EFFECT OF RESISTANCE AND AEROBIC EXERCISE ON

EXCESS POST-EXERCISE OXYGEN CONSUMPTION

IN YOUNGER AND OLDER MEN

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ABSTRACT

The effect of exercise mode and age on excess post-exercise oxygen consumption (EPOC) has not been previously considered. Therefore, this study determined EPOC following aerobic versus resistance exercise in 9 healthy younger men (age = 22.9 ± 2.3 yr; VO_2max = 48.3 ± 5.9 ml/kg/min) and 10 healthy older men (age = 65.8 ± 3.3yr); VO_2 max = 37.9 ± 5.1 ml/kg/min) using a repeated measures ANOVA crossover design. Resistance exercise consisted of one set of ten repetitions at 50% 1-RM followed by five sets of eight repetitions at 75% of 1 RM for leg press and leg (knee) extension for 30 minutes. Aerobic exercise consisted of 5 minutes of cycling at 50% VO_2max followed by 30 minutes cycling at 70% VO_2max. Resting energy expenditure (EE) was measured via indirect calorimetry at baseline before each exercise condition and post-exercise for 6 hours. No difference was observed in resting EE, between groups or days, prior to exercise. At 6 hours following exercise, EPOC remained significantly ($p \leq 0.05$) above resting values, following both types of exercise in both age groups. The results also showed that EPOC was significantly ($p \leq 0.05$) greater in younger men compared to older men, regardless of exercise mode. Further, there was a trend for aerobic exercise to exhibit a greater post-exercise VO_2 than resistance exercise in older men. These findings suggest that men embarking on an exercise program to increase their energy expenditure in order to lose or maintain body weight may want to consider aerobic or resistance exercise of moderate intensity for at least 30 minutes in order to significantly extend energy expenditure beyond the cessation of the exercise session itself. The results also suggest that for younger men there does not seem to be one exercise mode that is superior

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in terms of energy expenditure. However, older men may benefit more from aerobic

exercise than resistance exercise to maximize post exercise energy expenditure.

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ABBREVIATIONS

EPOC: excess post-exercise oxygen consumption (ml/kg/min)
VO_2: Volume of oxygen (L, ml)
VCO_2: volume of carbon dioxide (L, ml)
ml: millilitre
kg: kilogram
min: minute
cm: centimetre
m: meter
yr: year
d:day
kcal: kilocalorie
kJ: kilo joule
RM: repetition maximum
VO_2max: maximum volume of oxygen per minute
PAR-Q: Physical Activity Readiness Questionnaire
PARmed-X: Physical Activity Readiness Medical Examination
RMR: resting metabolic rate
TEF: thermic effect of feeding
TEA: thermic effect of activity
TEM: thermic effect of a meal
EE: energy expenditure
O_2: oxygen
ATP: adenosine tri-phosphate
ADP: adenosine di-phosphate
CP: creatine phosphate
BMI: body mass index
BLS-C: basic life-saving – CPR
VE: ventilatory equivalent
TG-FA: Triglyceride- fatty acid
L: litres
kp: kilopond
rpm: revolutions per minute
GG: Greenhouse-Geisser
CV: coefficient of variation
SD: standard deviation
REE: resting energy expenditure
RER: respiratory exchange ratio

CHAPTER 1:
SCIENTIFIC FRAMEWORK

1.1 Introduction

Exercise is often prescribed to increase daily energy expenditure and fat oxidation. The alterations in metabolic rate brought about by participation in different modes of exercise training help to maintain proper levels of body weight and composition (Poehlman & Melby, 1998).

Numerous studies (Bielinski, Schutz & Jequier, 1985; Chad & Wenger, 1988, Gore & Withers, 1990) have examined the impact of steady-state aerobic exercise on energy metabolism and suggest that steady-state exercise can significantly elevate metabolic rate. Further work has also shown that exercise can produce an increase in metabolism that extends beyond the exercise session itself; termed excess post-exercise oxygen consumption (EPOC). Although steady-state exercise has been shown to be a major determinant of EPOC, few studies have addressed the impact of different exercise modes on the post-exercise energy expenditure. Furthermore, the effect of age on energy expenditure after these two exercise modes has not been investigated.

Therefore, the objective of this research will be to examine post-exercise energy expenditure in response to intermittent resistance exercise and aerobic steady-state cycling in younger and older men.

1.2 Review of Literature

1.2.1 Components of Daily Energy Expenditure

There are three major aspects of total energy expenditure that modulate body weight: metabolic factors, diet, and physical activity (Van Zant, 1992). These three factors are synonymous with the three components of total daily energy expenditure; resting metabolic rate (RMR), thermic effect of feeding (TEF), and thermic effect of physical activity (TEA or EE) (Van Zant, 1992).

Resting metabolic rate represents the largest portion of daily energy expenditure (60-75%) and is the measurement of energy expended to maintain normal body functions and homeostasis. This includes the functioning of the resting cardiovascular and pulmonary system, energy consumed by the central nervous system, and all other biochemical reactions involved in maintaining resting metabolism (Poehlman & Melby, 1998). The RMR is primarily related to the amount of fat-free mass in the body and is also influenced by age, gender, body composition, and genetic factors. For example, it is well known that RMR decreases 2 to 3% per decade with advancing age (Poehlman, Arciero & Goran, 1994; Tzankoff & Norris, 1977), and this decrease is primarily attributed to the decrease in physical activity, subsequent loss of fat-free mass, and increase in adiposity (Gardner & Poehlman, 1993; Poehlman et al., 1995). Males tend to have a higher RMR than females because of their greater body size and proportion of lean mass and burn more calories due to the greater energy cost of moving a larger body mass (Poehlman & Melby, 1998). Moreover, a low RMR for an individual's body size is a predictor of weight gain over time (Ravussin et al., 1988). Therefore, the dependency of

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RMR on body composition must be considered when individuals of different age, sex and physical activity status are compared.

The thermic effect of feeding (TEF) is the increase in energy expenditure associated with food ingestion. The TEF represents approximately 10% of daily energy expenditure and includes the energy cost of food absorption, metabolism and storage. The magnitude of TEF depends on several factors, including caloric content and composition of the meal as well as the individual's previous diet. Following meal ingestion, energy expenditure increases depending on the macronutrients consumed (Poehlman & Melby, 1998). The thermic effect of feeding varies within individuals, and has been shown to decrease with advancing age (Poehlman, Arciero & Goran, 1994).

Morgan and York (1983) measured the thermic response 3 hours following administration of two mixed meals containing 480 kcal and 950 kcal in a group of younger (24 ± 0.7 years) and older (71 ± 1.4 years) men. Although the thermic response was positively related to the size of the meal in both groups, the older men had significantly lower thermic response than the younger group, despite the fact that both meal challenges consisted of a relatively greater proportion of the daily food intake of the older men. The investigators hypothesized that the blunted thermogenic response in the older individuals is due to a chronic adaptation to a lower food intake in an attempt to maintain body energy stores. Bloesch, Schutz, Breitenstein, Jequier and Felber, (1988) measured TEM (TEF) for 3 hours following a 75 g oral glucose load in 12 older (61 ± 3 years) and 12 younger (25 ± 1 years) men and showed a 15% lower thermogenic response in the older compared to the younger. These findings were more recently extended by Schwartz, Jaeger and Veith, (1990) who showed that a lower thermic response to a meal

in the elderly was associated with reduced sympathetic nervous system activity. These findings favor the interpretation that the lower TEM (TEF) in older individuals may represent an energy conservation mechanism that contributes to their lower energy needs and propensity to accumulate body fat (Poehlman et al., 1994).

The most variable component of daily energy expenditure is the thermic effect of physical activity (TEA). This component includes the energy expended above the resting metabolic rate and the thermic effect of feeding, which includes the energy expended through voluntary exercise and the energy devoted to involuntary activity such as shivering, fidgeting, and postural control (Poehlman & Melby, 1998). The major determinant of TEA is the amount of physical activity performed, which varies according to the mode, intensity and body size. The greater the energy output through purposeful physical activity, the greater the overall daily energy expenditure. There are also variations between people in the energy cost of physical activity (Hill & Melanson, 1999). In sedentary individuals, the thermic effect of activity may comprise as little as 100 kcal per day; whereas in highly active individuals it may be closer to 3000 kcal per day. As we age there is a trend for physical activity to decrease, therefore the thermic effect of activity decreases substantially in those that are not active. Thus, physical activity is a significant factor moderating the daily energy expenditure in humans because it is extremely variable and subject to voluntary control (Poehlman & Melby, 1998).

1.2.2 Resting Metabolic Rate and Aging

The process of aging is one of transition. Over several decades, many age-related changes occur that can influence energy expenditure. One of the most consistent physiological changes to occur is the progressive decline in resting metabolic rate (Poehlman et al., 1994). Earlier cross-sectional studies (Tzankoff & Norris, 1977) and longitudinal investigations (Keys, Taylor, & Grande, 1973; Tzankoff & Norris, 1978), along with more recent findings (Poehlman, Arciero & Goran, 1994), have supported a decline in RMR with age. It is suggested that the decline in RMR is curvilinear with advancing age, with the decline accelerating beyond the middle age and postmenopausal years (Poehlman, et al., 1992). Tzankoff and Norris (1978); Keys et al. (1973), have reported a decline of 1-4% per decade of age in men 20-75 years old.

It is apparent from the past literature that a decline in resting metabolic rate is observed with increasing age. The next uncertainty, are the reasons or mechanisms responsible for the inverse relationship. Studies such as the Baltimore Longitudinal Study have suggested that the age-related decline in RMR is primarily due to the loss of fat-free mass (Tzankoff & Norris, 1977; Tzankoff & Norris, 1978). Both cross-sectional and longitudinal designs in the Baltimore Study showed that the loss of muscle mass in healthy men, up to age 65, as measured by 24 hr creatinine excretion, fully accounted for the age-related decline in RMR.

Fukagawa, Bandini and Young (1990), more recently examined the relationship between fat-free mass and RMR in young men (18-33 years), older men (69-80 years), and older women (67-75 years). They found that absolute RMR was significantly lower in older men (1.04 kcal/min) and older women (0.84 kcal/min) than in younger men (1.24

kcal/min), and the lower RMR persisted even after adjusting for differences in fat-free mass. However, RMR did not differ between older men and older women after controlling for differences in fat-free mass. Therefore, the authors concluded that differences in fat-free mass between younger and older individuals can not fully account for the lower RMR in older individuals, thus suggesting that aging is associated with an alteration in the metabolic activity of lean tissue contained in the fat-free mass component.

Other studies (Fukagawa et al., 1990; Vaughan, Zurlo, & Ravussin, 1991) have suggested that other physiological variables may contribute to the lower RMR in the elderly. In a study by Vaughn et al. (1991), 24-hour energy expenditure and its components were measured in younger (18-30 years) and older (>60 years) individuals in a room calorimeter. They found that basal metabolic rate was significantly lower in both groups of older subjects than in younger subjects, even after adjustment for differences in fat-free mass, fat mass, and gender. This group suggested that sympathetic nervous system activity, another determinant of energy expenditure, may account for some of the lower adjusted basal metabolic rate and lower ratio of basal to sleeping energy expenditure found in the older subjects. Collectively, these studies (Fukawaga et al., 1990; Tzankoff & Norris, 1978; Vaughn et al., 1991), suggest that age and alterations in body composition are independent predictors of the decline in RMR, but they cannot fully account for the decrement.

Poehlman, et al. (1992) performed a series of experiments to examine other possible modulators of the fall in RMR in older men and women. They examined whether differences in maximal aerobic capacity (VO$_2$max), daily energy intake, and

plasma concentrations of thyroid hormones in a large group of 300 healthy males (17-78 years) could explain the reduction in RMR with age, independent of changes in fat-free mass. They found a curvilinear decline in RMR with age, in which the reduction in RMR was accelerated in males over forty years of age. Furthermore, fat-free mass could not fully account for the lower RMR in the men over forty. It was only after statistically controlling for differences in fat-free mass, fat mass and maximal aerobic capacity that the association between RMR and age became non-significant. Variations in dietary practices and thyroid hormones were not independent predictors of the decline in RMR (Poehlman et al., 1992).

In a further study, Poehlman and Danforth (1991), endurance trained 19 older individuals on a cycle ergometer three times a week for eight weeks, while maintaining the subjects' energy balance. These investigators reported that RMR increased by 10% following endurance training, in the absence of changes in fat-free mass. The increase in RMR was associated with a higher concentration of norepinephrine in circulation indicating that the increase in RMR may be mediated by an enhanced sympathetic nervous system activity. These findings suggest that a state of "increased energy flux" (i.e. an increased energy intake matched to an increased level of energy expenditure) increases RMR in older adults. Therefore, it is possible that a threshold of energy expenditure generated by exercise may be necessary to enhance RMR and subsequent food intake in elderly persons.

It is apparent that aging is associated with a loss of lean body mass and a subsequent decline in RMR (Tzankoff & Norris, 1978) and gain in body fatness. Thus,

interventions aimed at attenuating this decline in RMR are important to slow the positive energy balance and subsequent gain in body fat that occurs during aging (Starling, 2001).

1.2.3 Energy Expenditure and Types of Exercise

The effects of aerobic and resistance exercise training on body composition need to be considered independently as their effects on body composition may differ. For example, aerobic exercise training primarily reduces fat by promoting negative energy balance; whereas resistance exercise primarily increases fat-free mass by stimulating skeletal muscle growth (Toth & Poehlman, 1995).

Aerobic training stresses the cardio-respiratory system and is thought to increase resting metabolic rate. The increase in resting metabolic rate is due to an increase in total energy output, an increase in fat-free weight in the body, and an increase in body temperature and heat production (Van Zant, 1992). This aerobic activity provides an energy deficit and produces exercise-induced reductions in body fat (Ballor & Poehlman, 1992). Cross-sectional studies (Ballor & Poehlman, 1992; Poehlman et al., 1992) have suggested that aerobically trained individuals have a higher resting metabolic rate (RMR) for their metabolic size than untrained individuals. For example, Poehlman et al. (1992) examined RMR in young males who participated in aerobic exercise (ran an average of 77 km/week) and sedentary young individuals. They found that resting metabolic rate was 10% higher in the aerobically trained individuals compared with the untrained young men. This difference corresponded to 187 kcal/day greater resting energy expenditure in the aerobically trained young men. In a similar study of young women, Ballor and

Poehlman (1992), found a 6% higher RMR in women who participated in aerobic activities three times per week or more, compared to untrained women.

Energy expenditure in aerobically trained older individuals has also been investigated. The male and female participants in both of the following studies consisted of endurance runners who reported exercising at least three times a week for at least five years prior to testing. In middle-aged men (36-59 years), Toth, Gardner and Poehlman (1995) found that aerobically trained men had a higher RMR than untrained volunteers (86kcal/d). In the middle-aged, aerobically trained, women RMR was increased by about 16% or approximately 150 kcal/day (Toth & Poehlman, 1995). From these studies it seems evident that aerobic exercise training causes an increase in resting metabolic rate in middle-aged men and women that could positively affect body composition.

In the past, the primary focus of investigators has been on the influence of the endurance and/or the aerobically trained state on RMR, as reviewed above. More recently the focus has shifted to other modes of exercise, such as resistance training. The role of resistance exercise on RMR, regulation of energy balance and body composition has become of particular interest; since it has been shown to increase fat-free mass by stimulating skeletal muscle growth. Therefore, this could influence RMR by increasing the total amount of metabolically active tissue (Fukagawa et al., 1990). Theoretically, even small changes in RMR may significantly affect the regulation of body weight and body composition over extended periods of time (Poehlman & Melby, 1998)

Several investigators have examined the effects of resistance exercise training programs on energy expenditure in younger and older individuals (Ballor et al., 1996; Ballor & Poehlman, 1992; Campbell, Crim, Young, & Evans, 1994; Toth, Gardner &

Poehlman, 1995). Poehlman et al. (1992) examined RMR in resistance trained and sedentary younger (18-30 years) men. The resistance-training group consisted of body builders who had been training for 4 ±1 years, five to six times a week. Their weight training exercises consisted of moderate resistance (70-85% of 1-RM) and high repetitions (10 - 20) in three to five sets, with short rest intervals between exercise bouts. Resting metabolic rate was 5% higher in the resistance-trained men than in the untrained men. This difference corresponds with 86 kcal/day greater resting energy expenditure. This study provided the first evidence of a higher RMR in resistance-trained individuals relative to non-exercising controls (Poehlman et al., 1992).

Van Etten, Westerterp, and Verstappen (1995) investigated changes in energy expenditure in 21 healthy younger males (25-45 years) after a 12-week weight-training program. The subjects completed a moderate training protocol consisting of ten minutes of cycling to warm-up, fourteen strength exercises, and five minutes of cool down and stretching; twice a week for the 12 weeks. Sleeping metabolic rate was measured in a respiration chamber. Weight training increased fat-free mass (1.1 ± 1.3 kg) and decreased fat mass (2.3 ± 1.5 kg), but contrary to the study by Poehlman et al. (1992), no change was found in metabolic rate. It is possible that if changes in RMR are mediated by changes in body composition in response to resistance training, the small changes in fat-free mass observe by Van Etten et al. (1995), were not sufficient to impact RMR. A more intense protocol with more than two sessions a week may have been needed to show any significant results.

In a further study of younger women, Ballor and Poehlman (1992) found no difference in RMR between resistance-trained and untrained women. It is unclear what

factors may account for the absence of a higher RMR in the resistance trained women, although it is possible that there may be inherent differences between the sexes in anabolic hormones or possibly the great volume and intensity of resistance exercise training in the men could account for the absence.

The energy expenditure of resistance trained older individuals has also been investigated and is of particular interest because of the suggested age related decline in energy expenditure. Pratley and colleagues (1994) examined changes in RMR following 16 weeks of resistance training in 13 older men (50-65 years). The resistance training program consisted of 14 exercises performed at 90% of 3-RM for the first three repetitions, after which the resistance was gradually reduced to permit the subject to complete 15 repetitions. RMR increased by approximately 8% or 120 kcal/day. Although fat-free mass increased during the training program (+1.6 kg), the increase in RMR persisted even after controlling for fat-free mass. These findings suggest that the elevation of RMR was due both to the increased quantity and metabolic activity of fat-free mass. Investigators speculated that the increase in RMR was related to the increase in plasma levels of norepinephrine. However, they could not rule out the possibility that the elevated RMR was due to the residual effect of the last bout of exercise, given that the RMR measurement was performed 22-24 hours following the last training session.

Campbell and coworkers (1994) investigated the effects of a 12-week program of progressive resistance training on muscular strength, body composition, and the components of energy balance in sedentary, healthy older adults. The subjects consisted of twelve untrained male and female subjects between the ages of 56 and 80 years. Each subject's baseline body weight was maintained during the resistance-training period

through adjustments in energy intake, making it possible to accurately estimate the resistance training-induced changes in energy requirements and to measure the impact of resistance training on body composition. It was found that resistance training resulted in a significant and substantial increase in energy requirements in older men and women. The subjects in this study required approximately 15% more energy intake to maintain body weight during the resistance-training period than during baseline. The mean fat loss during the program was 1.8 kg which represents an additional 2.1 kJ/kg/day (0.5 kcal/kg/day) in energy expenditure and suggests that despite the increased intake, the subjects were still in a small energy deficit during the resistance-training period. In addition, a 6.8% average increase in RMR was reported. Fat-free mass increased following training (1.4 kg) due to an increase in total body water, thus, changes in RMR were not attributable to alterations in respiring tissues. These findings suggest that resistance training stimulates RMR in older individuals through a mechanism that is independent of an increase in fat-free mass.

Trueth, Hunter, Weinsier, and Kell (1995) also found an increase in RMR (9%) in 13 elderly untrained women (60-77 years) after 16 weeks of resistance training. However, total daily energy expenditure as measured by whole room calorimetry was unchanged. Since there were no changes in fat-free mass during the program, these results suggest that the increase in RMR was independent of increases in fat-free mass.

Collectively, these studies (Ballor & Poehlman, 1992; Campbell, Crim, Young & Evans, 1994; Pratley et al., 1994; Van Etten et al, 1995) suggest that resistance training stimulates RMR in older but not in younger individuals and that the effect is independent of changes in fat-free mass. However, changes in fat-free mass are frequently small and

within the error of measurement techniques, so it is possible that small changes occur that are not detected by the measurement instruments, due to lack of sensitivity. Long-term (6 months or greater) resistance training programs that result in large changes in fat-free mass may help to resolve whether there is an increase in RMR above which can be accounted for by changes in body composition.

Another suggested benefit of resistance training is the maintenance of RMR after weight-loss. Ballor et al. (1996) examined whether resistance training would help subjects maintain body weight following weight-loss by attenuating weight loss induced reductions in RMR. Thermic effect of a meal and RMR were measured in a group of 18 older volunteers, ages 55-70 years, who had recently lost a mean of 9 ± 1 kg. The weight loss program reduced RMR by approximately 260 kcal/day. Weight training during the 12-week program consisting of three sets of eight repetitions at 50% of 1-RM three times a week, increasing to 80% of 1-RM by the ninth week. The 12 weeks of weight training tended to increase RMR by 72 kcal/day and the thermic effect of a meal by 16 kcal over a five-hour post-prandial measurement period in individuals who lost weight. Collectively, resistance training restored approximately 34% (88 kcal) of the 290 kcal lower energy expenditure generated by the weight loss program. From the research it appears that resistance training has an important role in maintaining fat-free mass when used in conjunction with dieting.

Together, these findings suggest that regular resistance exercise may serve as an effective intervention to offset the age-related decline in RMR and have an important role in maintaining fat-free mass, resulting in enhanced resting energy requirements (Toth & Poehlman, 1995). Beyond the maintenance of resting metabolic rate, resistance training

has also been reported to have additional benefits, such as improvement and maintenance of muscular strength and flexibility (Stone, Fleck, Triplett, & Kraemer, 1991), injury prevention, prevention of osteoporosis, and improvement of cardiovascular risk factors (DiNuble, 1991; Verrill & Ribisl, 1996)

Now that the individual effects of aerobic and resistance training in younger and older individuals have been reviewed, it is important to look at studies that have compared the two exercise protocols. The study by Poehlman and colleagues (1992), mentioned earlier, examined RMR in aerobic trained and resistance trained individuals and untrained male volunteers. Resting metabolic rate was 5% higher in resistance-trained men than in untrained men, whereas aerobic-trained individuals had a 10% higher RMR compared with untrained men. Therefore, the increase in RMR doubled in aerobic trained men compared to resistance-trained men. Ballor and Poehlman (1992) found no difference in RMR between resistance-trained and untrained younger women, whereas, a six percent higher RMR was found in aerobically trained compared to untrained women. In middle-aged men (36-59 years), Toth, Gardner and Poehlman, (1995) found no difference in RMR between 19 resistance-trained and 30 untrained volunteers. However, aerobic-trained middle-aged men had a higher RMR than untrained volunteers (86 kcal/day). In middle-aged women (Toth & Poehlman, 1995), RMR was 16% higher in resistance-trained volunteers (40-46 years) than untrained volunteers (36-50 years), but RMR was similar between resistance-trained volunteers and the aerobic trained group. This elevation in RMR in resistance and aerobic trained middle-aged women translates into a 160 kcal/day and 150 kcal/day increase in daily resting energy requirements,

respectively. This suggests that resistance training may blunt the age-related decline of RMR in women (Toth & Poehlman, 1995).

1.2.4 Excess Post-exercise Oxygen Consumption

The effects of exercise on metabolic rate and energy expenditure are not limited to the time of the activity. Several studies have shown that exercise produces an increase in metabolic rate that outlasts the actual duration of the activity. This extra energy expenditure and increase in metabolism may potentially have a significant impact on body mass and body composition.

The elevated consumption of oxygen after exercise has been termed excess post-exercise oxygen consumption (EPOC) (Gaesser & Brooks, 1984). This phenomenon was first demonstrated in a 1926 study by Herxheimer, Wissing, and Wolf (as cited in Gore & Withers, 1990) who reported that metabolic rate remained 10% above the basal state for 48 hours after the completion of strenuous exercise.

In order to understand the metabolic basis of the excess post-exercise VO_2 one must consider the chemical and physical changes that occur in cells during exercise that persist in to recovery. Because the mitochondria is the site of O_2 consumption in the cell, the explanation of the elevated post-exercise VO_2 may be found at the level of this cellular organelle (Gaesser & Brooks, 1984). Although the control of mitochondrial respiration in vitro is understood relatively well, not nearly as much is known about mitochondrial energetics during and after exercise. It is probable that the physical and chemical changes occurring in muscle cells during contraction, which are necessary for increasing VO_2 and ATP production, persist some time after exercise cessation.

Therefore, some of the physiological mechanisms resulting in EPOC are thought to be re-synthesis of adenosine tri-phosphate, creatine phosphate, protein, and glycogen in the skeletal muscle. Other factors that also may contribute due to their influence on mitochndrial oxygen consumption include: metabolic hormone concentrations (catecholamines, thyroxine, and glucocorticoids), calcium ion concentration, sodium pump activity, and body temperature (Gaesser & Brooks, 1984).

Studies have shown that the duration of EPOC may vary from less than one hour to 24 hours post-exercise, increasing metabolic rate anywhere from 1-25% (Bahr, Ingnes, Vaage, Sejersted & Newsholme, 1987; Bielinski, Schutz & Jequier, 1985; Gore & Withers, 1990; Sedlock, Fissinger & Melby, 1989; Westrate & Hautvast, 1990). The magnitude of this elevated metabolism during recovery from an exercise bout may have important implications for individuals employing physical activity as part of a weight reduction or maintenance program.

Numerous studies have examined the intensity of steady-state aerobic exercise needed to prolong energy expenditure (Bahr & Sejested, 1991; Bielinski et al., 1985; Brockman, Berg, & Latin, 1993; Gore & Withers, 1990; Pacy, Barton, Webster, & Garrow, 1985). All the studies agree that there is indeed a critical threshold for intensity of exercise that exists before EPOC comprises a physiologically significant component of total energy expenditure. Exercise intensities above 50% VO_2 max are required to trigger the metabolic processes that are responsible for EPOC, and only after intensities of 70% or greater is there any sustained, prolonged increase of O_2 uptake that will contribute significantly to energy expenditure (Bahr, Ingnes, Vaage, Sejersted, & Newsholme,1987; Bahr & Sejersted, 1991). At this exercise intensity, EPOC is linearly related to exercise

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duration, equalling approximately 15% of total VO_2 consumption (Bahr & Sejersted, 1991). These findings suggest that intensity is an important factor in generating significant post-exercise oxygen consumption.

The second consideration with regards to EPOC is the duration of exercise needed to elicit a significant increase in post-exercise energy expenditure. Bahr et al. (1987), and Quinn, Vroman, and Kertzer (1993) have investigated the effect of exercise duration on the magnitude of EPOC in both young males and females. These studies suggest that when considering steady-state aerobic exercise, duration of greater or equal to 60 minutes at 70% VO_2max is necessary to provide a significant increase in post-exercise metabolism. The duration of steady-state exercise appears to influence EPOC in a linear fashion (Bahr et al., 1987), whereas increasing exercise intensity beyond 50-60% of VO_2max may influence EPOC in an exponential manner (Bahr & Sejersted, 1991).

Few studies have specifically addressed the impact of non-steady-state resistance exercise on the post-exercise metabolic rate. One of the earliest studies to consider recovery energy expenditure after resistance exercise examined oxygen consumption during recovery from bouts of circuit weight training in men 17 to 36 years (Wilmore et al., 1978). However, the calorimeter measurement never extended beyond 20 minutes post-exercise and thus, the post-exercise oxygen consumption could not be fully quantified. Melby, Ticknell, and Schmidt, (1992) found that following a 45-minute bout of resistance exercise, consisting of three consecutive sets of ten repetitions of four upper and three lower body lifts at a weight approximately equal to a 12 repetition maximum, metabolic rate remained elevated for at least one hour and possibly longer compared to metabolic rate measured for one hour after a control condition of quiet sitting on a

separate day. Neither of these studies examined the possibility of a more prolonged effect of such exercise on metabolic rate, and hence stopped their energy expenditure measures after one hour post-exercise.

It was not until further studies by Melby, Scholl, Edwards and Bullough (1993), that recovery O_2 consumption was assessed for an extended period of time. Melby and colleagues examined the effects of acute strenuous resistance exercise on metabolic rate during the two hours immediately following exercise, and on RMR the following day (15 hours post-exercise). In the first study, seven young male subjects (20-40 years) with previous weight lifting experience completed a 90-minute weight-lifting protocol consisting of six sets of 10 different weight-lifting exercises performed at 70% of the individual's 1-RM. The participant's RMR had been measured the same day. Post exercise metabolic rate was measured continuously for two hours following exercise and compared to a pre-exercise baseline. RMR was measured the following morning, 15 hours after completion of the workout. In the second study, six different young men (20-40 years) completed a similar experimental protocol but with only five sets of each exercise, as well as a control condition on a separate day in which metabolic rate was measured continuously for two hour following a period of quiet sitting. For both experiments, metabolic rate remained elevated following resistance exercise for the entire two hour measured recovery period. The average VO_2 measured 120 min after exercise cessation was elevated 11-12%. Resting metabolic rate measured the morning following resistance exercise compared to the previous day was 9.4% higher in the first study and 4.7% higher in the second study. This study provided evidence for a prolonged elevation period of post-exercise metabolic rate after strenuous resistive exercise, based on the

elevation of RMR in 12 of the 13 subjects when measured the following morning 14-15 hours after the exercise bout.

The studies above have provided information regarding the individual effects of aerobic and resistance exercise on post-exercise oxygen consumption. However, there is little data available comparing the post-exercise energy metabolism between aerobic and resistance protocols of equivalent caloric cost. The only study that has attempted to compare the two protocols on EPOC was performed by Gillette, Bullough, and Melby (1994). The subjects were ten trained males between the ages of 22 and 35 years. The study compared the recovery response between the two treatments: a strenuous bout of resistive exercise, consisting of five sets of ten different weight lifting exercises performed at 70% of each subject's 1-RM; a bout of stationary cycling at 50% VO_2max (with duration adjusted to approximate the estimated caloric cost of the resistive exercise), and a control condition of quiet sitting. Resting metabolic rate was measured the morning of and the morning following each of the exercise and control conditions. Oxygen consumption was measured for five hours following each treatment, including two hours immediately following each condition at which time a standardized meal was provided and calorimetry continued for another three hours. Average post-exercise oxygen consumption was elevated for the resistance exercise treatment (mean $VO_2 = 375$ ml/min) for the five hour recovery period compared to both aerobic exercise (mean $VO_2 = 348$ ml/min) and the control condition (mean $VO_2 = 338$ ml/min). Resting metabolic rate measured approximately 15 hour post-exercise for the resistance exercise condition was significantly elevated, compared to the aerobic treatment (at 1.5 hours), and control condition. However, oxygen consumption values were not significantly different

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between the exercise treatments after one and a half hours of recovery. These results suggest that strenuous resistance exercise results in greater post-exercise energy expenditure compared to steady-state endurance exercise of similar estimated energy cost.

The studies by Gillette et al., (1994) and Melby et al., (1993) suggest that strenuous resistance exercise appears to produce a perturbation of resting homeostasis resulting in an elevation of post-exercise metabolic rate for a prolonged period, with the recovery energy expenditure adding significantly to the total thermic effect of physical activity. Further Gillette and colleagues have suggested that resistance exercise may have an important role in the elevation of resting metabolic rate and post-exercise oxygen consumption comparable to, or possibly even to a greater extent than aerobic exercise. Whether this same phenomenon would be observed in the older population is not known.

1.2.5 Summary

Early research considered aerobic exercise the most valuable mode of exercise to positively affect energy expenditure and subsequently body composition. More recently, resistance exercise has gained attention for its energy consuming qualities and has been considered an effective intervention to enhance energy requirements and maintain metabolically active fat-free mass. When the two modes are compared in different populations it has been suggested that resistance training may blunt the age-related decline in RMR.

The effects of exercise on metabolic rate and energy expenditure are not limited to the time of the activity. Aerobic exercise of greater or equal to 60 minutes at an intensity

of greater than 70% VO_2max can significantly elevate metabolic rate for several hours after exercise (Bahr et al., 1987).   Resistance exercise can also provide a significant elevation of metabolic rate after exercise (Melby et al, 1993).

In further investigations, aerobic and resistance exercise protocols of similar energy cost have been compared as in the study by Gillette et al., (1994). When compared, it appears that resistance exercise may have even a greater potential to elevate post-exercise energy expenditure beyond that of aerobic exercise.   However, this study was completed in young trained individuals and needs to be further investigated in other populations, especially older individuals.

It is well known that physical activity declines with advancing age and adiposity increases, increasing the risk of obesity and related diseases such as diabetes, coronary artery disease and some type of cancers, such as breast cancer (Thune, Brenn, Lund, & Gaard, 1997) and colon cancer (Slattery et al., 2003). If the risk of these diseases could be decreased by enhancing energy expenditure, investigating the optimal modes of exercise to determine which will most efficiently combat the decrease in metabolism as we age may add significantly to the exercise literature.

The present study will be designed to compare the EPOC resulting from aerobic and resistance exercise in younger and older men, to determine the effect age may have on energy expenditure after exercise.

1.3 Statement of the Purpose and Hypotheses

1.3.1 Purpose of the Study

The purpose was to examine the effect of an acute bout of aerobic and resistive exercise on excess post-exercise oxygen consumption (EPOC) in younger and older men.

1.3.2 Hypotheses

1) Resting metabolic rate will be increased in both younger and older men after 30 minutes of aerobic or resistance exercise.

Aerobic exercise stresses the cardio-respiratory system and is thought to increase resting metabolic rate due to an increase in total energy output, an increase in fat-free weight in the body and an increase in body temperature and heat production (Van Zant, 1992). Similarly, resistance exercise has been shown to increase resting metabolic rate by stimulating skeletal muscle growth, and increasing the total amount of metabolically active tissue (Fukagawa, Bandini, & Young, 1990).

2) The resistance exercise will produce a greater EPOC than the aerobic exercise in younger and older men after 30 minutes of exercise.

Previous work has shown that post-exercise metabolic rate was elevated significantly more following resistance exercise compared to either an aerobic exercise bout or a control condition. These results suggest that strenuous resistance exercise results in greater post-exercise energy expenditure compared to steady-state endurance exercise of similar estimated energy cost (Gillette, Bullough, & Melby, 1994).

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3) The post-exercise increase in RMR will be greater in the younger men than the older men, regardless of exercise mode (i.e. aerobic or resistance).

Age related decrements in the basal metabolic rate due to changes in body composition have been well recognized. Earlier studies have shown that with succeeding age, muscle mass decreases. Because muscle alone requires a large amount of oxygen, it is reasonable to assume that the greater the muscle mass, the higher the RMR (Tzankoff & Norris, 1977).

4) The respiratory exchange ratio will decrease post- exercise in both younger and older men, regardless of exercise mode (i.e. aerobic or resistance).

Numerous studies have found an inverse relationship between duration and RER at the end of exercise that indicates a greater reliance on fat metabolism during exercise recovery (Gore & Withers, 1990; Maehlum et al, 1986; Chad & Wenger, 1988)

1.3.3 Limitations

1. Participants were not randomly selected to take part in the study, as they were individuals who responded to written advertisements and voluntarily participated.

2. Younger participants were students at the University of Saskatchewan and the older participants were residents of Saskatoon and area. Therefore, the results from this study may not be completely generalizable to men in other regions of the world.

CHAPTER 2:
METHODS AND PROCEDURES
2.1 Study Design

The study used a three factor repeated measures design, with repeated measures on two factors; time and exercise mode. The third factor, age group, does not have repeated measures. Each participant completed each of the two conditions: aerobic training and resistance training. The two modes of exercise were matched by duration of 30 minutes and the utilization of the same muscle groups. Each participant was randomly assigned to one of the two conditions for the first session. During the second session they completed the opposite exercise protocol, thus acting as their own control. Each protocol was completed only one time per subject. Resting metabolic rate was measured at baseline before each exercise session and post exercise for six hours after each protocol. There was at least a one-week washout period to control for any residual effects the exercise may have had on resting metabolic rate beyond the measurement period, and to allow the muscles adequate rest and recovery. After the washout period the second randomly assigned protocol was administered.

2.2 Study Participants

Ten healthy male volunteers between 60 and 70 years of age were recruited for the older adult group and ten healthy volunteers between 18 and 25 years of age were recruited for the younger group in this study. The physical characteristics of the subjects participating in the study are reported in Appendix A, and summarized in Table 2.1. Healthy participants were chosen for the study because of the moderately high intensity of the exercise protocols to be performed. It was unlikely that unhealthy individuals

would be able to complete the exercise safely. Fitness status was evaluated by cardio-respiratory fitness level and compared to normative VO_2max (ml/kg/min) data used by the Canadian Society for Exercise Physiology (Katch and McArdle (as cited in the PFLC Resource Manual, CSEP, 1993)). Body mass index (BMI) was used to describe the subjects. The average BMI for the younger and older men was 27.0 ± 2.7 and 26.6 ± 2.2, respectively, which falls in the overweight category according to the guidelines developed by Health Canada (2003). Advertisements were used to establish a subject pool from which the participants were non-randomly selected for the study (Appendix B). All individuals gave informed consent prior to participating in the study that was approved by the University of Saskatchewan Advisory Committee on Ethics and Human Experimentation (Appendix C and D).

Table 2.1

Physical Characteristics (mean $\pm$ SD) of younger (n=9) and older (n=10) men

	Age (yr)	Height (cm)	Weight (kg)	BMI (kg/m^2)	VO_2max (ml/kg/min)
Young (n=9)	23.2 ± 2.2	179.4 ± 6.6	87.0 ± 10.1	27.0 ± 2.7	48.0 ± 6.2
Old (n=10)	65.8 ± 3.3	178.0 ± 5.3	84.3 ± 9.5	26.6 ± 2.2	37.9 ± 5.1

2.2.1 Exclusion Criteria:

Exclusion criteria included cardiovascular disease, diabetes, or any other cardiovascular, respiratory or endocrinological diseases that may require the use of prescribed medication that might affect energy expenditure. Subjects were also excluded

if they were currently smoking, had any knee or joint problems that prevented participation in the exercise.

2.3 Procedures:

2.3.1 Baseline data: Session 1 & 2

Demographic data, medications, height and weight were obtained in order to describe the subjects. All subjects completed a Physical Activity Readiness (PAR-Q) form (Appendix E). The older subjects were also required to obtain physician approval if they answered "yes", to any questions on the PAR-Q. This involved having the physician complete the PARmed-X form (Appendix E). In the first session maximal oxygen uptake (VO_2max) was measured in a standard fashion with a graded exercise program using a Monarch 818E cycle ergometer as described below, with a Basic Life Saving-CPR certified investigator present during maximal testing. After the maximal oxygen uptake test a familiarization session was completed with the resistance exercise and metabolic equipment, in order to minimize the effect of learning during the data collection.

In the second baseline session, the 1-RM strength test was administered for leg press and leg (knee) extension. To reduce the possibility of a residual effect on energy expenditure during data collection, maximal oxygen uptake and strength were determined at least 48 hours prior to the first exercise session, as described in the measures section.

2.3.2   Experimental data: Session 3 & 4

Subjects arrived in the morning having fasted for eight hours to minimize the thermic effect of food. The subjects were randomized by opening a numbered envelope containing one of a set of computer-generated random numbers. Even numbers randomized the subject to begin with the aerobic exercise; odd to the resistance exercise. Each subject crossed over to the other mode of exercise, the following week (aerobic to resistance and vice versa).

Resting metabolic rate (RMR) was determined using the RMR procedure described in the measures section below. The participant then completed the first protocol they were assigned i.e. either aerobic or resistance exercise.

Aerobic-group subjects rode a cycle ergometer. The cycle ergometer was chosen as the mode of aerobic exercise as it is the most common mode utilized in previous studies with older adults. A five-minute warm-up at 50% of VO_2max was performed, after which time they rode for thirty minutes at 70% of VO_2max. This intensity was chosen to provide a significant post-exercise increase in metabolism. The duration of 30 minutes was chosen, as it was a duration that the subjects could complete at 70% VO_2max. The duration was also chosen to match the duration of the resistance exercise.

Resistance-group subjects were given a set of graded exercises lasting 30 minutes on the leg press and leg (knee) extension machine. The free-weight machines were used due to time restraints and familiarity of the subjects with free weights. These two exercises using the quadriceps were chosen because similar muscle groups are used in the cycling. This allows for better comparison between the aerobic session and the resistance session and the effects on RMR. The resistance exercises consisted of one set of ten

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repetitions at 50% 1-RM as a warm-up, followed by five sets of eight repetitions at 75% of 1-RM. If a subject failed to do eight repetitions, the weight was reduced so they were able to do eight repetitions on the next set. The subjects were able to complete the protocol of five sets of eight repetitions at 75% 1-RM but the weight had to be reduced on the leg extension in order for a few of the younger and older subjects to complete eight repetitions on all the sets.

All subjects then underwent measurement of RMR immediately post-exercise and at 30-minute intervals for two hours with a 15-minute measurement and a 15-minute break; then hourly, consisting of a 15-minute measurement and a 45-minute break each hour. This produced a set of nine measurements for each subject. The duration of measurement for RMR in the literature ranges from one hour to fifteen hours post-exercise; six hours is considered a sufficient duration to observe any post-exercise response that may occur. During the six hours of post-exercise assessment of RMR, the participants were required to sit quietly, read, study, or watch television. No food or beverage consumption, other than water was allowed.

Schedule: Session 3 and 4

08:00	Arrive; rest
08:30	RMR
08:45	Exercise for 30 minutes
09:15	RMR; then rest
09:45	RMR; then rest
10:15	RMR; then rest
10:45	RMR; then rest
11:45	RMR; then rest
12:45	RMR; then rest
13:45	RMR; then rest
14:45	RMR; then rest
15:00	May eat and go home

2.4 Measures:

2.4.1 Height and Weight

Height and weight were used to describe the two groups of participants (i.e. older and younger men). All the participants wore light clothing and removed their footwear for the measurements. Weight (kg) was measured twice to the nearest 0.1 kg on a calibrated electronic scale. Height (cm) was obtained using a measuring board and recorded to the nearest 0.1 cm. These measurements were used to calculate Body Mass Index (BMI) = weight (kg) / height (m^2), and were in the calculations of RMR by the metabolic cart.

2.4.2 Resting Metabolic Rate

The resting energy expenditure of each participant was measured by a VMAX 29 series metabolic cart by Sensormedics, after an eight-hour fast and thirty minutes supine rest. The VMAX 29 employs an analyser module, pneumatics module, and an AST 486 desktop computer; mass flow sensor, 16% oxygen, 4% CO_2 calibration cylinder with gas valve and calibration syringe. It provides an open-circuit, indirect method of calorimetry through the use of a dilution test. A ventilated hood was placed over the participant's head, through which they inhaled room air and exhaled into the hood, which is hooked up to the gas analyzers via a collection tube. The accuracy of the gas and flow analyzers across a wide range of O_2 levels, CO_2 levels and flow rates has been validated.

The baseline RMR measurement continued until subjects reached "steady state", defined as five consecutive readings, separated by at least one minute, with exhaled volume (VE), VO_2, VCO_2 values within 5% of their previous values. This is the standard

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criterion for the definition of steady state energy expenditure. To exclude inadvertent elevations in RMR due to body movement(s) the lowest 15 (totalling 5 minutes) readings (preset to 20-second intervals) were averaged and recorded as the baseline RMR for each session. All participants were tested at the same time of day. Each individual was instructed to refrain from caffeine intake and participation in physical activity for twenty-four hours prior to the assessment to minimize the effect these activities may have on RMR. Resting energy expenditure was estimated using measured respiratory exchange ratio to establish the caloric equivalent of VO_2 (Barsztein, Elwyn, Askanazi & Kinney, 1989). Respiratory exchange ratio (RER) was calculated by dividing the volume of CO_2 produced by the volume of O_2 consumed. The RER was also used to determine substrate utilization during recovery. A respiratory exchange ratio of 0.7 indicates a total reliance on fat for energy, whereas, a ratio of 1.0 indicates a complete reliance on carbohydrate for energy (McArdle, Katch & Katch, 1999).

Data from one subject in the younger group was removed from this the baseline measurement point, onwards, due to mechanical error of the metabolic cart, which resulted in subsequent loss of this individual's data. Therefore, in subsequent analysis the sample size included nine younger men, and ten older men.

2.4.3 Cardiovascular Fitness:

Maximal oxygen uptake (VO_2max) was measured in a standard fashion with a graded exercise program using a Monarch 818E cycle ergometer. Introduction to the cycle ergometer was done at the lowest load unless the subject requested a different resistance or pedaling cadence. Warm-up was five minutes or until the subject was

comfortable with the exercise mode. The initial workload of 1.5 kp was applied at the end of the second minute; the protocol continued to increase the workload by 0.5 kp after each two minutes of the test were completed. Subjects pedaled at 70 rpm for 8-12 minutes.

VO$_2$max was considered to be achieved when two of the following three criteria were met: 1) a levelling off of oxygen uptake (<2 ml/kg with increasing workload), 2) a respiratory exchange ratio > 1.10, or 3) a heart rate within 10 beats of their age-predicted maximal heart rate. Once two of the three criteria were met the subjects cooled down by resuming moderate exercise at a lower resistance or velocity for several minutes until initial recovery was achieved.

2.4.4 Muscular Strength (1-RM)

All strength testing occurred after the completion of a warm-up on a cycle ergometer and stretching exercises. Strength was measured using a maximal one-repetition lift, defined as the maximal amount of weight that can be lifted successfully one time only. The muscular strength tests were conducted on the leg press and leg (knee) extension machines, which utilize similar muscles to cycling. Following instruction as to the proper way to complete the exercise, subjects were asked to lift progressively heavier weights until they reached a weight they were not able to lift successfully. Weights to be lifted were selected such that each subject reached their maximum capacity in four to six lifts, with two minutes rest between trials. This value was used to calculate the loads used during the treatment protocol.

2.4.5 Total Post-exercise VO$_2$ (EPOC) and Kilocalories and (REE)

Indirect calorimetry provides a printout of total oxygen consumption (VO$_2$) for each 20 seconds of measurement time, including, baseline and nine post-exercise measurements for each subject and treatment in each group. The values for each 20 second period, for each subject were averaged to find the mean value for each measurement period. These calculated values were used to represent not only the actual measurement time, but were also extended to represent the rest periods between when no measurement was being conducted. With the exception of t first 15 minutes that the measurement was not extended over any rest time. VO$_2$ for each of the nine post-exercise measurement periods for each subject in both groups was then subtracted from the measured baseline VO$_2$ for each subject to represent EPOC. Total EPOC was calculated by adding up the EPOC calculated for each measurement and rest period to represent the entire 6 hours. The group mean for total 6 hour EPOC was used to compare between treatments and groups and in comparison between studies.

The calculation for total kilocalories (post-exercise REE) as a result of EPOC was calculated with the same procedure as described above for total VO$_2$. However, REE is recorded in kcal/kg/min for each 20 second interval and then converted to kilocalories by multiplying by body weight and dividing by the number of minutes in the each measurement period. The group mean for the total kilocalories expended, above baseline, in 6 hours was used to compare between treatments and groups, and between studies

2.5 Statistical Analysis:

Descriptive statistics were used to examine the physical characteristics of age (yr), height (m), weight (kg), VO_2max (ml/kg/min) and strength (1 repetition maximum)of the older and younger participants. All statistics are presented using mean ± standard deviation. The participant characteristics were analyzed for differences using a one-way ANOVA. The hypotheses were tested using a 3-factor 9 (time) x 2 (exercise mode) x 2 (age group), analysis of variance (ANOVA) with repeated measures on both the exercise mode and time. This determined the separate and combined effects of exercise mode and age group on post-exercise O_2 consumption over time. The confidence level was set at $p = 0.05$ (95%).

Mauchly's test of homogeneity of variance was performed to evaluate whether the repeated measures ANOVA met the assumptions of sphericity, which was necessary to perform the ANOVA test. Sphericity requires that the repeated measures demonstrate homogeneity of variance (equal variance of the several repeated measures, or trials) and homogeneity of covariance (correlations among all combinations of trials are equal). The Mauchly's test revealed that assumption of sphericity could not be assumed, therefore, the Greenhouse-Geisser (GG) method was used to correct for the violation of the assumption. The GG modifies the degrees of freedom values for columns (treatments) and error. Within-subjects contrasts were conducted to further examine the details of any significant main effects or interactions that existed within the repeated measures ANOVA. The within-subjects contrast is a specialized type of hypothesis test, which, instead of testing that the means of the dependant variable are equal for all levels of a factor, it compares the means of selected levels of a factor, or combination of factors.

The within-subjects contrasts were used in this experiment whenever significant interactions were found by the repeated measures ANOVA. Contrasts were used to directly compare exercise mode or age group at each time point in order to determine the time at which the significant differences occurred.

CHAPTER 3:
RESULTS

3.1 Baseline Comparisons of Physical Characteristics Between Groups

All of the baseline comparisons between groups were analyzed using a one-way

ANOVA to determine group differences (Appendix F). The group mean data was

presented in Table 2.1. There were no significant differences between groups for height

[$F_{(1, 17)} = 0.28$, $p = 0.602$], weight [$F_{(1, 17)} = 0.37$, $p = 0.551$] or BMI [$F_{(1, 17)} =$

0.18, $p = 0.681$]. A significant difference between the older and younger age groups was

observed for age [$F_{(1, 17)} = 1049.10$, $p < 0.001$], as would be expected. Similarly, the

results showed a significant difference in VO_2max [$F_{(1, 17)} = 14.90$, $p = 0.001$], between

the groups as would be expected with this dependent variable, as aerobic capacity is

dependant on age and lean body mass. The mean values for 1-RM strength for the

younger and older men are reported in Table 3.1 and the individual values are provided in

Appendix G. A significant difference was found in strength between the younger and

older men for both leg press [$F_{(1, 17)} = 16.52$, $p = <0.001$] and leg (knee) extension [$F_{(1, 17)} = 62.17$, $p = <0.001$] (Appendix F).

Table 3.1
1 repetition maximum (1-RM) values (mean ± SD) younger (n=9) and older (n=10) men

	Leg Press 1-RM (kg)	Leg (Knee) Extension 1-RM (kg)
Younger (n=9)	244 ± 57	76 ± 32
Older (n=10)	168 ± 18	68 ± 13

3.2 Reproducibility of Baseline Measures

An ANOVA of the baseline VO_2 and RER among treatment interventions was

conducted to ensure that these measures were reliable from treatment day to treatment

day within-groups (Appendix H). Figure 3.1, illustrates the results of this analysis which demonstrated that there was no significant difference in resting VO_2 (ml/kg/min) from the day that resistance exercise was performed (2.97 ± 0.60 young / 2.78 ± 0.23 older) versus the day aerobic exercise was performed (2.92 ± 0.65 young / 2.85 ± 0.35 older) [$F_{(3, 34)} = 0.28$, $p = 0.839$]. Coefficient of variation (CV) for VO_2 between resistance and aerobic exercise days for the younger men was 13.2%, whereas the CV for the older men was 8.5%.

There was no significant difference in RER from day to day during the baseline measure for the exercise interventions (0.85 ± 0.01 older/aerobic day; 0.85 ± 0.01 older/resistance day; 0.85 ± 0.02 young/resistance day; 0.85 ± 0.01 young/aerobic day) [$F_{(3, 34)} = 0.22$, $p = 0.882$], as indicated in Figure 3.2. The coefficient of variation of RER between the aerobic and resistance days was 1.9% for the younger men and 1.7% for the older men. At baseline, in the present study, the RER of 0.85 reflects a 50/50 oxidation of carbohydrate and fat. This assumes minimal contribution from oxidation of protein.

The VO_2 and respiratory exchange ratio values in the present study are similar to those reported in the literature for a rested person who consumes a mixed diet (Brooks, Fahey, White & Baldwin, 2000). These results confirm that the participants who were included in the analyses were in a rested state and had followed the pre-testing procedures by abstaining from physical activity and caffeine for twenty-four hours prior, and food and drink for eight hours prior to reporting to the lab.
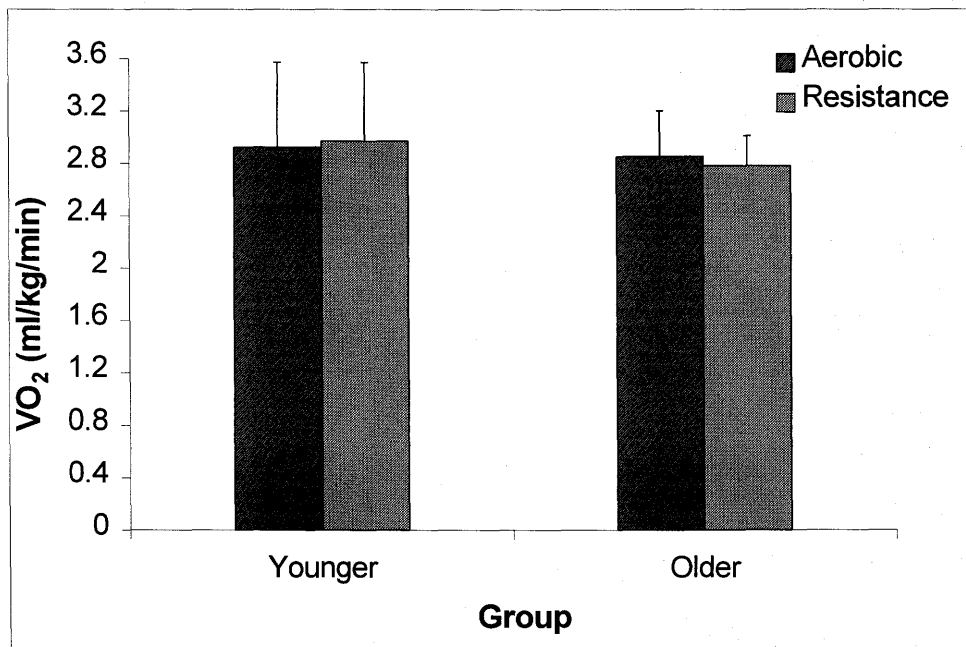
Figure 3.1: Comparison of baseline VO_2 values (mean ±SD) between aerobic and resistance exercise in younger (n=9) and older (n=10) men
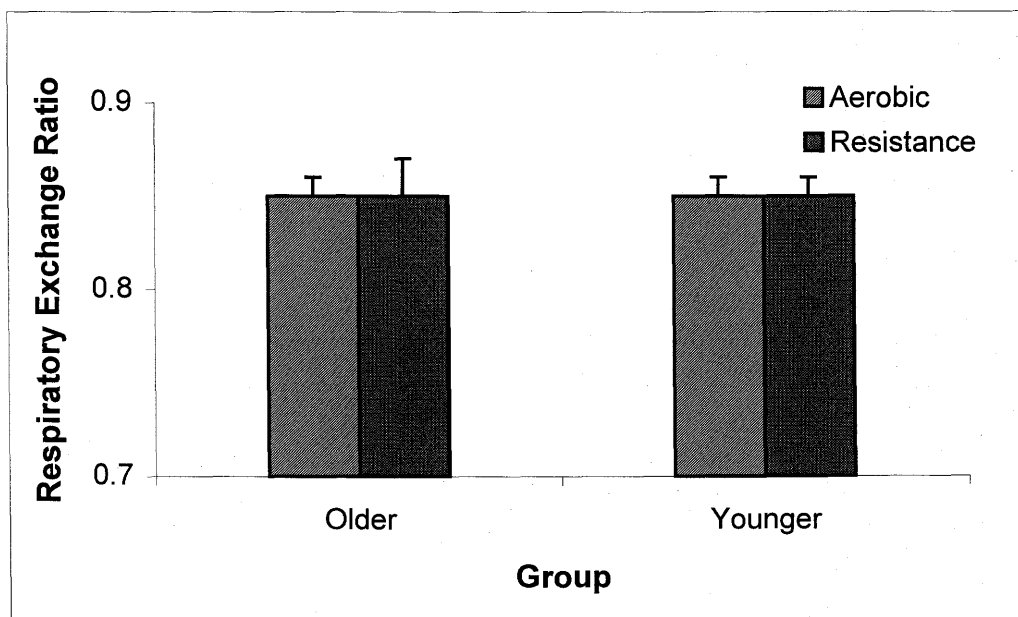
Figure 3.2: Comparison of baseline RER values (mean ±SD) between aerobic and resistance exercise in younger (n=9) and older (n=10) men

3.3 Post-Exercise Measures VO$_2$

3.3.1 Hypothesis 1: *Resting metabolic rate will be increased in both younger and older men after 30 minutes of aerobic or resistance exercise.*

The first hypothesis presented in this study stated that post-exercise metabolic rate would be increased above baseline values in both younger and older men, regardless of exercise mode (i.e. resistance or aerobic). The 3-factor ANOVA for VO$_2$, presented in table 3.2, revealed a significant main effect for time, indicating that VO$_2$ was significantly elevated above baseline values over time [F (3.27, 55.58) = 89.374, p = < 0.001]. The within-subjects contrast revealed that the elevation in VO$_2$ over time occurred at all measurement points compared to baseline values. Figure 3.3 depicts the effect of exercise mode and age group over time on VO$_2$. These results indicate that independent of age group and exercise mode, VO$_2$ remained elevated above baseline values for the entire six hours post-exercise. Therefore, the first hypothesis that metabolic rate, hence VO$_2$, will be elevated following resistance and aerobic exercise cessation in both younger and older men is accepted.

Table 3.2:
ANOVA table of main effects and interactions for post-exercise VO_2

Source	SS	DF*	MS	F	P
Group (G)	0.78	1	0.78	8.48	0.01
Error	1.57	17	0.09		
Time (T)*	47.69	8*	14.59	89.37	0.0001
T x G*	7.13	8*	2.18	13.36	0.0001
Error (Time)	9.07	136*	0.16		
Exercise Mode (M)	0.39	1	0.39	1.48	NS (.298)
M x G	1.89	1	1.89	7.22	0.016
Error (mode)	4.46	17	0.26		
T x M*	0.68	8*	0.24	1.25	NS (.303)
T x M x G*	1.18	8*	0.41	2.14	NS (.110)
Error	9.35	136*	0.19		

Epsilon: GG=

Time	0.283
Exercise Mode	1.000
Time x Exercise mode	0.300

GG Adjusted values for:

Time:	F = 89.37 df = 3.27, 55.59, p <.0 001
T x G:	F = 13.36 df = 3.27, 55.59, p < 0.001
T x M	NS
T x M x G	NS

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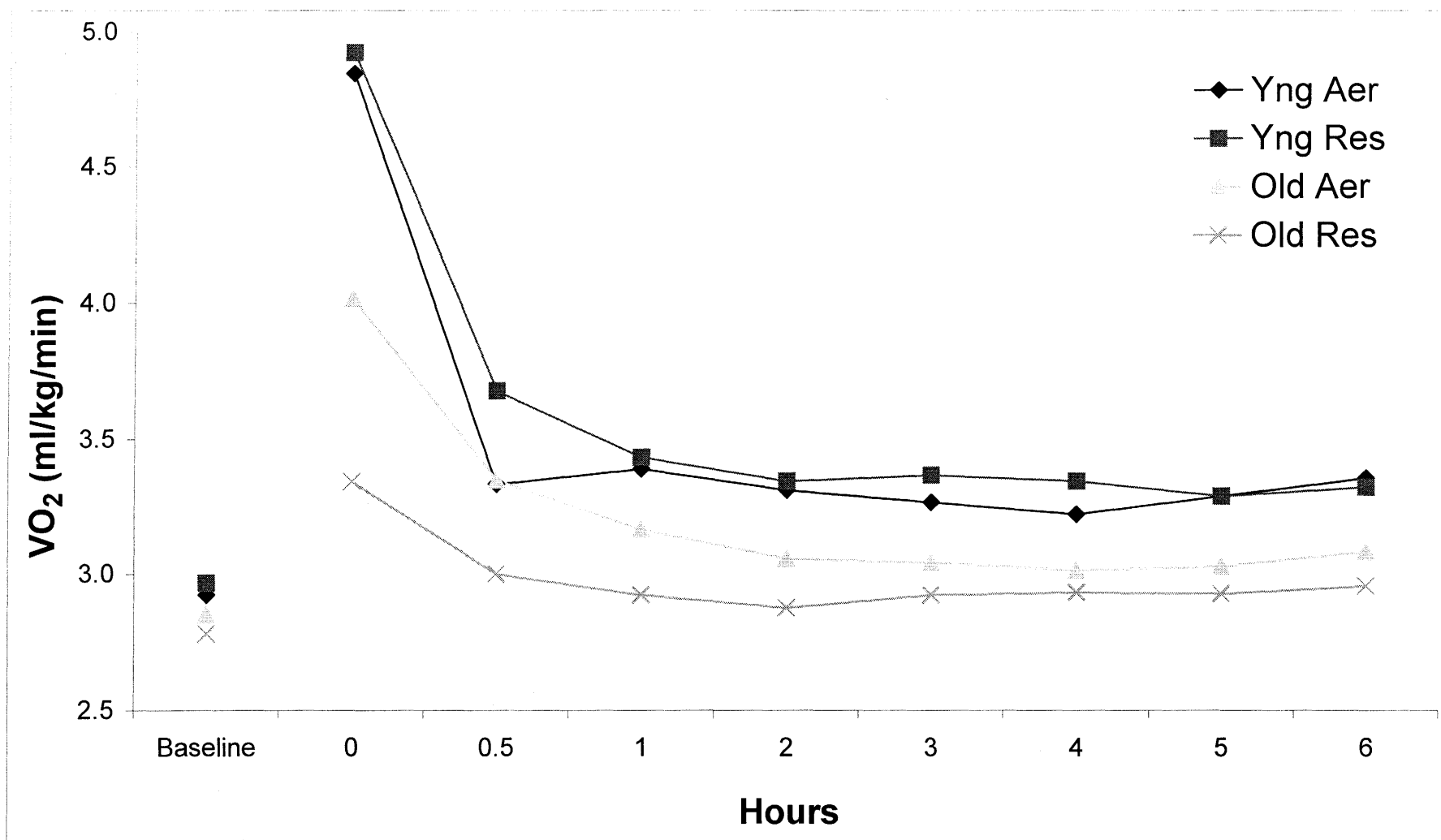
Figure 3.3: Volume oxygen consumed VO_2 (ml/kg/min) before and after aerobic and resistance exercise in younger (n=9) and older (n=10) men

3.3.2. Hypothesis 2: *Resistance exercise will produce a greater EPOC than the aerobic exercise in younger and older men after 30 minutes.*

There was no main effect for exercise mode, indicating that there was no significant difference found in VO_2 between the two exercise modes [$F_{(1, 17)} = 1.481$, p 0.240]. There was also no significant (time x exercise mode) interaction observed between the aerobic and resistance exercise over time [$F_{(2.9, 48.9)} = 1.245$, p = 0.303]. These findings indicate that post-exercise VO_2 was similar across exercise modes for the six hour time frame following aerobic or resistance exercise.

Figure 3.3 depicts treatment over time for the younger and older men, respectively. There was no significant interaction between time, exercise mode and age group, [$F_{(2.9, 48.9)} = 2.138$, p = 0.110]. These results indicate that regardless of age and exercise mode, VO_2 does not differ at any of the measurement points. However, it should be noted that there was a trend for aerobic exercise to exhibit a greater post-exercise VO_2 than the resistance exercise in older men.

3.3.3. Hypothesis 3: *The post-exercise increase in metabolic rate will be greater in younger men than in older men, regardless of exercise mode (i.e. aerobic or resistance).*

This hypothesis was based on the evidence that younger men have a greater quantity of fat-free mass, than older men, due to the decline of fat-free mass with age in the older men. A significant interaction (time x group) was observed between the older and younger men over time [$F_{(3.3, 55.6)} = 13.364$, p < 0.001]. The within-subjects contrast revealed that a significant difference in VO_2 occurred between the younger and older men only at time point 2 (i.e. immediately after exercise) compared to the baseline

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value. These results indicate that independent of exercise mode, the VO_2 for younger and older men differed significantly only at the first post-exercise measurement (i.e. immediately after the cessation of exercise) as observed in Figure 3.3.

A significant interaction occurred in VO_2 between the aerobic and resistance exercise and the two age groups, younger and older (exercise mode x group) [$F_{(1, 17)}$ = 7.218, $p = 0.016$]. This indicates that independent of time, the effects of the two exercise modes on VO_2 were significantly different between the younger and older men. The difference between the two groups showed that when all time points were collapsed together, the younger men were expending a greater total amount of energy (i.e. utilizing more VO_2) than the older men for both aerobic and resistance exercise. In Figure 3.3 all VO_2 values were higher in the younger men than the older men after both modes of exercise, throughout the 6-hour time frame. From Figure 3.3 it is also interesting to note that the difference between groups for resistance exercise was greater than the difference between the younger and older men for the aerobic exercise. From these results comparing VO_2 between the two exercise modes, the third hypothesis that post-exercise metabolic rate would be greater in younger men than in older men, regardless of exercise mode, is accepted.

3.4 Post-exercise Respiratory Exchange Ratio

3.4.1: Hypothesis 4: *The respiratory exchange ratio will decrease post- exercise in both younger and older men, regardless of exercise mode (i.e. aerobic or resistance).*

Figure 3.4 depicts the effect of exercise mode and age group over time on RER. The 3-factor ANOVA for RER, presented in Table 3.3, revealed a significant main effect for time, indicating that RER was significantly different than baseline values over time [$F (3.7, 62.0) = 47.30$, $p < 0.001$]. The within-subjects contrasts revealed that the significant elevation in RER over time occurred at all but three measurements compared to baseline values. Immediately after exercise the RER was significantly elevated, close to 1.0, indicating almost a complete oxidation of carbohydrates for energy. The RER was also found to be significantly different at the second post-exercise measurement (i.e. 30 minutes after the cessation of exercise) but at this point the RER was found to be less than the baseline value, indicating an increased proportion of fat being oxidized for energy. At measurements 1, 2, and 3 in figure 3.4 (1hour, 1-1/2 hour, and 2-1/2 hour) post-exercise the RER was not significantly different than baseline (i.e. 0.85 reflecting a 50/50 split between carbohydrate and fat oxidation). In contrast, for measures 4, 5, and 6 in figure 3.4 (3 1/2 hours, 4 1/2 hours, and 5 1/2 hours) the RER is significantly lower than baseline as a greater proportion of fat is relied on for energy.

Table 3.3:

ANOVA table of main effects and interactions for post-exercise RER

Source	SS	DF	MS	F	P
Group (G)	0.01	1	0.01	7.30	0.015
Error	0.02	17	0.00		
Time (T)*	0.73	8*	0.20	47.30	0.0001
T x G*	0.07	8*		4.57	0.004
Error (Time)	0.26	136*	0.00		
Exercise Mode (M)	0.01	1	0.01	1.37	NS (.258)
M x G	0.02	1	0.02	2.15	NS (.160)
Error (mode)	0.13	17	0.01		
T x M*	0.01	8*	0.00	0.84	NS (.478)
T x M x G*	0.02	8*	0.01	2.01	NS (.124)
Error (T x M)	0.13	136*	0.00		

Epsilon: GG=

Time	0.449
Exercise Mode	1.000
Time x Exercise mode	0.369

GG Adjusted values for:

Time:	F = 47.30 df = 3.65, 62.03, p < 0.001
T x G:	F = 4.6 df = 3.65, 62.03, p < 0.004
T x M	NS
T x M x G	NS
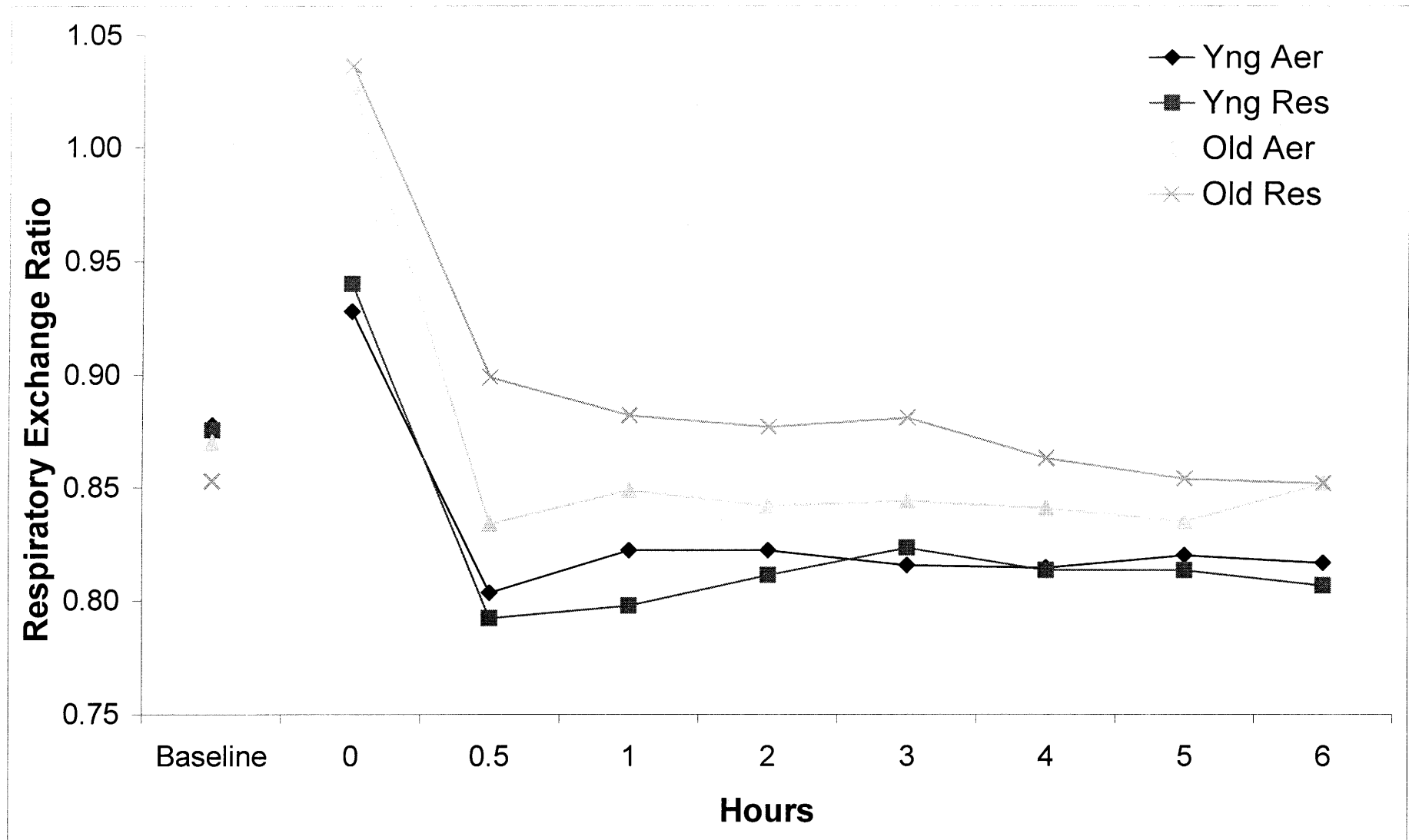
Figure 3.4: Respiratory exchange ratio (VCO_2/ VO_2) before and after aerobic and resistance exercise in younger (n=9) and older (n=10) men

The results from the present study also showed that exercise mode had no main effect on RER [F (1, 17) = 1.37, p = 0.258]. In addition, there was no significant (time x exercise mode) interaction observed between the aerobic and resistance exercise over time [F (3.02, 51.27) = .84, p = 0.478]. This means that the substrate being used for energy during the two types of exercise did not differ significantly. RER between the exercise modes in each age group is similar, indicating that regardless of exercise mode, the men are burning a similar proportion of carbohydrate and fat for energy within the six hour post-exercise measurement time.

There was no significant interaction for RER between the age groups and aerobic and resistance exercise (treatment x group) [F (1, 17) = 2.154, p = 0.160], indicating that the effects of the exercise mode was not different between the younger and older men. This means that if the RER at all time points was considered together for the two exercise modes, the proportion of substrates being utilized for energy are similar between younger and older men.

There was no significant interaction between time, exercise mode and age group [F (3.0, 51.3) = 2.01, p = 0.124]. These results indicate that regardless of age and exercise mode, RER does not differ significantly at any of the any measurement points.

A significant interaction (time x group) was observed for RER over time, between the older and younger men [F (3.7, 62.0) = 4.57, p = 0.004]. The within-subjects contrast revealed that significant difference in RER occurred between the younger and older men at all times compared to the baseline value. This indicates that regardless of exercise mode, the RER for younger and older men differed significantly at all measurement points, as shown in Figure 3.4. The graphs reveal that the older men had the greater RER

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over time after both exercise modes. From the RER values for the two age groups it is possible to see that although both age groups had similar baseline RER values, the older men have greater RER values at all measurements after both modes of exercise. In Figure 3.4, it is also possible to see that the first measurement immediately after exercise was close to 1.0, indicating a reliance on carbohydrate for energy. The remaining seven measurements are near the baseline value of 0.85, indicating that the energy is being provided by a combination of carbohydrate and fat, a ratio of 50/50.

3.5 Post-exercise Energy Expenditure

Post-exercise energy expenditure was determined to compare the average number of total kilocalories expended above baseline values, following aerobic and resistance exercise in both the younger and older men. The average number of kilocalories expended by the younger men six hours after aerobic exercise was 119 ± 63 kcal compared to 120 ± 44 kcal after resistance exercise. The difference in energy expenditure between the two types of exercise was not found to be significantly different $[F (1, 16) = 0.000, p = 0.976]$. However, in the older men, the average number of kilocalories expended after the two exercise modes was significantly different $[F (1, 18) = 8.722, p = 0.008]$. The average kilocalories expended during aerobic exercise was 71 ± 34 kcal versus 33 ± 24 kcal expended during the recovery from resistance exercise.

A significant difference also occurred between the age groups with each exercise mode. In comparison, the post-exercise energy expended by the younger men after aerobic exercise was 119 ± 63, versus 71 ± 34 kcal in the older men $[F (1, 17) = 4.454, p = 0.049]$. Similarly, a significant difference occurred between the postexercise energy

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expended after resistance exercise with the younger men expending 120 ± 44 kcal versus

the older men expending 33 ± 24 kcal [$F (1, 17) = 29.645$, $p < 0.001$].

CHAPTER 4:
DISCUSSION

4.1 Introduction

The literature to date has clearly shown that steady-state aerobic exercise can significantly elevate metabolic rate during the time frame that the activity is being conducted (Bielinski, Schutz & Jequier, 1985; Chad & Wenger, 1988, Gore & Withers, 1990). Further work has also shown that exercise can produce an increase in metabolism that extends beyond the exercise session itself; termed excess post-exercise oxygen consumption (EPOC) (Bahr, Ingnes, Vaage, Sejersted & Newsholme, 1987; Bielinski et al., 1985; Gaesser & Brooks, 1984). Although steady-state exercise has been shown to be a major determinant of EPOC, few studies have addressed the impact of intermittent resistance exercise on the post-exercise energy expenditure. Similarly, there is a lack of research comparing aerobic and resistance exercise of similar energy cost and in different age groups. Therefore, the purpose of this study was to examine the effect of an acute bout of aerobic steady state cycling and intermittent resistive exercise, of the same duration, on excess post-exercise oxygen consumption (EPOC) in younger and older men.

The results of the present investigation revealed that thirty minutes of either aerobic or resistance exercise significantly elevated metabolic rate in both younger and older men and remained elevated above baseline for the entire six hours of post-exercise measurement after both exercise modes. The findings also showed that the magnitude of recovery EPOC between resistance and aerobic exercise was similar; however younger men have a greater EPOC and subsequent energy expenditure compared to older men. Previous studies in this area are summarized and presented in Table 4.1.

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Table 4.1 Summary of Previous EPOC Studies

Authors	Subjects	Protocol	Results
AEROBIC			
Gore & Wither (1990)	9 males Average age = 21.9 ± 2.2 years VO_2max = 63.0 ± 5.7 ml/kg/min	Cycling at 70% VO_2max for 20 and 50 minutes	8-hour EPOC: 5.68 ± 4.89 L (20 min) 10.04 ± 3.26 L (50 min)
Bahr & Sejersted (1991)	6 males Average age = 23.0 ± 0.6 years VO_2max = 49.9 ± 1.4 ml/kg/min	80 minutes cycling at 50% VO_2max, 75% VO_2max	EPOC = 50%= 5.7 ± 1.7 L in 3.3 ± 0.1 hours 75%= 30.1± 6.4 L in 10.5 ± 1.6 hours
Bahr, Ingnes, Vaage, Sejersted, & Newsholme (1987)	6 males Average age: 22.7 ± 0.8 years VO_2max = 54.1 ± 1.5 ml/kg/min	Cycling 20, 40 and 80 minutes at 70% VO_2max	12-hour total oxygen consumption: 231.0 ± 8.1 L (20 min), 234.6 ± 7.7 L (40 min), 251.8 ± 10.5 L (80 min) slightly more than double found in current study – 30 min exercise, 6 hr measurement
RESISTANCE			
Melby, Tincknell, & Schmidt (1992)	6 males Age = 24.5 ± 6.1 years	3 sets of 10 repetitions at 12 RM for 42 min with 2 minutes rest between sets	1-hour oxygen consumption = 343.0 ± 52.6 ml O_2/min compared to pre-exercise of 272.2 ± 44.1 ml O_2/min or sitting =283. ± 41.0 ml O_2/min
Melby, Scholl, Edwards, & Bullough (1993)	1) 6 males 2) 7 males All subjects 20-40 years	1) 6 sets of 10 exercises at 70% 1-RM, 8-12 repetitions 2) same but only 5 sets	3) 2 hour EPOC = 7.0 ± 1.0 L 4) 2 hour EPOC = 7.2 ± 1.2 L
AEROBIC AND RESISTANCE			
Gillette, Bullough,, & Melby (1994)	10 males Average age = 27 ± 4.3 years VO_2max = 52 ± 8.4 ml/kg/min	1) Cycling at 50%vo2max 2) Resistance – 70% 1-RM	5 hour EPOC: 1) 349 ± ml O_2/min 2) 376 ± ml O_2/min

4.2 EPOC and Exercise Mode

The results from the present study that showed an elevated EPOC in men, following both exercise modes supports the findings of previous studies, which have also showed an elevated post-exercise metabolism after aerobic (Bahr et al., 1987; Bahr & Sejersted, 1991) and resistance exercise (Melby et al., 1992; Melby et al., 1993; Gillette et al., 1994). Bahr et al. (1987), found that excess post-exercise O_2 uptake occurred for at least 12-hours after cycling for 20, 40, or 80 minutes at a work intensity corresponding to 70% of maximal aerobic capacity in six males (22.7 ± 0.8 years). The total oxygen consumption for the 12 hours of recovery varied from 231.0 ± 8.1 litres, 234.6 ± 7.7 litres, and 251.8 ± 10.5 litres, for the three lengths of the exercise bout. The total oxygen consumption for the six hours of recovery in the present study was 100.4 litres for the younger men and 90.8 litres for the older men. It appears that the total O_2 consumption measured by Bahr et al. (1987), for 12 hours after 20 and 40 minutes of exercise at the same intensity as the present investigation, was slightly more than double the total oxygen consumption found in the present study following 30 minutes of exercise measured for six hours. The greater EPOC in the Bahr study can likely be explained by the thermic effect of the three meals that were fed to the participants over the twelve hours, as EPOC is also influenced by an increased energy expenditure associated with food ingestion, which can account for approximately 10% of daily energy expenditure.

In a second study by Bahr & Sejersted, (1991) O_2 consumption was significantly elevated above the level of the control experiment following 80 minutes of cycling at three various exercise intensities, creating a total EPOC of 5.7 ± 1.7 litres in 3.3 ± 0.1 hours at 50% VO_2max, and 30.1 ± 6.4 litres in 10.5 ± 1.6 hours at 75% VO_2max. In the

present study 30 minutes of aerobic cycling at 70% VO_2max, created a total EPOC of

14.3 litres of oxygen in six hours. In comparison to the 80 minutes of exercise at 75%

VO_2max performed in the Bahr study, the present study found a little less than half the

recovery EPOC in slightly more than half the duration of measurement. This would be

expected as the duration of exercise was more than double the present study, and the

intensity was 5% greater, than the current investigation. In addition, the participants in

the Bahr study were fed at two hours, seven hours and twelve hours, possibly inducing a

greater elevation in energy metabolism due to the thermic effect of food. Although a

higher EPOC was found, in the Bahr study, the results of that investigation provide

support for the present study's findings that oxygen consumption stays significantly

elevated above baseline values for at least six hours after exercise of moderately high

intensity.

Gore and Withers (1990), investigated EPOC in nine males for eight hours after

aerobic exercise at 70% VO_2max for durations of 20 and 50 minutes. To compare

between the Gore and Withers study and the present study is difficult because although

the intensity of exercise was the same in both studies, the duration of exercise and the

duration of EPOC measurement are not directly comparable. The recovery EPOC in the

Gore and Withers study was 5.68 ± 4.89 litres in eight hours following the 20 minute

exercise bout and 10.04 ± 3.26 litres following the 50-minute exercise bout compared to

14.3 litres in the present investigation after six hours of recovery from aerobic exercise at

70% VO_2max for 30 minutes. It is possible that differences in methodologies and subject

participants could account for the variation in EPOC between the two studies. For

example, the participants in the Gore and Withers study ran on the treadmill, whereas in

the present study, the subjects cycled. The subjects in the Gore and Wither's (1990) study were also endurance trained (average VO_2max was 63.0 ml/kg/min) and thus it is possible that their lower absolute values for EPOC may be a reflection of their training status. At this point, no research is available on possible differences between trained and untrained subjects in EPOC (Bahr, 1992). However, it may be that the post-exercise oxygen consumption is less in trained men than in untrained men due to the greater aerobic fitness and decreased physical stress of exercise on the body.

One of the first studies to investigate EPOC after resistance exercise was Melby, Tincknell and Schmidt (1992) who found that after 60 minutes of recovery from 42 min of resistive exercise, oxygen consumption was 343.0 ± 52.6 ml O_2/min compared to the pre-exercise (272.2 ± 44.1 ml O_2/min) and to the control condition of sitting values (283.0 ± 41.0 ml O_2/min). In the present study, the O_2 consumption for one hour following the resistance exercise in the younger and older men was 338.6 ± 57.0 ml O_2/min and 257.6 ± 15.5 ml O_2/min, respectively, which was significantly elevated compared to the pre-exercise values (255.0 ± 40.4 ml O_2/min; 234.0 ± 30.6 ml O_2/min). Melby et al. (1992), and the present study both agree that one-hour EPOC is significantly elevated after resistance exercise. In addition, the present study found that the significant elevation of energy expenditure after exercise also occurs in older men (60-75 years).

Melby, Scholl, Edwards and Bullough (1993) completed two experiments investigating EPOC after resistance exercise with a group of six and a group of seven 25 to 35 year old men. The two experiments found similar post-exercise outcomes. All the subjects' post-exercise metabolic rates were elevated above resting baseline values continuously up to and at two hours post-exercise. The average total EPOC for the two

hours after exercise was 7.0 ± 1.0 litres, and 7.2 ± 1.2 litres of oxygen. Furthermore, a prolonged elevation of metabolic rate was found when RMR was measured the following morning 14-15 hours after the exercise bout. In the present study, the total EPOC calculated for two hours post-exercise was 7.2 litres of oxygen, similar to the total EPOC found by Melby et al. (1993), after resistance exercise. Thus, the present study supports Melby's findings that resistance exercise of sufficient intensity metabolic rate remains elevated above resting values for a significant period of time, contributing to daily energy expenditure. It is interesting to note that when the two hour EPOC for resistance exercise was compared between younger and older men, the resulting EPOC in older men in the present study was only 2.19 litres of oxygen in two hours, which was substantially lower than the younger men in both Melby's investigation and the present study.

Aerobic and resistance exercise have been investigated independently to evaluate their effects on EPOC, however, few studies have compared the two modes of exercise to determine if one mode of exercise produces a greater magnitude of EPOC than the other. One comparison between exercise modes was made by Gillette, Bullough and Melby (1994), who compared the post-exercise response for five hours following a bout of cycling at 50% VO_2max and a session of resistance exercise at 70% of each subject's 1-RM in ten men. Aerobic and resistance exercise were both found to elevate metabolic rate above the control condition for the entire five hour post-exercise period. The average VO_2 values for the five hour recovery period were 376 ml O_2/min (resistance), 349 ml O_2/min (aerobic cycling), and 334 ml O_2/min (control). To compare these results to the present study EPOC was calculated over the first five hours. The present investigation found the average total EPOC in the younger men to be 401.85 ml O_2/min (resistance)

and 384.54 ml O_2/min (aerobic) and 121.9 ml O_2/min (resistance) and 229.5 ml O_2/min (aerobic) for the older men. It appears from this data, that resistance exercise provided a similar magnitude of EPOC and resulting total energy expenditure in the younger men in the present study, whereas, the aerobic exercise provided greater EPOC and total energy expenditure than resistance in the older men in the present study. These findings are in contrast to Gillette et al. (1994) who found the energy expended after resistance exercise to be significantly greater than after aerobic exercise. The discrepancy in the findings between the studies is likely due to the difference in study protocol. For example, the aerobic protocols differed across the studies for intensity levels. In the Gillette study the aerobic exercise was a bout of stationary cycling at 50% of VO_2max with the duration adjusted to approximate the estimated caloric cost of the resistive exercise (approximately 60-65 minutes), whereas, in the present study the aerobic protocol was 70% of VO_2max for 30 minutes. Exercise at intensities above 50% VO_2max are required to trigger the metabolic processes that are responsible for EPOC, and only after intensities of 70% VO_2max or greater is there any sustained, prolonged increase of O_2 uptake that will contribute significantly to energy expenditure (Bahr, 1987; Bahr & Sejersted, 1991). Therefore, it is likely that the intensity of the aerobic exercise in the Gillette study was enough to trigger the metabolic processes that are responsible for EPOC, but the intensity may not have been high enough to elicit an EPOC response comparable to the response found after the more intense resistance exercise protocol. Another discrepancy between studies was the type of resistance protocol used. In the present study the resistance protocol consisted of five sets of eight repetitions of two different leg exercises at 75% of 1-RM for a total 30 minutes. The duration was matched with the aerobic protocol which

was performed at 70% VO_2max for 30 minutes. The resistance protocol in the Gillette et al. (1994) study was five sets of eight to twelve repetitions of ten different exercises at 70% 1-RM for a total of 100 minutes. The greater intensity used for the resistance protocol versus the aerobic protocol in the Gillette study is likely responsible for the greater elevation of post-exercise energy expenditure after the resistance exercise as compared to the much less intense aerobic protocol.

4.3 EPOC and Age

Another objective of the present study was to investigate the effect of age on post-exercise metabolism. Since limited work has been done comparing EPOC in differing age groups, it is difficult to compare results and understand the mechanisms involved. The present study found that the younger men had a greater magnitude of EPOC than the older men after both aerobic and resistance exercise. Since it is known that age is associated with an age-related decline in fat free mass, the physiological explanation for the significantly higher VO_2 in the younger men can likely be attributed to the greater proportion of metabolically active lean tissue mass, and hence more oxygen needed during recovery to produce energy in order to restore the tissues to homeostasis (Fukagawa, Bandini, & Young, 1990; Poehlman, Arciero & Goran, 1994). From the results of this investigation it appears that post-exercise metabolic rate is greater in younger men than in the older men, regardless of exercise mode. During this investigation it was also noted that when the post-exercise response was compared between exercise modes in the older men, there was a trend for aerobic exercise to exhibit a greater post-exercise VO_2 than the resistance exercise. This may be attributed to the

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lower proportion of lean body mass in the older men. With age, it is possible that these men have lost some lean tissue and hence strength in their legs. Therefore, based on their 1-RM they may be doing less total work during the resistance exercise, which requires muscular strength in their legs compared to the aerobic exercise that is more dependant on cardiovascular fitness.

4.4 Mechanisms Responsible for EPOC

Exercise triggers a multitude of processes that must return to a basal turnover rate during the exercise recovery period. The majority of the literature agrees that there are two phases of EPOC, the rapid (fast) and the prolonged (slow), with different mechanisms being responsible for the energy expenditure associated with each phase (Bahr, 1992; Gaesser & Brooks, 1984). The rapid EPOC phase refers to the first 60 minutes after exercise (Bahr, 1992) and is comprised of both the fast and slow components of the EPOC. In the present study, the rapid phase of EPOC occurring in the first hour immediately after exercise accounted for 30-40% of the total EPOC measured.

4.4.1 Mechanisms Responsible for the Rapid Componenent of EPOC

The mechanisms associated with the rapid component of EPOC include a combination of re-saturation of myoglobin and hemoglobin with O_2 (Bahr & Sejersted, 1991; Gore & Withers, 1990) restoration of phosphagen levels in the exercising muscles (Nordheim & Vollestad, 1990) removal of lactate produced during exercise (Gasser & Brooks, 1994) increased levels of circulation and ventilation (Bahr, 1992) and increased body temperature (Gore & Withers, 1990). Bahr (1992) evaluated the contribution of re-

saturation of hemoglobin and myoglobin after sub-maximal exercise and found that within one hour the O_2 stores in the blood and muscle were replenished to resting levels. Bahr (1992) estimated the total contribution of EPOC from O_2 store replenishment has estimated to be around 0.3 litres after exercise at 70-80% VO_2max for 70-80 min. Total replenishment was accomplished in a few minutes and the contribution to EPOC is probably limited to this period.

During submaximal exercise CP and ATP concentration decrease as these systems are being used to supply energy to the muscle for contraction and relaxation. During recovery, energy in the form of ATP is expended in order to remove the calcium ions from the Ca - troponin bond at the site of muscle contraction, and return this calcium to the sacroplamic reticulum for future use. ATP is also used during recovery from exercise at the cellular membrane in order to pump potassium ions back into the cell and to remove the sodium ions, and to detach the cross-bride between actin and myosin, allowing the muscles to relax. During recovery O_2 is also being expended in the mitochondria in order to create ATP, which aids in the reformation of creatine phosphate by combining with creatine and donating a phosphate in order to form creatine phosphate and ADP.

Although these processes have a significant role in the recovery of energy after muscle contraction, at the end of exercise, Bahr (1992) found that any reduction in ATP concentration is restored within seconds, and CP concentration is restored within minutes to resting levels. In the present study it is likely that these processes contribute to EPOC, but the contribution would be very small as these processes occur very rapidly and would not contribute significantly to our six hour measurement of EPOC.

The cost of glycogen re-synthesis from lactate is another mechanism thought to contribute to the rapid component of EPOC. The fate of lactate is a matter of debate, but it is generally accepted that two main pathways are oxidation and re-synthesis to glycogen in the liver and muscle (Brooks & Gaesser, 1984). The lactate that is oxidized during recovery supplies ATP, which would otherwise have come from the oxidation of other substrates and should not be included in the O_2 cost of lactate removal. Glycogen re-synthesis on the other hand increases O_2 demand; since it is assumed that 7 mol phosphate bonds are consumed in order to convert 2 mol lactate to 1 mol glucose units in glycogen (Nordheim & Vollestad, 1990). It appears that in the presence of large amounts of lactate available as substrate for glycogen re-synthesis, there is a close relationship to the rapid component of EPOC. However, using subjects of similar age and training status Bahr and Sejersted (1991) found no progressive increase in blood lactate concentration during exercise at intensities ranging from 70-78% of VO_2max, indicating that none of the subjects appeared to be above the lactate threshold. Lactate concentrations reached in five to sixty minutes after exercise did not differ from resting values, and a weak relationship was found between lactate concentrations at the end of exercise at 75% of VO_2max and EPOC. Considering the subjects were of similar age, and training status and the exercise intensity was similar, it likely that our study would find similar lactate concentrations and the cost of O_2 removal would not contribute significantly to EPOC.

Bahr (1992) investigated the cost of increased circulation after exercise, and found that there is a slow return of heart rate to resting levels during recovery, and that the time course and magnitude of the changes were comparable to the changes in O_2

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consumption. After exhaustive prolonged exercise heart rate was significantly increased for the entire twelve hour observation period, therefore, Bahr (1992), assumed that the increased circulation would not only contribute to the increased O_2 uptake during the first hour after exercise, but also to the prolonged EPOC component. In Bahr's study using an exercise intensity of 70-80% VO2max for 70-80 minutes the calculated O_2 cost of moving the additional blood volume through circulation in the twelve hours was about 1.3 litres. Of this, it was estimated that the O_2 cost of increased circulation during the first hour after exercise was about 0.3 litres. Bahr (1992) also examined the cost of increased ventilation with respect to EPOC. The changes in ventilation after exercise were, as for heart rate, similar to the changes in O_2 consumption, but less pronounced. In the same experiment, Bahr (1992) found the contribution of increased pulmonary ventilation to EPOC to be minimal at an estimated <0.1 litres after submaximal exercise recovery.

Elevated body temperature has been suggested as an important factor contributing to the increase in metabolic rate after exercise (Brooks & Gaesser, 1984). The decline in whole-body post-exercise VO_2 and the return to control levels of tissue temperatures are very closely associated (Claremont, Nagle, Reddan & Brooks, 1975). The extent to which the temperature contributes to the post-exercise VO_2 is probably related to the effects of elevated temperature on mitochondrial energetics. Elevated temperature has been shown to increase respiration and to decrease phosphorylative coupling efficiency in mitrochondria (Brooks et al., 2000). As a consequence, more O_2 would be required for a given amount of ATP to be synthesized (Gaesser & Brooks, 1984). Hagberg, Mullin, and Nagle (1980), calculated that the effect of temperature on metabolism could account for 60-70% of the slow component of recovery VO_2 after exercise of intensities between 50-

80%VO$_2$ max. More recently, Bahr and Sejersted (1991) measured rectal temperature in subjects of similar age and training status as the present study. After sub-maximal exercise of similar intensity to the present study, they found that body temperature returned to resting levels in less than one hour, with the resulting increase in O$_2$ consumption being estimated to be 1.2 litres. However, because the temperature returned to resting levels within the one hour, it is unlikely that increased body temperature contributes any increased O$_2$ cost to the later phase of EPOC.

In summary, the most significant mechanisms that could be responsible for producing EPOC in the rapid phase of EPOC after both aerobic and resistance exercise, in the present study, appear to be a combination of small contributions to EPOC provided by the restoration of phosphagen levels, resaturation of myoglobin and hemoglobin, and increased ventilation. The largest component of rapid EPOC appears to be the combination of increased circulation and the increase in body temperature leading to decreased phoshorylative coupling efficiency, causing more O$_2$ to be required for a given amount of ATP to be synthesized.

4.4.2 Mechanisms Responsible for the Prolonged Component of EPOC

The second phase of EPOC is referred to as the prolonged or slow component as it occurs slowly over a number of hours (Bahr, 1992; Gaesser & Brooks, 1984). In the present study, this portion of EPOC occurred from the first to sixth hour, accounting for 60-70% of the total EPOC for the entire six hour duration. The mechanisms suggested to be responsible for this phase of EPOC include glycogen re-synthesis from ingested carbohydrates (Bahr & Sejersted, 1991), a potentiated thermic effect of food (TEF) (Bahr

& Sejersted, 1991), increased rate of substrate cycling (Maehlum, Grandmontagne, Newsholme, & Sejersted, 1986; Bahr, Hansson & Sejersted, 1990; Wolfe, Klein, Carraro, & Weber, 1990), and increased hormone levels (Maehlum et al. 1986). In the present study the first two suggested mechanisms can be ruled out as the study protocol did not allow for ingestion of carbohydrates and therefore, there would not be a resulting thermic effect of food. The increased rate of substrate cycling and increased hormone levels are likely the important mechanisms involved.

Exercise at high intensities, as in the present study, result in activation of the sympathetic nervous system with elevated concentrations of plasma catecholamines. Triglyceride-fatty acid (TG-FA) cycling, which consumes ATP, is among the many metabolic processes stimulated by catecholamines. Two studies have demonstrated that the rate of TG-FA cycling is elevated for at least three hours after exercise (Bahr et al., 1990; Wolfe, et al., 1990). Since one rotation of this cycle requires the hydrolysis of eight molecules of ATP to ADP, an increase in the mobilization of fat from the adipose tissue reserves and an increased rate of cycling between the triacylglycerol and fatty acids would result in a marked increase in O_2 consumption after exercise. Wolfe (1990) found that a high rate of cycling during recovery accounted for a considerable percentage (14%) of the increase in energy expenditure above the resting values before exercise. Similarly, the additional energy cost of increased cycling after exercise in the Bahr (1990) study was estimated to be 0.22 kJ/min (0.05 kcal/min), whereas the excess postexercise energy expenditure was estimated to be 0.42 kJ/min (0.10 kcal/min). Thus, the extra energy cost associated with increased TG-FA cycling may account for as much as half of EPOC, making this mechanism the most significant in terms of post-exercise energy expenditure.

For a better understanding of this cycle it may help to look at substrate utilization during and after exercise. Results of the classic indirect calorimetry studies indicate that in a resting post-absorptive state, most energy (~60%) is from lipid oxidation, with the remainder coming from carbohydrate oxidation (~35%), and approximately 5% from proteins. However, as soon as exercise starts, even though the same amount or more lipid is used, the relative contribution of lipid declines, and that of carbohydrate rises. Then, as exercise power output increases from mild to moderate and then to high intensity, the relative contribution of lipid declines, while that of carbohydrate increases. Thus, high intensity exercise is accomplished by "crossover" of metabolism to a dependence on carbohydrate oxidation and utilization as the predominant energy source. In the present study substrate oxidation was calculated from the respiratory measures obtained via indirect calorimetry after exercise and up to six hours. Immediately after exercise the respiratory exchange ratio was close to 1.0, indicating an almost complete reliance on carbohydrate, which supports the crossover concept during exercise. However, once recovery began we saw a reversed crossover in substrate utilization indicated by the decreasing RER value. This increase in the utilization of lipid during recovery is essential to replenish the muscle glycogen used during exercise and allows the necessary metabolic functions to return to normal in the individual. This post-exercise decrease in the value of RER indicates a greater proportion of fat being oxidized in the subjects and hence, a higher plasma fatty acid level. Once exercise has finished, the plasma level of fatty acids further increases and this increase may be proportional to the rate of fatty acid utilization during the exercise period. One role of the triacylglycerol-fatty acid cycle in adipose tissue may be to decrease gradual and progressively, the rate of fatty acid

mobilization. Exercise of insufficient intensity or duration to raise plasma fatty acids and/or catecholamine levels may not result in a marked EPOC.

In summary, during the prolonged component of EPOC that continues up to six hours in the present study, the most significant mechanism that could contribute to the EPOC may be the stimulation of the Triglyceride-fatty acid (TG-FA) cycle by elevated concentrations of catecholamines resulting from the activation of the sympathetic nervous system in response to exercise at high intensities, such as those observed in the present study. Bahr (1990) found that the extra energy cost associated with increased TG-FA cycling might account for as much as half of EPOC, making it the most significant mechanism responsible for post-exercise energy expenditure.

4.4.3 Possible Mechanisms Responsible for EPOC after Resistance Exercise

To date, the research to determine the physiological mechanisms responsible for EPOC has concentrated on recovery from aerobic exercise. To our knowledge the mechanisms responsible for EPOC after resistive exercise have not been directly investigated, and thus it is important to discuss this topic in order to gain some understanding of what may be happening during the post-exercise period following this type of exercise mode. Kraemer (1988) reviewed the endocrine responses during resistive exercise and described elevations in plasma catecholamines, cortisol, growth hormone, and testosterone in response to resistance activity. Exercising using eccentric muscle contractions has been found by others to induce derangements of skeletal muscle fibrils, membranes and ion transport (Armstrong, 1990; Byrd, 1992; Friden & Lieber, 1992). In addition to these mechanisms, Cannon et al. (1989) reported an increased

production of the cytokine interlukin-1 in response to eccentric muscle contraction. Interlukin-1 is a protein released from blood monocytes and related cells in response to an inflammatory or infectious stimuli. Although interlukin-1 is elevated in circulation for only a few hours after an acute bout of exercise, it is thought to mediate catabolic and anabolic processes that can last for several days. It is possible that any of these perturbations associated with resistive exercise could potentially result in the prolonged elevation of post-exercise metabolic rate.

Although neither the present study nor any of the other resistance exercise studies reviewed made an attempt to identify the thermogenic factors responsible for the elevation of post-exercise metabolic rate after resistance exercise, it has been shown that acute strenuous resistive exercise causes dramatic homeostatic perturbations (Kraemer 1988; Kraemer et al., 1992), including elevations in anabolic hormones (Kraemer, 1992) and catecholamines (Kraemer, Noble, Clarke, & Culver, 1987). It is possible that some of the mechanisms responsible for EPOC after resistance exercise may be similar those responsible for the EPOC after aerobic exercise. During weight lifting phosphocreatine and skeletal muscle glycogen are the major sources of fuel for the ATP synthesis required for forceful muscle contraction (Poehlman & Melby, 1998). Therefore, the resynthesis of adenosine triphosphate, creatine phosphate and glycogen in the muscle is thought to be a large part of the rapid component of EPOC after resistance exercise (Van Zant, 1992). In addition, the primary fuel source for high intensity resistance exercise would be carbohydrate, similar to high intensity aerobic exercise. Therefore, fat would be a major contributor to energy needs during recovery and it is likely that the TG-FA substrate cycling would also occur in the prolonged component of EPOC after resistance exercise,

although no studies have investigated this possibility. Further research is needed to identify the physiological mechanisms that are responsible for the extended post-exercise metabolism after resistance exercise.

CHAPTER 5:
CONCLUSIONS

5.1 Conclusions

For men wishing to reduce body weight through an exercise program, the possibility of extended energy expenditure for hours after exercise is an intriguing concept. This additional energy expenditure has been used as an argument in favour of exercise as an alternative adjuvant treatment strategy to reduced food intake in the treatment and prevention of obesity (Thompson, Jarvie, Lahey & Cureton, 1982). However, studies have shown that not all kinds of exercise are effective.

The findings from the present study suggest that both aerobic and resistance exercise produce an elevation of post-exercise metabolic rate that extends hours into recovery. It is interesting to note, however, that in younger men the magnitude of this EPOC is similar after aerobic and resistance exercise and thus in this age group, it does not appear that one mode of exercise is superior to the other in producing elevated metabolism during recovery. However, in the older men there was a trend towards a greater increase in EPOC with total caloric expenditure being significantly greater after the cycling versus weight lifting. In this respect, it would appear that for this age group aerobic exercise is likely to produce a superior post-exercise metabolism compared to resistance exercise.

5.2 Recommendations for Future Research

In order to further address the role of EPOC after exercise, future research should be directed towards the contribution of EPOC to total daily energy expenditure in other populations. It would be important to evaluate the role of EPOC in untrained or obese

people in order to determine if exercise of sufficient intensity and duration to elicit EPOC would be tolerable in these groups. It is also recommended that future research be carried out to further investigate the specific mechanisms and their relative contributions to the post-exercise oxygen consumption after resistance exercise.

Exercise is known to be beneficial in weight control, not only because of the direct caloric cost of the activity and the residual elevation of post-exercise VO_2 but also because of the greater post-exercise fat oxidation. The important mechanism for weight control may be the extended fat oxidation rather than extended caloric expenditure beyond the exercise bout itself. Future research should examine the effect of resistance and aerobic exercise of different intensities on energy balance and weight regulation by evaluate the impact of each exercise mode on total energy expenditure, 24-hour substrate utilization, and energy and macronutrient intake over time, not just during the exercise bout itself.

It will also be important in future research to address some of the limitations that were apparent in the current study. One of the limitations is that it is virtually impossible to match the caloric expenditure between resistive and aerobic exercise. Few studies examine the energy cost of non steady state anaerobic activities due to the difficulties in using indirect calorimetry for the measurements. However, as the calorimetry technology advances this will become more attainable. Another limitation was not having a direct measure of body composition. A direct measure of body composition such as dual energy x-ray absorptiometry (DEXA) would allow for oxygen consumption and calories to be calculated relative to lean body mass rather than total body mass. This would also

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APPENDIX A

Physical Characteristics of Subjects

Physical Characteristics of Older Male Subjects

	Age	Height (cm)	Weight (kg)	VO$_2$max (ml/kg/min)
20	67	184	94.5	33.5
21	67	167	75.9	49.4
22	62	175	74.1	38.3
23	70	178	87.3	34.0
24	60	179	90.9	44.0
25	63	180	97.7	34.4
26	68	181	76.0	35.3
27	69	172	70.0	34.4
28	68	181	87.7	38.1
29	64	183	89.0	37.9
Mean	65.8	178.0	84.3	37.9
SD	3.3	5.3	9.5	5.1

Physical Characteristics of Younger Male Subjects

	Age	Height (cm)	Weight (kg)	VO$_2$max (ml/kg/min)
10	24	168.0	78.0	46.3
11	23	184.0	91.0	46.7
12	22	186.0	102.0	48.4
14	24	181.0	83.0	53.5
15	24	176.0	83.0	52.9
16	22	184.0	104.0	40.6
17	28	171.0	87.0	38.3
18	22	186.0	79.5	57.9
19	20	179.0	76.0	47.0
Mean	23.2	179.4	87.1	48.0
SD	2.2	6.6	10.1	6.2

APPENDIX B

Recruitment Poster Advertisement

ATTENTION!
Physically Fit Men

- **Are you between the ages of 60 and 75**

- **Would you like to know what method of exercise burns the most calories?**
-
- **Would you like to know how energy expenditure changes as you age?**

We are looking for subjects to participate in a study completed as part of a Masters of Science thesis titled:

"Effect of Aerobic and Resistance Exercise on Energy Expenditure in

Older and Younger Men"

If interested please contact:

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Karen Chad, advisor
College of Kinesiology
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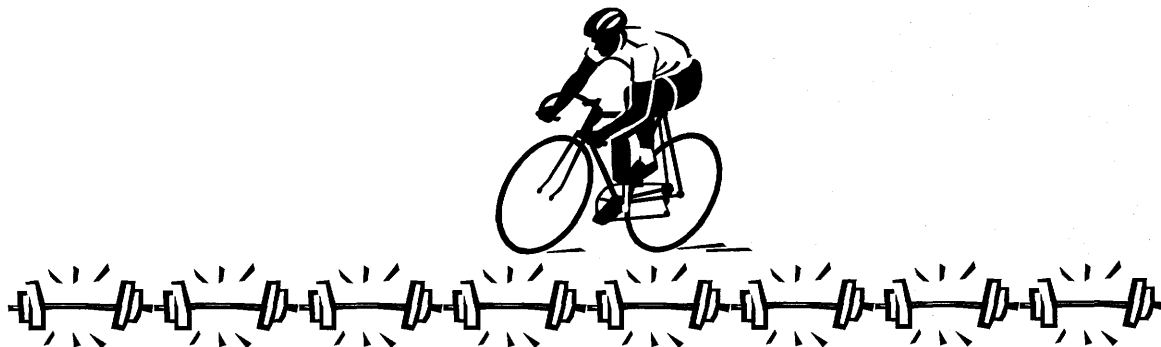
APPENDIX C

Participant Informed Consent

Consent Form
**EFFECT OF ACUTE RESISTANCE AND AEROBIC EXERCISE ON EPOC IN
YOUNGER AND OLDER MEN**

Kristina Campbell, M.Sc student   Karen Chad PhD, Advisor
College of Kinesiology,   Associate Professor
University of Saskatchewan   College of Kinesiology
934-7296   University of Saskatchewan

Aerobic exercise has often been considered the most valuable mode of exercise to positively affect energy expenditure and body composition and more recently, resistance exercise has been considered as an effective intervention to enhance energy requirements. When the two modes are compared in different age populations it has been suggested that resistance training may blunt the age-related decline in resting metabolic rate.

It has been found that the effects of exercise on metabolic rate and energy expenditure are not limited to the time of the activity but may elevate metabolic rate for several hours after exercise. This extension of energy expenditure after exercise is called the post-exercise oxygen consumption (EPOC).

The present study will allow us to compare the energy expenditure that results from aerobic versus resistance exercise in younger and older men. This information will help us to determine which mode of exercise is more effective in expending calories both during and after exercise. By comparing the younger and older adults we will also be able to investigate the effect age may have on energy metabolism during and post-exercise.

The possible benefits provided to you through participation in this study include knowledge of your cardiovascular fitness level and an indication of the amount of energy you expend during different types of exercise. However, these benefits are not guaranteed.

The procedure will require three visits. The first visit, to establish, baseline data will last about one hour. The next two, for experimental data, will take all day – eight AM to three PM. The visits must be at least 2 days apart.

During the first visit, we will weigh and measure you, and introduce you to the apparatus used to measure metabolism during rest and exercise. You will then be shown how to use the exercise equipment. A cardiovascular fitness test will be completed to measure your maximal oxygen consumption. This test will be conducted on a stationary bicycle following a five-minute warm-up. The resistance on the bicycle will be increased every two minutes for the remainder of the test, which will make you work a little harder at each interval. The complete test will last approximately 10-12 minutes. Another test will be completed to evaluate your maximal strength. All strength testing will occur after the completion of a warm-up on a cycle ergometer and stretching exercises. Strength (maximal power) will be measured using a maximal one-repetition free weight lift, defined as the maximal amount of weight that can be lifted successfully one time only. The muscular strength tests will be conducted on the leg press and leg (knee extension) machines which utilize similar muscles

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to cycling. Following instruction as to the proper way to complete the exercise, you will be asked to lift progressively heavier weights until you reach a weight that you are not able to lift successfully. This value will be used to calculate the loads for treatment protocol.

On the second visit you will complete one exercise condition, either aerobic or resistance. You will then rest for the next six hours, with repeat resting metabolic rate measurements, to describe your energy expenditure, taken immediately after exercise, and at various time intervals (i.e. every half hour for the first 2 hours, and then once an hour for the remaining four hours). The resting metabolic rate test requires you to lie on a bed during this measurement. A ventilated hood will be placed over your head, through which you will naturally inhale room air and exhale into the hood. Between measurements, activity is limited to resting, reading, studying, or watching television.

The third visit is essentially the same as the second, except that if you were randomized to aerobic for the second visit, you will do the resistance exercise on the third visit, and vice versa.

This experiment involves minimal risk with no anticipated side effects since you are already accustomed to this level of moderate exercise. However, you may experience some muscle soreness as a result of the exercise protocol.

You will be excluded from this study if you do not have a high fitness score (based on your VO_2max test) or have any joint problems that interfere with the exercise protocol, or are found to have cardiovascular disease, diabetes, or any other cardiovascular, respiratory or endocrinological diseases that may require the use of prescribed medication and may affect energy expenditure. You will also be excluded if you are currently smoking.

You are free to withdraw from the study at any time without fear that withdrawal might affect your health care or access to any public services. If you are a student at the University, withdrawal will not affect your academic status in any way.

All information about you gathered during this study will be kept in securely locked storage, accessible only to the investigators. Publication of the results will be in scientific publication. Articles will not refer to identifiable individual subjects but rather reported as a group mean.

Should any questions arise in regard to this research study, please contact the principal investigator, Kristina Campbell at 934-7296 or her advisor Dr. Karen Chad at 966-6511.

The researchers involved in the project will advise you if new information comes to attention of the Investigators, which might have a bearing on your wish to continue in the study.

You will receive feedback throughout your participation in the study. In addition at the conclusion of the study, you will receive a copy of your own individual results as well as copy of any potential publications arising from this research study.

If you require clarification concerning the ethical aspects of your participation in this study, you may contact the Office of Research Services, University of Saskatchewan at (306) 966-4053.

I agree to participate in the study as described and the contents of the consent document have been explained to me. I understand the contents of the consent. I have received a copy of the consent for my records.

Subject: _____   _____
                    Print   Signature

Witness: _____   _____
                    Print   Signature

Researcher: _____   _____

                    Print   Signature

APPENDIX D

Certificate of Approval

Certificate of Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	Bio#
Karen Chad (K. Campbell)	College of Kinesiology	02-456

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT

College of Kinesiology
R.J. Williams Building
University of Saskatchewan

SPONSORING AGENCIES

Unfunded

TITLE:

Effect of Resistance and Aerobic Exercise on Energy Expenditure in Younger and Older Men

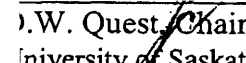| ORIGINAL APPROVAL DATE	CURRENT EXPIRY DATE	APPROVAL OF
June 14, 2002	June 1, 2003	Protocol and consent form as revised 12 June 02

CERTIFICATION

The University of Saskatchewan Biomedical Research Ethics Board (Bio-REB) has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to governing law. This Certificate of Approval is valid for the above time period provided there is no change in experimental procedures.

ONGOING REVIEW REQUIREMENTS / REB ATTESTATION

In order to receive annual renewal, a status report must be submitted to the Chair for Committee consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: http://www.usask.ca/research/ethics.shtml. In respect to clinical trials, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

APPROVED.

D.W. Quest, Chair
University of Saskatchewan
Biomedical Research Ethics Board

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APPENDIX E

PAR-Q and PARMED-X Questionnaires

APPENDIX F
ANOVA of Baseline Physical Characteristics between Groups

One-way ANOVAs - Physical Characteristics

AGE

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	8587.265	1	8587.265	1049.067	1.01E-16	4.451323
Within Groups	139.1556	17	8.185621			
Total	8726.421	18				

HEIGHT

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	9.883041	1	9.883041	0.282742	0.60179	4.451323
Within Groups	594.2222	17	34.95425			
Total	604.1053	18				

WEIGHT

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	35.70667	1	35.70667	0.37058	0.550737	4.451323
Within Groups	1638.011	17	96.3536			
Total	1673.718	18				

BMI

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	1.057495	1	1.057495	0.1754	0.6806	4.451323
Within Groups	102.4938	17	6.029045			
Total	103.5513	18				

VO$_2$max

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	476.1084	1	476.1084	14.92439	0.001247	4.451323
Within Groups	542.3232	17	31.90137			
Total	1018.432	18				

1-RM Leg Press

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	28044.23	1	28044.23	16.51643	0.000807	4.451323
Within Groups	28865.3	17	1697.959			
Total	56909.53	18				

1-RM Leg (Knee) Extension

ANOVA

Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	6273.087	1	6273.087	62.17184	4.44E-07	4.451323
Within Groups	1715.286	17	100.8992			
Total	7988.373	18				

APPENDIX G
Individual 1-RM values for all younger and older subjects

Individual 1-RM values for Older Men

Subject #	Leg press 1 RM (kg)	Leg Extension 1RM (kg)
20	173	66
21	145	43
22	166	73
23	186	68
24	195	86
25	155	77
26	164	64
27	136	61
28	182	82
29	173	57
Mean	168	68
SD	18	13

Individual 1-RM values for Younger Men

Subject #	Leg press 1 RM (kg)	Leg Extension 1RM (kg)
10	214	97
11	336	153
12	132	60
14	220	100
15	225	102
16	268	122
17	286	130
18	255	116
19	264	120
Mean	244	111
SD	57	26

APPENDIX H

ANOVA of Reproducibility of Baseline Measures

One -way ANOVAs- Baseline Reproducibility

VO$_2$

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.193607	3	0.0645357	0.2808914	0.8388036	2.8826008
Within Groups	7.8116068	34	0.2297531			
Total	8.0052138	37				

Respiratory Exchange Ratio

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.000184	3	6.134E-05	0.2194545	0.8822133	2.8826008
Within Groups	0.0095036	34	0.0002795			
Total	0.0096876	37				