ARC Journal of Research in Sports Medicine
Volume 1, Issue 1, 2016, PP 4-8
www.arcjournals.org

What Maintains Total Energy Release at Peak Anaerobic Effort in Young and Old Men?

Moran Saghiv [a], Michael Sagiv [b], Ben Sira D [b], Goldhammer E [c]

[a]Exercise Science Department, University of Mary, North Dakota, USA
[b]Sports Medicine & Rehabilitation Division the Zinman College of Physical Education and Sport Sciences Wingate, Israel 42902
[c]Heart Institute Bnai-Zion Haifa Medical Center, Technion, Israel
mssaghiv@marry.edu

Running head: Aerobic input to anaerobic bout in aged.

Abstract: *This study was designed to estimate the relative contribution of the aerobic pathway during the Wingate Anaerobic Test in fourteen young men (25.0± 1.0 years) and fourteen older healthy men (57.0± 2.0 years). Indirect measure of the anaerobic energy release was compared with a direct value obtained from measured oxygen uptake. Results: At rest, significant (P< 0.05) differences were noted between the groups in heart rate, diastolic and mean arterial blood pressure. At peak exercise, five elderly experiencing ECG abnormality, significant (P< 0.05) differences were noted between elderly and young in: heart rate, diastolic and mean arterial blood pressures, oxygen uptake (0.9±0.2 and 1.6±0.3 L•min^{-1} / 2 respectively), peak power output (2.0±0.7 and 4.3±1.1 L•min^{-1} / 2 respectively) and lactic acid (8.5±0.7 and 12.6±1.1 mmol•L^{-1} respectively). Conclusions: Although the absolute contribution of oxygen pathway during the Wingate Anaerobic Test was larger in the young than old, yet, these results show that the aerobic process contribute significantly during intense exercise lasting 30 s in elderly as in young. In addition, it may suggest of the existence of an inherent characteristic of the interplay between aerobic and anaerobic pathways during exercise within the reduced exercise tolerance due to aging limitations.*

Keywords: *Aging, oxygen uptake, power output, Wingate Anaerobic Test.*

1. Introduction

Aerobic pathway capacity is reduced in older subject compared to young once, thus, maximal energy provided at peak endurance exercise is limited (1). Anaerobic metabolic pathways have received less attention in old subjects: anaerobic energetic release during exercise has not been evaluated previously. Therefore, no data are available on anaerobic energetic yield during all out strenuous exercise. More importantly, evaluation of maximal performance of both aerobic and anaerobic pathways may enable to calculate the aerobic/anaerobic relative contribution to total energy release at peak Wingate Anaerobic Test (2,3).

Maximal rate of anaerobic energy release is characterized by exposing the subjects to a very high degree of all-out strenuous exercise. It has been assumed that this type of activity is potentially dangerous for the older population, due to hypoxia and a seemingly inappropriate blood pressure response (4, 5).That, in addition to the effect of placing a large metabolic load on the aged skeletal muscles. As a consequence, it may alter the interplay between the different energy pathways and hence, ATP production.

The Wingate Anaerobic Test exposes the subjects to a very high degree of sudden strenuous all-out exercise (6). In young healthy subjects a significant percentage of the energy provided during the Wingate Anaerobic Test is aerobically derived and is not accounted for when quantifying anaerobic capacity as the total work performed (7). Therefore, the purpose of this study was to evaluate the effect of aging on the relative contribution of the energy systems with particular emphasis on the role of the aerobic pathway in old males during the Wingate Anaerobic Test.

2. Materials and Methodology

Subjects: Twenty eight well trained healthy males volunteered for this study. They were divided into two groups: 14 young men (25±1 yrs) and 14 older men (57±2 yrs). Subjects were in good health, aerobically active (4 times•wk-^{1}) for at least 18 months. A written informed consent was obtained from each subject, which was approved by the Clinical Science Center Committee on Human Subjects.

Procedure and Measurements: Subjects reported 3 times to the laboratory. The 1st session was devoted to accustoming the subjects to the study's procedures and equipments. During the 2nd session, subjects were judged free of coronary artery disease by clinical history, absence of major risk factors and by normal graded exercise stress test to peak oxygen uptake.

Following warm up, subjects underwent a graded maximal bicycle exercise test on a mechanical weight-adjusted Monark cycle-ergometer (Model 818). Maximal tests were terminated by the following criteria: a) leveling off or no further increase in VO_2 with increasing work rate, b) attainment of the age predicted maximum heart rate, c) respiratory exchange ratio > 1.1, and d) when the subject could not keep up with the load, according to the guidelines of the American College of Sports Medicine (8).

During the 3rd session, following warm-up, subjects performed the 30 seconds all-out Wingate Anaerobic Test (9), utilizing a weight-adjusted Monark cycle-ergometer (Model 864). The subjects were seated on the ergometer with their feet fastened to the pedals by means of racing-type toe-clips, and seat height was adjusted. The Wingate Anaerobic Test consisted of 30 seconds supramaximal pedaling against a resistance determined relative to the subject's body mass at $80 g \cdot kg^{-1}$ for the young group (9), and a lower resistance of $40 g \cdot kg^{-1}$ body weight for the older group (6). Subjects commenced cranking as fast as they could against the ergometer's inertial resistance only. The full, predetermined resistance load was applied within 3-4 seconds once the inertial resistance had been overcome. Pedal revolution count started at that instant by means of an electro-mechanical counter and subjects maintained an all-out effort throughout the test. Strong verbal encouragement was given to ensure maximal effort. Tests were performed at the same time of the day in order to avoid diurnal variations.

During the 2nd and 3rd sessions, oxygen uptake was determined breath by breath utilizing the Medical Graphics (St. Paul, MN) metabolic cart. The metabolic cart was calibrated before each test with known primary standard quality gases. Heart rate and electrocardiogram were monitored continuously, using a Burdick Eclipse 400 3-channel, 12-lead ECG recorder system, and oscilloscope. Five-second recordings were obtained at rest and at peak exercise. Blood pressure was taken using a standard sphygmomanometer cuff and mercury manometer mounted at eye level, in the sitting position at rest and at peak exercise.

Calculations:

Peak power output (P) in $L \cdot min^{-1}$ for 30 seconds was calculated as follow:

$P(L \cdot min^{-1}) = [(D \cdot kg \cdot 2\ mL0_2) + VO_{2rest}] / 2$

Whereas: D = distance (rpm • 6m); kg = pedaling resistance; $2mL0_2$ = energy cost per pedal revolution, VO_2 = oxygen uptake.

Aerobic energy portion (%) = VO_2 ($L \cdot min^{-1}$) divided by P ($L \cdot min^{-1}$).

fatigue index was calculated as the absolute difference between the highest and the lowest work rate expressed as a percent of the highest work rate.

Mean arterial blood pressure = [(systolic pressure - diastolic pressure)/3 + diastolic pressure).

Lactic acid concentration: A 25 μ fingertip blood sample was taken at rest and during the 2nd minute post exercise for the determination of lactic acid concentration at peak anaerobic effort. The sample was immediately transferred to a micro-tube containing 100 μ of 7% perchloric acid. The tubes were centrifuged after standing for at least 1 hour. Twenty microliter aliquots of the supernatant were subsequently used for lactic acid analysis on the Analox LM3 analyzer (Analox Instruments, England; Reagent Kit No. GMRD-071).

Statistical methods: One-way ANOVA with repeated measures was employed for each of the variables measured in order to detect variations in the experimental parameters. In addition, the Students Newman-Keuls procedure was used for specific Post-Hoc comparisons.

3. RESULTS

Young subjects completed the exercise challenges without difficulties or abnormal symptoms. In the elderly group, five subjects experienced ECG abnormality (e.g. 1.7±0.2 mm S-T segment depression). Mean descriptive data are presented in table 1

Physiological responses at rest and during the Wingate Anaerobic Test are presented in table 2. At rest, significant ($P < 0.05$) differences were noted between the groups with regard to heart rate, diastolic blood pressure and mean arterial blood pressure. At peak exercise, significant ($P < 0.05$) differences were noted between the groups with regard to heart rate, diastolic blood pressure, mean arterial blood pressure, oxygen uptake, rpm achieved in 30 seconds of testing, peak power output and lactic acid.

Table1. *Subjects' physical characteristics, echocardiographic and hemodynamic measurement at rest (mean ± S.D.)*

Variable	Elder	Young.
N of subjects	14	14
Age (years)	57.0± 2.0	25.0± 1.0
Weight (kg)	72.1 ± 3	70.4 ± 3
Height (cm)	177.0±2.0	180.0±2.0

Table2. *Physiological responses measured at peak Wingate anaerobic tests (mean + SD)*

	YOUNG		ELDERLY	
VARIABLE	REST	EXERCISE	REST	EXERCISE
VO2 ($L•min^{-1}/2$)	0.25±0.1	1.6±0.3	0.26±0.1	0.7±0.2†
VO2/P (%)	--------	40.0±5.2	---------	33.1±4.1
P($L•min^{-1}/2$)	---------	4.0±0.7	---------	2.1±0.5†
RPM	---------	55.0±4.1	---------	53.7±4.4
HR ($beats·min^{-1}$)	68.7±9.3	187.2±8.1	81.3±8.2*	156.3±7.4†
SBP (mmHg)	112.2±7.9	198.1±10.6	119±7	187±13
DBP (mmHg)	76.1±10.0	96.7±9.8	84.0±7.3*	84.0±9.1†
MABP (mmHg)	88.1±9.1	130.5±11.2	95.7.1±6.6*	118.3±8.2†
LA ($mmol·l-^{1}$)	1.3±0.3	12.6±1.1	1.4±0.3	8.5±0.7†

** = Significant differences between groups at rest (P< 0.05).*

† = Significant differences between groups at peak Wingate Anaerobic Test (P< 0.05).

VO2 = Oxygen uptake, P = Peak power output, RPM = Revolution Per Minute, HR = Heart Rate, SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure, MABP = Mean Arterial Blood Pressure, LA= Lactic Acid, P = Power output.

4. DISCUSSION

This study indicates that at peak anaerobic bout, energy pathway; aerobic and anaerobic responded to the demands of intense exercise in a parallel manner, and that the aerobic system responds fast to these energy demands, thereby playing major role in determining performance over short durations (10). In addition, the magnitude of the energy system response was related to age and not to absolute work-load.

The anaerobic pathways are capable of regenerating ATP at high rates yet are limited by the amount of energy that can be released in a single bout of intense exercise. In contrast, the aerobic system has an enormous capacity yet is somewhat held back in its ability to supply energy rapidly. The duration of maximal exercise at which equal contributions are derived from the anaerobic and aerobic energy systems appears to occur between 1 to 2 minutes and most probably around 75 seconds, a time that is considerably earlier than has traditionally been suggested (11).

All-out Wingate Anaerobic Test is characterized by the attainment of peak power output in the first 5 to 10 seconds followed by a progressively declining power output until either completion of the test or voluntary cessation. Energy supply is given in oxygen equivalents, having been derived from actual measures of VO_2 and calculated energy demand (12).

Although, the young group compared to the older subjects performed at a significantly higher peak power output and absolute VO_2 during the test, an equal fatigue index of 46% was obtained by both groups. This suggests that the older subjects had lower peak rates of ATP resynthesis from the ATP-PCr and glycolytic systems (12). Interestingly, in both groups the final power output is almost directly attributable to the rate of aerobic energy supply, providing clear support for the existence of an anaerobic capacity. In addition, the contribution of the aerobic pathway in the formation of ATP was significantly lower in the elderly compared to the young group (33.1 vs. 40.0 % respectively).

The results for the young group in the present study are in agreement with results reported previously (10). These results show that the contribution of the aerobic pathway is significant during intense exercise lasting 30 to 180 s (13). It seems that in the older men, the observed lower aerobic ability at peak Wingate Anaerobic Test is due, at least partially, to the aged decreased capacity to produce ATP by oxidative phosphorylation owing it to dysfunctional mitochondria. The impairment of mitochondrial function is owed to decreased rates of electron transfer by the selectively diminished activities of the four electron transfer or respiratory complexes (complexes I–IV) (14). In the olds compared to young subjects, Mitochondria do not only produce less ATP, with increase production of reactive oxygen species as by-products of aerobic metabolism in the aging tissues of humans and animals. Moreover, the activities of free radical-scavenging enzymes are altered in the aging process. The concurrent age-related changes of these two systems result in the elevation of oxidative stress in aged tissues (15).

In the present study, ECG abnormalities were observed in five older subjects. This was seen earlier in several studies on the effect of strenuous exercise. It had been shown that strenuous exercise may produce ischemia-like ECG abnormalities in young healthy subjects (16,17). Others (18) have reported normal ECG during sudden strenuous exercise following warm-up. It seems that our five older subjects with ECG abnormalities reached an imbalance stage of myocardial oxygen supply-demand.

5. Conclusions

This study demonstrated the existence of a relative aerobic vs. anaerobic metabolism contribution to total energy release during the 30-s Wingate Anaerobic Test with a larger anaerobic component. Although the absolute contribution of oxygen pathway during the Wingate Anaerobic Test was larger in the young than old yet, these results show that the aerobic process contribute significantly during intense exercise lasting 30 s in elderly as in young. In addition, it may suggest the existence of an inherent characteristic of the interplay between aerobic and anaerobic pathways during exercise within the reduced exercise tolerance due to aging limitations.

References

[1] Betik AC, Hepple RT. Determinants of VO2 max decline with aging: an integrated perspective.Appl Physiol Nutr Metab. 2008; 33:130-140.

[2] Zagatto A, Redkva P, Loures J, Kalva Filho C, Franco V, Kaminagakura E, Papoti M. Anaerobic contribution during maximal anaerobic running test: correlation with maximal accumulated oxygen deficit. Scand J Med Sci Sports. 2011; 21:e222-230.

[3] Li Y, Niessen M, Chen X, Hartmann U. Overestimate of relative aerobic contribution with maximal accumulated oxygen deficit: a review. J Sports Med Phys Fitness. 2015; 55:377-382.

[4] Sagiv M, Goldhammer E, Abinader EG, Rudoy J. Aging and the effect of increased after-load on left ventricular contractile state. Med. Sci. Sports Exerc. 1988; 20:281-284.

[5] Sagiv M, Ben-Sira D, Goldhammer E. Direct vs. indirect blood pressure measurement at peak anaerobic exercise. Int J Sports Med 1999; 20:275-278.

[6] Sagiv M, Ben-Sira D, Sagiv M, Goldhammer E. Left ventricular function at peak all-out anaerobic exercise in older men. Gerontology 2005; 51:122-125.

[7] Friedmann B1, Frese F, Menold E, Bärtsch P. Effects of acute moderate hypoxia on anaerobic capacity in endurance-trained runners. Eur J Appl Physiol. 2007; 101:67-73.

[8] American College of Sports Medicine. 2014. ACSM's Guidelines for Exercise Testing and Prescription, 9th edition, Philadelphia, PA: Lippincott Williams & Wilkins; pp. 145-147 and 165-199.

[9] Dotan R. The Wingate anaerobic test's past and future and the compatibility of mechanically versus electro-magnetically braked cycle-ergometers. Eur J Appl Physiol 2006; 98:113-116.

[10] Layec G, Bringard A, Vilmen C, Micallef JP, Le Fur Y, Perrey S, Cozzone PJ, Bendahan D. Does oxidative capacity affect energy cost? An in vivo MR investigation of skeletal muscle energetics. Eur J Appl Physiol. 2009; 106:229-242.

[11] Medbo JI, Tabata I. Anaerobic energy release in working muscle during 30 s to 3 min of exhausting bicycling. J Appl Physiol 1993; 75:1654-1660; Bangsbo J. Quantification of anaerobic energy production during intense exercise. Med Sci Sports Exerc 1998; 30:47-52.

[12] Noordhof DA, de Koning JJ, Foster C. The maximal accumulated oxygen deficit method: a valid and reliable measure of anaerobic capacity? Sports Med. 2010; 40:285-302.

[13] Medbo JI, Tabata I. Anaerobic energy release in working muscle during 30 s to 3 min of exhausting bicycling. J Appl Physiol 1993; 75:1654-1660.

[14] Navarro A and Boveris A. The mitochondrial energy transduction system and the aging process. Am J Physiol Cell Physiol 2007; 292:C670-686.

[15] Wei YH, Wu SB, Ma YS, Lee HC. Respiratory function decline and DNA mutation in mitochondria, oxidative stress and altered gene expression during aging. Chang Gung Med J. 2009; 32:113-132.

[16] Homans DC, Laxson DD, Sublett E, Pavek T, Crampton M. Effect of exercise intensity and duration on regional function during and after exercise-induced ischemia. Circulation. 1991; 83:2029-2037.

[17] Baur DM, Leiba A, Christophi CA, Kales SN. Low fitness is associated with exercise abnormalities among asymptomatic firefighters. Occup Med (Lond). 2012; 62:566-569.

[18] Sagiv M, Ben-Sira D, Goldhammer E and Soudry M. Left ventricular contractility and function at peak aerobic and anaerobic exercises. Med Sci Sports Exerc 2000; 32:1197-1201.