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Original Article

Improvement of Muscle Endurance in Men with Low Activity Levels After Above Anaerobic Threshold Exercise Intensity

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Abstract

Background : Low level of physical activity can reduce physical fitness. Aerobic training can improve physical fitness. A precise aerobic training based on anaerobic threshold (AT) is recommended by American College of Sports Medicine (ACSM) whenever possible.

Methods : This was a randomized-single blinded control trial including 24 male subjects with low level of physical activity in Kariadi hospital during December 2023 until February 2024. It was randomized with a sealed envelope. Subjects were allocated in 2 groups (above AT and below AT). Physical performance was measured using SPPB score and muscle endurance that was presented using total repetition of 1RM of knee flexor muscle.

Results : There was no significant difference between two groups for total SPPB score (p=0.053). There was a significant difference of muscle endurance between two groups (p=0.010) with the above AT group resulting in higher improvements of muscle endurance (12.00 ± 5.71 vs. 6.67 ± 3.26).

Conclusion : Aerobic exercise with intensity based on AT did not show significant differences in total SPPB score. However, aerobic exercise above AT showed a better improvement of muscle endurance in healthy adult men with low levels of physical activity.

Keywords : anaerobic threshold, SPPB, endurance

INTRODUCTION

Sedentary lifestyle is a recognized risk factor for adverse cardiovascular events and multiple cardiometabolic comorbidities, and contemporary guidance emphasizes that exercise prescriptions should account for individual variability rather than rely solely on generic recommendations.[1,2] The American College of Sports Medicine (ACSM) exercise guidelines recommend aerobic exercise in these conditions, but are still considered to fail to consider wide variations, so the ACSM stresses that exercise programs should be modified based on an individual's specific health status, physical function, exercise response, and personal goals.[3] Exercise intensity is typically prescribed based on percentages of HRreserve, HRmax, VO2max, or VO2reserve. However, such prescriptions may be imprecise due to wide variability, potentially leading individuals to train at inappropriate intensitieseither failing to achieve desired physiological benefits or increasing the risk of orthopedic or cardiovascular injury.[4]

Aerobic activities such as walking, jogging, structured aerobics, swimming, and cycling are consistently recommended to improve cardiorespiratory fitness, and when performed regularly they enhance oxygen delivery and utilization by working muscles, thereby increasing aerobic capacity and functional performance. In patients with cardiovascular disease, such structured training within cardiac rehabilitation programs yields clinically meaningful benefits, but the magnitude of benefit depends on the precision of exercise intensity prescription and periodic reassessment.[5,6]

Cardiorespiratory exercise testing (CPET) is widely regarded as the most appropriate tool for individualized exercise prescription because it integrates ventilatory, cardiovascular, and metabolic responses to determine thresholds and capacities that are directly actionable for training.[7] CPET is a device that combines measurements of gas exchange, including oxygen uptake (VO2) and exhaled carbon dioxide (VCO2), with traditional exercise testing parameters such as electrocardiogram (ECG), blood pressure and peripheral oxygen saturation (SpO2), thus providing an integrative assessment of exercise response involving the pulmonary, cardiovascular, hematopoietic, neuropsychological, and musculoskeletal systems, which is not adequately reflected through measurements of individual organ system function. In fact, CPET is indicated for prescribing exercise in cardiac/pulmonary rehabilitation, CVD, pulmonary disease and as the gold standard for prescribing exercise.[8]

During exercise testing with CPET, objective assessment of Anaerobic threshold (AT) measurements is used to determine the effort made by the training subject.[9] AT is the point at which muscle O2 demand exceeds the ability of the cardiorespiratory system to supply O2. The use of AT in prescribing exercise should be more viable so that it will avoid limitations on maximal exercise testing, and can further show quantitatively the response to an exercise more accurately and is expected to ultimately improve a person's physical performance.[10–12] This approach helps bridge the gap between evidence and practice in cardiovascular rehabilitation, supporting personalized training zones that improve adherence, safety, and outcomes across cardiometabolic conditions.[7] Exercise prescription based on the anaerobic threshold (AT) obtained from cardiopulmonary exercise testing (CPET) is objective and cannot be determined solely by symptoms or signs during exercise. This method has the potential to resolve issues of under- or over-prescription of exercise intensity. It has also been recommended by the American College of Sports Medicine (ACSM) to provide beneficial physiological outcomes, reduce injury risk, and improve exercise adherence. The use of AT in exercise prescription should allow for a more accurate quantitative assessment of exercise response.[13,14]

Cardiopulmonary exercise testing (CPET) is typically performed using a cycle ergometer or treadmill. The cycle ergometer is generally safer, more suitable for a wide range of patients, allows for a more comfortable procedure, and provides accurate measurements of external work rate. The treadmill enables subjects to walk or run at controlled speeds and inclines, activates more muscle groups, induces greater oxygen desaturation, and results in higher peak oxygen uptake. In most clinical settings, the cycle ergometer is the preferred modality; however, depending on the purpose of the CPET, treadmill ergometry may be a more appropriate alternative. Another advantage of using a treadmill is that, unlike cycling, walking and running are common daily activities. Therefore, this study uses a treadmill.[15]

Currently, there are only 5 centers in Central Java that have CPET; namely Dr. Kariadi General Hospital Semarang, UNS Surakarta Hospital, Dr. Soeharso Surakarta Hospital, Moewardi Surakarta Hospital, and Semarang State University. With all the advantages of CPET, it is expected that its use can support excellent cardiac and pulmonary rehabilitation services at Dr. Kariadi General Hospital Semarang. In addition, by providing appropriate exercise prescriptions, it is expected that promotive and preventive aspects for sedentary individuals can be achieved.

METHODS

This study was a randomized single blinded control trial that included 24 male subjects with low level of physical activity in Kariadi hospital during December 2023 until February 2024. Subjects criteria were male around 25 – 35 years old, with manual muscle strength grade 5 using MRC grading scale, have low level of PA based on

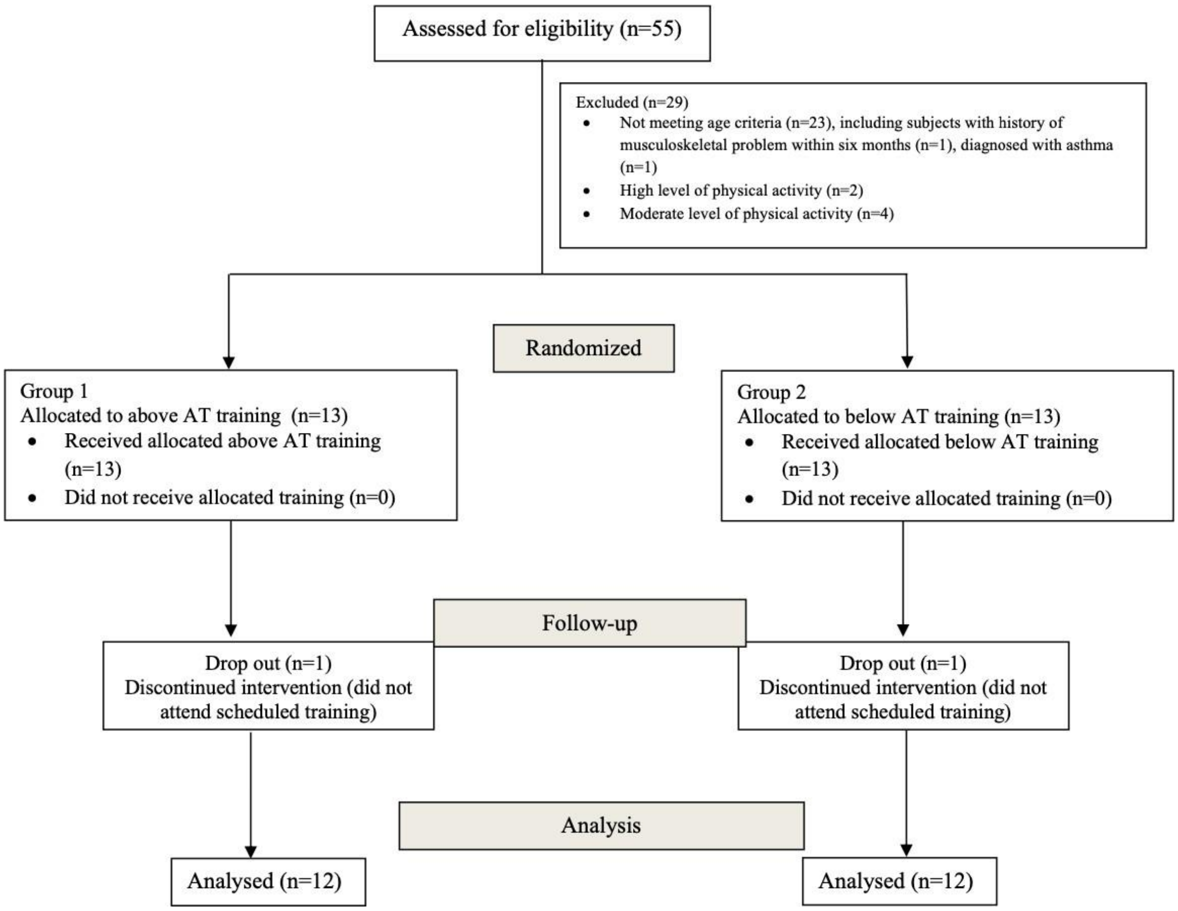

Figure 1. Enrollment based on CONSORT diagram

International Physical Activity Questionnaire Short Form (IPAQ- SF), no history of metabolic disease, cardiorespiratory disorder and history of recent neuromusculoskeletal problem (less than 6 months). Any subject meeting the criteria was given informed consent and familiarized with CPET. All of the subjects were then randomized with sealed envelope. Subjects were allocated in 2 groups (above anaerobic threshold and below anaerobic threshold). Exercise prescription based on the anaerobic threshold (AT) allows training to be individualized. Some studies suggest that when the respiratory compensation point (RCP) cannot be determined, exercise intensity can be prescribed at 20% above the AT. Other research involving healthy sedentary individuals has categorized AT-based prescriptions into groups above, below, and near the AT. Baseline data from these studies indicate that the "near AT" group typically trains within ±10% of the AT. Therefore, in this study, the training range was set between 10% and 20% above the AT.[14,16,17]

All the eligible subjects were evaluated for physical performance, lower muscle endurance, and CPET (to decide the AT for intensity prescription) before intervention. Both groups were given aerobic exercise training based on the AT from the CPET. First groups were given exercise with the range 10–20% above AT. Second group were trained with the range 20–10% below AT. The assessment of physical performance by using SPPB was obtained using the balance function, 5x chair stand, and 4- meter walking.[18] The balance function data had a range of scores 0 to 4. The 4-meter walking data had a score range of 1–4 points (score 1 if > 8.7 seconds, 2 if 6.21–8.7 seconds, 3 if 4.82–6.2 seconds, 4 if <4.82 seconds). The 5 times chair stand test had a range of score from 0–4 points (point 4 if the time data obtained was <11.19 seconds, point 3 if it was 11.2–13.69 seconds, point 2 if it was 13.7–16.69 seconds, 1 if it was >16.7 seconds, and 0, if it was >60 seconds). Thus, the highest SPPB score was 12 and the lowest was 0. The lower extremity endurance was presented as total repetition of 1-RM which could be performed by subjects for dominant knee flexor based on subject preferences.[19,20] It was measured by entree. The SPPB and lower endurance measurement were done before intervention and after 4 weeks intervention. The diagram consort was shown at Figure 1. All data were analyzed descriptively and analytically.

RESULTS

From the 26 subjects involved, all of them were active residents at varying levels from the Physical Medicine and Rehabilitation study program (38.5%), Surgery (3.85%), Neurosurgery (7.7%), Internal Medicine (11.5%), Neurology (11.5%), Microbiology (3.85%), Cardiology (7.7%), Ophthalmology (3.85%), Anatomical Pathology (3.85 %), and Clinical Nutrition (7.7%). The subjects were divided into two groups, namely the training group above AT and the training group below AT. Both groups received exercise with the same frequency, in which 3 times a week intervention for 4 weeks was given. The pre-intervention of SPPB and 1-RM muscle endurance was carried out 1 day before the intervention and post-intervention assessment was carried out 1 day after the last intervention. There were no complications, either musculoskeletal or cardiorespiratory injuries, during the study. Until the end of the study, the data analyzed was 24 subjects. The data was input into sample codes in SPSS ver.26 app for Windows. Characteristic distribution for IPAQ score was analyzed using the Mann-Whitney test, while the others using the independent-t test. The comparison of exercise intensity on total SPPB score was analyzed using the Mann-Whitney test, and the independent-t test on muscle endurance. Demographic and clinical characteristics of research subjects in both

TABLE 1
Characteristic distribution of all subjects

Variable	Groups		*p* value
	Above AT	Below AT	
IPAQ Score	520.25 ± 72.68	447.50 ± 122.28	0.192‡
Age	31.17 ± 2.44	31.33 ± 2.06	0.858§
Body weight (BW)	70.06 ± 5.21	74.00 ± 6.76	0.245§
Body Height (BH)	170.75 ± 3.08	170.08 ± 4.06	0.655§
BMI	24.37 ± 1.67	25.59 ± 2.27	0.150§

‡Mann-Whitney; §Independent-t

TABLE 2
Absolute changes with training for below AT group in total SPPB score, balance score, gait speed, chair stand test, and muscle endurance

Variable	Groups		*p*
	Above AT	Below AT	
Total SPPB score			
Baseline	520.25 ± 72.68	447.50 ± 122.28	0.192‡
After training	31.17 ± 2.44	31.33 ± 2.06	0.858§
p	70.06 ± 5.21	74.00 ± 6.76	0.245§
Delta	170.75 ± 3.08	170.08 ± 4.06	0.655§
Muscle endurance			
Baseline	9.67 ± 10.44	8.33 ± 6.24	0.908‡
After training	21.67 ± 11.69	15.00 ± 7.53	0.111§
p	<0.001¶*	<0.001¶*	
Delta	12.00 ± 5.71	6.67 ± 3.26	0.010§*

‡Mann-Whitney; †Wilcoxon, ¶Paired t, §Independent t

groups are shown in Table 1. The comparison of baseline and after training in above AT and below AT groups were presented in Table 2.

DISCUSSION

Based on the data in Table 1, the characteristics of the subjects in both groups were not significantly different. It showed that the characteristics of the study subjects in both groups were homogeneous. Of all candidate subjects (n = 55 subjects) without considering inclusion or exclusion criteria, 49% had low levels of physical activity. Our finding was almost similar with other study in Malaysia using the same instrument which found that 41.4% of students ranging from 18–25 years old had low levels of physical activity.[21] Other studies also shown that around 40% and 45.6% of health professionals tend to have low levels of physical activity in Africa and Malaysia. A cohort study in the UK showed that 25–34 years old respondents had the highest proportion (45%) of low levels physical activity.[22,23] The reasons why the health professionals in this age group have low levels of physical activity were due to lack of free time, long working hours and negligence.[24,25] Other study assume that young doctors are very busy because related to financial building issue and social life that cause them have little time to exercise.[26]

The sample in this study comprised individuals whose body mass index (BMI) ranged from normal to overweight according to WHO criteria.[27] The distribution of BMI and other anthropometric measures (body weight and height) did not differ statistically between the two groups, indicating homogeneity at baseline and reducing the likelihood that differences in body size confounded the observed effects of the intervention. This is inferred that the exercise intervention effects on functional outcomes were unlikely to be driven by baseline differences in body composition or somatic size; nevertheless, this study did not perform formal statistical analyses of the relationships between BMI or other anthropometrics and outcomes such as SPPB or muscle endurance. A recent study has examined associations between anthropometric characteristics and muscle endurance or performance tests, highlighting that body composition and segmental anthropometrics can influence strength and endurance measures and the interpretation of functional tests like the SPPB, but findings vary by age, sex, and activity level and underscore the need for population specific analyses.[28] To the best of our knowledge, there remains limited published data specifically addressing how BMI or simple anthropometric measures affect SPPB scores and knee flexor 1 RM endurance outcomes in young male individuals with low physical activity, which supports the rationale for reporting our results while acknowledging this gap for future targeted investigation. Although the Short Physical Performance Battery (SPPB) was originally developed and remains most widely validated for identifying mobility limitations and predicting adverse outcomes in older adults, interest has grown in applying the SPPB to younger and clinical populations to explore how sedentary behavior and disease processes influence functional performance across the lifespan.[29]

In general, the effect of exercise on SPPB scores had been studied in the elderly, with few studies correlates the relationship of SPPB to younger ages, especially young sedentary. One study used the SPPB to evaluate the associations with sedentary activity in multiple sclerosis patients ranging from young to old age. Among young multiple sclerosis patient (20–39 years), the SPPB summary score was associated with sedentary behavior patterns (ρ range between −0.354 and −0.350, $p < 0.05$), but not with volume ($\rho = -0.289$, $p > 0.05$). The SPPB balance, gait, and strength component scores were not associated with volume or sedentary behavior patterns.[30,31]

The Short Physical Performance Battery is a method for assessing physical performance and has been shown to predict fall risk in the elderly. A cross-sectional study with two research groups, namely healthy young adult women aged 19–23 years and healthy elderly women aged 59-66 years showed that the total score of the SPPB test for young adults was 10,950 ± 0.959 and for the elderly 9,225 ± 1,310 (p = 0.000). In that study, the correlation test between age and the 4-m walking test was weakly correlated r = 0.367 (p = 0.001), with the chair stand test was weakly correlated r = 0.494 (p = 0.000), and with the total score of the SPPB test was strongly correlated r = -0.557 (p = 0.000). It showed that aging causes a decrease in muscle mass and strength as seen from a decrease in physical performance through the SPPB test.[32] Our study showed no correlation between aerobic treadmill training in both above and below AT with total SPPB score. This could be because the samples in our study who were young sedentary had initial SPPB scores that were already high and normal so that an increase in SPPB score could no longer be observed (ceiling effect). These observations are reinforced by recent population and intervention studies showing that task□specific, higher□resolution functional tests or instrumented gait and balance measures are often more needed to detect change in younger, higher□performing groups.[33]

Exercise prescription based on the anaerobic threshold (AT) emphasizes peripheral vascularization and the recruitment of active muscle groups to maintain a steady-state aerobic metabolism. The AT represents a physiological tipping point where the body transitions from purely aerobic energy production to a mix of aerobic and anaerobic metabolism. Training at or just below this threshold allows the body to operate efficiently, with minimal lactate accumulation, while maximizing oxygen delivery and utilization in the working muscles. From a physiological standpoint, this training intensity stimulates adaptations in the peripheral musculature, particularly in the capillary networks and mitochondrial density. These adaptations enhance the muscles' ability to extract and utilize oxygen, which is essential for sustaining prolonged aerobic activity without fatigue. The concept of steady-state metabolism refers to a condition where oxygen supply meets the metabolic demands of the muscles, allowing for a stable internal environment during exercise. Peripheral adaptations, such as increased capillarization and improved oxidative enzyme activity, are critical for maintaining steady-state aerobic metabolism during submaximal exercise intensities. These changes acts in optimizing oxygen delivery to impaired or deconditioned muscles. Exercising based on anaerobic threshold enhances the muscles' metabolic flexibility, allowing for more efficient energy production and reduced reliance on anaerobic glycolysis. This metabolic efficiency is directly linked to improved endurance and reduced fatigue, especially in clinical populations with compromised cardiovascular or muscular function.[34]

The exercise-induced adaptation in skeletal muscle fibers is specific to the type of exercise stimulus i.e., endurance exercise. The adaptation is the result of an increase in the number of specific proteins (calcineurin, CaMK, AMPK, p38, and NFκB). These proteins result in activation of PGC-1α. All of the signaling pattern results in fast-to-slow fiber type shift, synthesis of antioxidant enzymes, and mitochondrial biogenesis. Increased mitochondria number decreases lactate and ion hydrogen formation to maintain the blood pH. Aerobic exercise increases endogenous antioxidants in trained muscles which protects muscle fibers against free-radical mediated damage and fatigue during prolonged exercise. The regular exercise results in less disruption of the blood pH during submaximal work as muscles produce less lactate and hydrogen ions.[35–39] No previous study is yet to show this fatigue tolerance as muscle endurance which is measured by maximum repetition.

However, our study has some limitations such as small sample size that result in no control subject without intervention in this study. Moreover, blinding could not be implemented to all subjects since they were medical professionals who previously have a prior knowledge about exercise training. The last, physical performance measurement using the SPPB score may not be appropriate for young subjects with previously high performance.

Besides all the limitations mentioned, this research offers a new perspective because there has been no previous empirical study that provides new information related to a more precise prescription such as CPET. The aerobic exercise with precise prescription above each individual AT results in a better muscle endurance outcome in adult men with low levels of physical activity, acting as a promotive and preventive effort for diseases caused by sedentary life. Until now, there has been no previous research that specifically examined the clinical outcomes of precision prescriptions on muscle endurance, so this study has significant novelty value.

This research highlights a foundational gap in precision exercise prescription using CPET for improving muscle endurance, especially regarding peripheral adaptations. It may represent emerging information about improvement of muscle endurance through precision aerobic exercise prescription using CPET, which is expected to be both effective and safe. Most of exercise protocols based on AT are studied primarily from a systemic perspective. There is lack of study concerning peripheral muscle endurance adaptation. That kind of study will provide data about understanding local muscle fatigue, recruitment patterns, and oxygen utilization, which are directly linked to endurance capacity.

This research encourages further study to close a gap which is a notable absence of research applying aerobic capacity assessments to samples with musculoskeletal or neurological impairments. These populations often present with specific conditions, making it imperative to tailor exercise prescriptions based on objective physiological data. The use of CPET in these groups could offer a more accurate and individualized approach to rehabilitation, enhancing safety and efficacy.

The ideas presented in this study are expected to serve as a foundation for future research. It would allow for the development of protocols that are both physiologically sound and functionally relevant, ultimately improving patient outcomes. Researchers and clinicians can develop more refined and targeted exercise prescriptions which can be ensured as effective and safe.

CONCLUSION

Aerobic exercise with intensity based on AT did not show significant differences in total SPPB score. However, aerobic exercise above AT showed a better improvement of muscle endurance in healthy adult men with low levels of physical activity.

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CONFLICT OF INTEREST

There is no conflict of interest regarding this manuscript.

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