacity, low to moderate intensity resistance exercise with short rest periods may improve aerobic capacity, especially old adults and most low to moderate risk patients suffering from CAD. This review is to understand that a number of physiological changes occur during both aerobic and resistance exercise, and to support that resistance exercise has advantages for improving aerobic capacity.

**Key words** : Maximum oxygen consumption, heart rate, stroke volume, blood pressure, arteriovenous oxygen difference

### Introduction

Aerobic capacity, measured by maximum oxygen consumption ( $VO_{2max}$ ) or peak oxygen consumption, is associated with mortality. Low aerobic capacity is related to increased risk of cardiovascular disease, stroke, hypertension, and mortality. Interventions that improve aerobic capacity can have important health implications by decreasing the probability of disease, disability, and mortality [1].

Endurance exercise is traditionally used as the primary method of increasing aerobic capacity, while resistance exercise is not typically considered for improving aerobic capacity [7]. Hurley et al. [10] and Hickson et al. [9] found that young and middle aged subjects using resistance exercise regimens did not significantly improve their aerobic capacity. On the other hand, Stone and his colleagues demonstrated that resistance exercise increased  $VO_{2max}$  [19]. In addition, other investigators have suggested that a combination of aerobic and resistance training improves aerobic capacity more than aerobic exercise alone [5,13].

Unfortunately, since these studies used different regimens and duration, there is no agreement on the effects of resistance exercise on  $VO_{2max}$ . The purpose of this article is to briefly review pertinent literature that examines the ef-

fect of resistance exercise on aerobic capacity. Additionally, we will review the studies that showed the effect of combined aerobic and resistance exercise on the aerobic capacity. Our discussion will support the concept that resistance exercise has advantages for improving aerobic capacity, especially in the older adult.

### Factors affecting aerobic capacity

A number of physiological changes occur during both aerobic and resistance exercise; increased cardiac output, increased skin blood flow, decreased blood flow to the kidneys, decreased visceral blood flow, increased active muscle blood flow and coronary artery blood flow, and maintenance or a slight increase in brain blood flow. These distinctive responses are influenced by numerous factors, including the active muscle mass, intensity of the exercise, type of exercise, duration of exercise, use of rest periods between exercises, and the intermittent nature of the exercise performance.

#### Heart rate

Heart rate (HR) is an important factor to increase cardiac output during exercise. HR increases with increasing exercise intensity and oxygen consumption. Typically, HR will increase from about 70 beats/min at rest to 180 to 200 beats/min at maximal exercise [4]. During a constant intensity of exercise, HR increases and is maintained when

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the oxygen requirements of the activity have been satisfied. As intensity increases, HR needs a longer time to level off. HR is lower during resistance exercise than during endurance exercise. During resistance exercise, it has been shown that the magnitude of the HR response is directly influenced by the percentage of maximum voluntary contraction (MVC). When the percentage of MVC increases above 20% and is continually maintained, the HR will increase in proportion to the duration, tension exerted, and amount of muscle mass utilized [4].

#### Oxygen consumption

Oxygen consumption increases in proportion to the intensity of exercise. It is influenced by the rate of oxygen transport, the oxygen carrying capacity of blood. As intensity of exercise gradually increases, stroke volume increases during the early phase of exercise when upright exercising then plateaus. HR and (a-v) O<sub>2</sub> increase almost linearly with exercise intensity. During submaximal exercise, cardiac output and (a-v) O<sub>2</sub> each account for about 50% of the increase in oxygen consumption [4]. Cardiac output plays a more important role in increasing oxygen consumption as the intensity approaches maximum. Several studies have observed small increases in oxygen consumption during resistance exercise [3,16] while others report greater elevation with the magnitude of the response which is associated with the type of resistance exercise and with the intensity of contraction [6].

#### Stroke volume

SV is influenced by preload, afterload, contractility, catecholamines, and HR [4]. Resistance exercise primarily increases afterload. SV increases steadily until about 25 to 50% of maximum then tends to level off. Higher intensity muscle contractions results in decreased preload, increased afterload, and an overall diminished SV response [15]. The SV increases during resistance exercises that involve small muscle groups or during exercises that are performed at a low percentage of maximal voluntary contraction [16]. Several studies indicate that increased intensity or a greater active muscle mass during resistance exercise are accompanied by an unchanged or significantly reduced SV compared to rest [14,20].

#### Blood pressure

BP must be increased during exercise. Systolic blood

pressure rises steadily during exercise. It increases from about 120 mmHg at rest to 180 mmHg or more during maximal exercise. However, diastolic pressure is either unchanged or decreases slightly in healthy people during aerobic exercise. This increase in exercise blood pressure varies among people. Failure to increase systolic blood pressure and mean arterial pressure during exercise is a predictor of heart failure. Resistance exercise causes a sudden and very large elevation of systolic and diastolic blood pressure. It is considered discordant to the amount of work performed by the contracting muscle. Since both systolic and diastolic pressure increase, mean arterial pressure increases to a greater extent than doing aerobic exercise. The mechanism of the dramatic rise in blood pressure during resistance exercise is comprised of both central and peripheral components [4].

#### Arteriovenous oxygen difference (a-vO<sub>2</sub>Δ)

a-vO<sub>2</sub>Δ increases with exercise intensity from a resting value of about 5.6% to about 16% at maximal exercise [4]. Some oxygenated blood is always returning to the heart, even at exhaustive levels of exercise. This is because some blood continues to flow through metabolically less active tissues, which do not fully extract the oxygen from the blood. The change of a-vO<sub>2</sub>Δ may be related to mitochondria density, hemoglobin and myoglobin concentrations, and muscle capillary density. Specially, the number of capillaries around each fiber is a good predictor of aerobic capacity. Although resistance training increases the cross sectional area of muscle which is termed hypertrophy, mitochondrial volume density and capillary density actually decrease with high resistance training [4]. Therefore, individuals who train only with high resistance exercises decrease aerobic capacity.

#### Studies

It is of practical interest to determine whether resistance exercise may improve aerobic capacity. It is very difficult to say that it is effect on aerobic capacity since the studies used different exercise regimens and variables. However, the low intensity and short rest period between sets may increase aerobic capacity.

Gettman et al. [8] have reported that programs of circuit weight training characterized by moderate resistance and numerous repetitions with short rest periods are effective

in producing modest increases in  $\text{VO}_2\text{max}$ . The strength trained subjects in Gettman's study performed weight training 3 days per week for 12 weeks. Three circuits of 10 weight training exercises were completed with 12-15 repetitions performed in 30 s at 40% of one-repetition maximum (1RM) at each station. The 22.5 min CWT program included a 15 s rest period between stations. In this study, Gettman et al. studied 3 groups; circuit weight training (CWT), combined running and circuit weight training (RCWT), and control group.

The result of Gettman's study [8] indicated that both CWT and RCWT groups had a significant increase in  $\text{VO}_2\text{max}$ . Treadmill performance times increased 22% and 16% for the female and male RCWT groups, respectively, while the increases for the female and male CWT groups were 14% and 10%. All of these increases were significantly different from the control group changes, but there were no differences between the two different training groups. The increase in maximal aerobic capacity found in this study may be due to the training mode rather than the duration of training, since subjects in a study by Wilmore et al. had a similar improvement after CWT in spite of a different duration. Wilmore's study [21] protocol was similar to that used in Gettman's study when 30 s of CWT at 40-55% of 1RM was followed by 15 s of rest for 8 weeks. Similarly, Kaikkonen et al. [11] showed that circuit weight training with resistance of 20% 1RM with an appropriate HR level had effects comparable to an equal amount of endurance training on the aerobic capacity of sedentary adults. The CWT group trained with air resistance machines for 12 weeks, 3 days a week in sessions of 40 minutes, with a HR level of 70-80%  $\text{HR}_{\text{max}}$ .

However, Kraemer et al. [12] have reported that weight training with heavy resistance and long rest periods between sets is not an effective method for improving aerobic capacity. In addition, Hurley et al. [10] also showed that strength training failed to produce substantial increases in  $\text{VO}_2\text{max}$ . The subjects of Hurley's study trained on Nautilus exercise machines 3-4 times per week for 16 weeks. The subjects performed between 8 and 12 maximum repetitions for all exercises during each training session. Subjects were also encouraged to move as quickly as possible to the next machine after completing an exercise.

These findings suggest that maximal intensity resistance strength training produces no improvement in cardiovascular function even though HR elevation was

sustained. Despite sustained elevation of HR during strength training, this form of exercise may attribute to the low relative 45%  $\text{VO}_2\text{max}$ . The major reason for the low  $\text{VO}_2$  was explained by the much greater sympathetic adrenergic response to the resistance exercise.

In 1980, Hickson et al. [9] also reported that resistance training did not have an effect on aerobic capacity. They examined the effect of concurrent resistance and aerobic training on aerobic capacity, and they found that resistance exercise or the combination of resistance and aerobic exercise didn't increase  $\text{VO}_2\text{max}$  and peak oxygen consumption. The strength trained subjects in Hickson's study performed weight training 5 days per week for 10 weeks. Three days per week they performed parallel squats, 5 sets of 5 repetitions and knee flexions and knee extensions both for 3 sets of 5 repetitions. Two days per week leg presses, 3 sets of 5 repetitions and calf raises, 3 sets of 20 repetitions were performed. Throughout the training all exercise were performed with the maximal resistance possible for the required number of repetitions. The endurance group of subjects trained 6 days/week for 10 weeks. Three days per week they performed interval-training on a cycle ergometer consisting of 65 minute work bouts at a rate which approached  $\text{VO}_2\text{max}$ . The combined strength and endurance group performed the exact exercise regimens as the strength only and endurance only groups.

The results of Hickson's study showed that concurrent training resistance and endurance induces increases in muscular strength and in aerobic power. However, the increase in aerobic power of the group was no greater than that induced by endurance training only. The resistance training improved muscular strength but not aerobic power. On the contrary, Butler et al. [5] and McCartney et al. [13] have shown that a combination of aerobic and circuit weight training improves aerobic capacity more than aerobic exercise alone. Unfortunately, in these studies the duration of training was short and  $\text{VO}_2$  was not measured directly.

Stewart et al. [18] have reported the effect of both aerobic and weight training exercise on aerobic capacity for CAD patients. Exercise sessions of this study were held 3 times per week for 10 weeks. The patients performed 5 minutes of warm-up on cycle and 8 minutes of cycling at 70-80% of  $\text{HR}_{\text{max}}$  and performed 6 circuit of 6 weight training exercise for 30 s with the goal of completing 10-15 repetitions at 40% of 1 RM. There was 30 seconds of rest

between exercises. The results indicated a 14 % increase in  $VO_{2peak}$  and a 10 % increase in exercise time on the treadmill in CAD patients who performed both exercise for 10 weeks. However, there was an 8 % increase in both maximal oxygen uptake and exercise duration for the group that undertook aerobic training only and there was no significant difference between groups. Interestingly, the improvement in  $VO_{2peak}$  and time on the treadmill were significant in the combined exercise group, but not in the aerobic training group. In another study by Santa-Clara [17] performed the longer training program (12 months) has a similar result as Stewart's study. The aerobic exercise prescription was set at a heart rate of 60-70% of  $HR_{max}$  for 30 minutes. The subjects performed 2 circuit of 8 weight training with 8-12 repetitions at 40-50% of 1 RM. The combined exercise group showed an increase in  $VO_{2peak}$  of 24% compared to a 21% increase in the aerobic only group. Time on the treadmill also increased by 4% in the combined exercise group, but did not change in the aerobic exercise group. Although the combined exercise group had slightly greater relative improvement, there was no significant different between groups.

### Conclusion

The results of this article suggest that low to moderate intensity resistance exercise with short rest periods may improve aerobic capacity although resistance exercise is still not considered a good method of improving aerobic capacity. As we discussed, the traditional high intensity resistance training does not have an effect on aerobic capacity. In addition, moderate intensity resistance training with aerobic training may increase aerobic capacity more than aerobic training alone. Low intensity resistance exercise may increase time on the treadmill which can affect on aerobic capacity for the CAD patient and old adult. This article supports the recommendations of the American Association of Cardiovascular and Pulmonary Rehabilitation [1], and the American College of Sports Medicine [2] that older adults and most low to moderate risk patients suffering from CAD should perform resistance exercise training.

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### 초록 : 저항운동이 CAD환자와 노인의 유산소 능력에 미치는 영향

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심폐지구력은 질병, 장애, 수명 등과 연관된 중요한 건강 지표이다. 지구성 운동이 대개 심폐지구력향상을 위한 방법으로 알려져 있는 반면 대부분의 저항성 운동은 심폐지구력향상을 위한 좋은 방법으로 고려치 않고 있다. 그러나, 짧은 휴식기간을 가진 저 강도 혹은 중간 강도의 저항성운동은 특히 노인들이나 관상동맥질환을 가진 환자들의 심폐지구력향상에 도움을 줄 수 있을 것이다. 본 총설은 지구성운동과 저항성운동 시의 생리학적변화를 이해하고, 저항성운동이 심폐지구력향상에 도움을 줄 수 있다는 사실을 이론적으로 뒷받침하고자 한다.