Analysis of resting metabolic rate and body composition in elderly males before and after six months of endurance exercise

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ABSTRACT

The aim of this study was to compare basal metabolic rate and body composition before and after an endurance-type physical fitness program. The study involved 46 sedentary aging males, aged 60-75 (66.97 ± 4.80 years), who were randomly allocated to two groups: 1) control group, which was asked not to change their daily routine or join a regular physical fitness program; and 2) experimental group, who took part in an aerobic fitness program consisting of working on cycle ergometer three times a week (60 minutes) on alternate days for six months, at heart rate corresponding to ventilatory threshold 1 (VT-1) intensity. Subjects were submitted to measurement of body composition (DEXA); indirect calorimetry, blood analysis and ergospirometric testing. After the study period, the authors found a significant decrease in thyroid hormones as well as basal metabolism changes in both groups, but no changes in body composition. The experimental group, however, showed a significant increase in peak oxygen uptake and workload at VT-1 intensity. The data suggest that although an aerobic exercise program at VT-1 intensity is not enough to alter the basal metabolism and body composition of healthy seniors, it does lead to cardiovascular benefits.

Key words: Basal metabolic rate. Seniors. Body composition. Endurance exercise.

INTRODUCTION

All living organisms spend energy attempting to maintain cellular homeostasis. Everyday energy consumption in humans may be divided into three parts: the energy consumed at rest accounts for 60-75% of the total daily energy expenditure, the thermal effect of food (10%) and the physical activity (15-30%)[1].

The basal metabolic rate (BMR) measures the minimum amount of energy required to maintain physiological functions at rest[2,3]. The knowledge of this rate is important in clinical applications for defining appropriate nutritional support and determining caloric needs for energy balance[4].

Several studies have reported reduced BMR with age[5-7] attributed to factors such as a decreased amount of lean mass and concomitant increase in fat mass[8], altered contents of body water[4,9], altered body temperature[4,10], mood disorders or stress[11], hormonal alterations[5], body area[4], physical inactivity[5,7], individual genetics[10], and aging[12].

There has been growing concern with studying basal metabolic rate due to its relation with the risk of fat mass gain[13,14], particularly for seniors, since a low metabolic rate may contribute to the prevalence of high rates of overweight and obesity in this age group[15].

Classically, endurance exercises have been used to prompt alterations in body composition, largely due to their ability to boost energy use, particularly the use of fats, but many of the results reported are inconclusive[16]. Some studies have reported higher BMR after endurance exercise[17], while others found no significant alterations[18], and others yet only a small decrease in BMR[19].

In view of these discrepancies in the literature and the importance of BMR in aging, this study sought to examine the effects of a fitness-endurance program on the intensity of ventilatory threshold 1 (VT-1) in basal metabolism and body composition of healthy sedentary seniors.

METHODOLOGY

Forty-six Brazilian elderly males were selected from an initial pool of 118 using the following criteria: no clinical symptoms or indicators of cardiovascular disease; no medication that could alter cardiovascular function or basal metabolic rate; no psychotropic drug use; no metabolic disorders; sedentary lifestyle (i.e. no habitual physical activity), and no recent surgical intervention. The criterion used to determine the sedentary lifestyle was based on interview, on the use of a short questionnaire for the measurement of habitual physical activity[20] and on oxygen uptake analysis.

The Committee of Ethics in Research of the Federal University of São Paulo approved all methods and procedures (# 207/01). The nature of the study, its aims and possible risks were carefully explained to all volunteers beforehand and they signed consent forms.

The final sample consisted of 46 healthy sedentary male volunteers aged 60-75 (66.97 ± 4.80 years), randomly allocated to two groups: the control group (n = 23) and the experimental group (n = 23). The characteristics of both groups are presented in table 1. Prior to the procedure, a medical evaluation included electrocardiograms at rest and with effort to assess cardiovascular parameters. There was no control over diet and subjects continued with their own eating routines *"ad libitum"*.

Description of groups

Members of the control group were asked not change their daily routines or join a fitness program. Subjects were monitored longitudinally through monthly phone calls for us to maintain contact and keep them informed of the course of the study. They were also informed that, although they would not be taking part in the fitness program, they could do so after the intervention period for the experimental group.

The experimental group took part in an aerobic fitness program every other day (three times a week) for six months. Sessions were continuous with the initial duration of 20 minutes, gradually increas-

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ing to a maximum of 60 on a cycle ergometer (*Lifecycle* 9.500 HR) prescribed after ergospirometric evaluation (VT-1) of variations in subjects' heart rates. The workload was adjusted as according to the principles of training; we observed the relationship between volume and intensity. In all sessions, all subjects had their arterial pressure checked and their heart frequency monitored at 5-second intervals using a *Polar Advantage* NV.

Experimental procedure

Physical evaluation

Body composition – Body composition was measured by DEXA scan (Dual Energy X-ray Absorptiometry, using model DPX-IQ #5781 from Lunar Radiation, Madison, WI). Body mass was determined to the nearest 0.001 kg using electronic scales with subjects barefoot in light clothing. Height was measured by a stadiometer accurate to within 1 mm.

Ergospirometric test – Cardiopulmonary assessment in which exhaled gases were analyzed with direct measurement of oxygen consumption to determine ventilatory threshold. This test determined the following variables: peak oxygen consumption ($\dot{V}O_2$ peak), ventilatory threshold 1 (VT-1), maximum ventilation ($VE_{max.}$); maximum heart rate (HR_{max}), ventilatory threshold 1 heart rate (VT-1 HR), and workload at threshold intensity. In order to obtain the respiratory and metabolic variables, we measured the respiratory gaseous exchanges (*SensorMedics* – V_{max} 29 series – Metabolic Measurement Cart, Yorba Linda, CA). The system was pre-test calibrated using known gas concentrations (O_2 and CO_2), and flow calibration was carried out using a 3-liter syringe. Testing was on a cycle ergometer (*Lifecycle* 9.500 HR). The procedure involved 25-watt load increments every two minutes; initial warm-up load was of three minutes at 25 watts and the test was terminated when the subjects reached the safety margin for peak oxygen consumption. Blood pressure was monitored during testing, and a *Polar Advantage* NV monitored heart rate at 5-second intervals. Tests were conducted at the same time of day (8 -11 a.m.) in an acclimatized and standardized laboratory environment. The criteria used to determine oxygen consumption at ventilatory threshold 1 were as described by Wasserman *et al.* (1973)[21] and Wasserman and Koike (1992)[22]: 1) exponential increase of ventilation (VE, L/min); 2) abrupt increase in breathing quotient (R); 3) systematic increase of ventilatory equivalent oxygen ($VE/\dot{V}O_2$), with no change in $VE/\dot{V}CO_2$ equivalent; 4) increase of exhaled fraction O_2 (FeO_2%).

Basal metabolism rate – Determined through indirect open circuit calorimetry, measured in laboratory standard conditions. In order to obtain the closest possible measures of their physiological conditions, we instructed subjects to sleep at least 8 hours at night, not to eat any food for at least 12 hours before determination of basal metabolic index, not to use any medication and caffeine for the BMR measurements and not to engage in physical activity for 48 hours preceding measurement. Each subject was transported to the testing site by motor vehicle to ensure minimal activity before BMR determination. Measurements were made from 6:30 to 8:00 a.m.; subjects were calmly lying still in supine position during the test, and in a state of wakefulness, in an environment with controlled temperature and humidity where noise was kept to a minimum. Intake of O_2 was measured for 30 minutes and analyzed at 20-second average intervals (*Vista Turbofit* software, Ventura, CA, USA), using a computerized metabolic system (*Vista Mini* CPX *Metabolic System*, Vacumed, California, *Pentium* II, 750 mHz, USA). A Hans Rudolph flow-by face-mask (Kansas City, MO, USA) was positioned on the subjects, all air exhaled through their mouths and noses was channeled to the gas analysis equipment. We calibrated the equipment before testing using known gas concentration (O_2 and CO_2), and a 3-liter syringe to calibrate flow. Energy expenditure (Kcal/day) was calculated using Weir's equation[23] and expressed per 24 h. We carried out a practice session to familiarize subjects with the apparatus and procedures before the first measurement in order to decrease their anxiety during assessment.

Blood analysis **–** Morning collection (pre- and post-intervention periods) through surface puncture of forearm vein, with the volunteers in 12-hour post absorptive state. Thyroid hormone analyses: T3 (triiodothyronine), T4 (thyroxine) and TSH (thyroid-stimulating hormone, thyrotropin). The principal of TSH assay was a two-site immunoenzymometric-assay and the principal of T3 and T4 assay was a competitive enzyme immunoassay (*TOSOH*, Tokyo, Japan) (T3 coefficient of variation (CV) – intra-assay: 3.3%; inter-assay: 2.6%; sensibility is estimated in 15 ng/dL; T4 CV – intra-assay: 5.7%; inter-assay: 4.5%; sensibility estimated in 0.3 ug/dL; TSH CV – intra-assay: 2.8%; inter-assay: 2.3%; sensibility estimated in 0.06 uIU/mL). These blood analyses were selected because of their relation with the basal metabolic rate.

Statistical analysis

We used the *Statistics for Windows*® version 5.5 for statistical analysis. To determine the number of the volunteers necessary, we used a power analysis. Student's *t* test for dependent samples was used to compare intra-group pre- and post-intervention results, and Student's *t* test for independent samples for inter-group comparisons. Delta s variation (post- *less* pre-intervention results) was calculated to show the size of differences in pre- and post-intervention periods and between groups. We used ANOVA (2x time/ 2x group) to determine the effects of intervention periods (time effect). We used the covariance procedures to analyze the metabolic rate, and statistically adjusted the data for changes in body composition (fat-free mass). The minimum significance level was set at 5%, and the data is shown as mean ± standard deviation.

RESULTS

Table 1 shows initial sample data. No significant inter-group differences were observed.

TABLE 1
Initial sample data

Variables	Control (n = 23)	Experimental (n = 23)
Age	65.86 ± 3.80	68.08 ± 5.49
Body mass (kg)	76.38 ± 11.10	77.56 ± 13.45
Height (m)	1.67 ± 0.58	1.69 ± 0.85
BMI	27.17 ± 3.09	27.06 ± 3.75

BMI – Body mass index (weight/height²).

Table 2 shows the results of the body composition analysis measured by DEXA. Significant inter-group differences were observed in the variable total fat (%) in the pre- and post-intervention periods ($p \leq 0.04$ and $p \leq 0.03$, respectively). No significant alterations were observed in the other analyses.

Table 3 shows the results of the physical tests, i.e. basal metabolic rate analysis and ergospirometric test. On comparing groups before and after the intervention period, we found a significant reduction in basal metabolism in both groups, with a significant inter-group difference in the post-intervention condition ($p \leq 0.03$). This data is shown in figure 1. The ANOVA analysis detected differences in time factor [$F_{(1,44)} = 35.77$; $p < 0.00001$] and interaction [$F_{(1,44)} = 4.85$; $p = 0.032$]. The comparison of the experimental group before and after the intervention period showed differences in the following variables: $\dot{V}O_2$ at VT-1 intensity (relative and absolute), heart rate and workload at the same intensity, and diastolic pressure pre- and post-ergospirometric test. On comparing groups in the post-intervention-period condition, we found significant differences between the experimental and control group regarding the following variables: peak $\dot{V}O_2$ relative and absolute ($p \leq 0.001$ and $p \leq 0.02$, respectively), workload and $\dot{V}O_2$ (absolute) in the intensi-

TABLE 2
Body composition evaluation results

Variables	Control (n = 23)		Experimental (n = 23)		Δ (Post-Pre)		
	Before	After	Before	After	Control	Experimental	P
Body mass (kg)	76.38 ± 11.10	76.90 ± 10.81	77.56 ± 13.46	77.06 ± 14.47	0.52 ± 2.54	–0.50 ± 2.07	0.14
BMI (weight x height)	27.17 ± 3.09	27.59 ± 3.23	27.06 ± 3.75	26.95 ± 4.04	0.42 ± 1.23	–0.10 ± 0.80	0.095
Total fat (%)	29.45 ± 3.56	29.53 ± 3.66	25.94 ± 7.68#	25.55 ± 7.86‡	0.8 ± 1.05	–0.39 ± 1.71	0.26
Total BMC	2837.17 ± 368.06	2845.78 ± 376.48	2966.34 ± 467.12	2970.13 ± 471.20	8.60 ± 31.94	3.78 ± 53.72	0.71
% total fat region	28.36 ± 3.43	28.43 ± 3.56	24.92 ± 7.40	24.56 ± 7.66	0.78 ± 1.05	–0.39 ± 1.70	0.26
Total issue	73.51 ± 9.64	73.74 ± 9.55	73.05 ± 12.96	72.77 ± 13.25	0.23 ± 1.10	–0.27 ± 2.11	0.30
Total lean mass (kg)	51.65 ± 5.47	51.74 ± 5.17	53.33 ± 6.20	53.34 ± 6.27	83.74 ± 810.66	8.91 ± 1914.01	0.86

\# Student t-test for independent samples, significant results for the pre-intervention condition, $p \leq 0.05$.
‡ Student t-test for independent samples, significant results for the post-intervention condition, $p \leq 0.05$.

TABLE 3
Results of physical tests

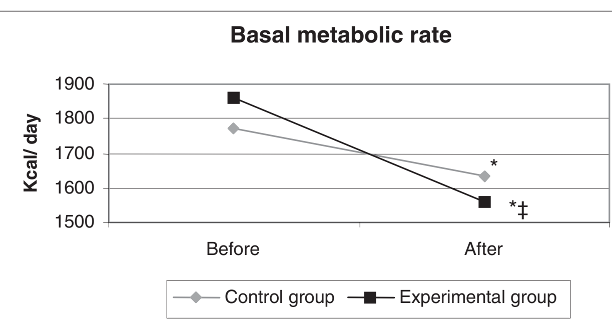
	Variables	Control (n = 23)		Experimental (n = 23)		Δ (Post-Pre)		
		Before	After	Before	After	Control	Experimental	P
Basal metabolic rate	Energy expenditure Kcal/day	1772.59 ± 304.64	1634.10 ± 302.66*	1861.51 ± 247.122	1561.47 ± 263.751*‡	–138.49 ± 251.48	–300.04 ± 245.73#	0.032
Ergoespirometric test	$\dot{V}O_2$ peak (L)	1.22 ± 0.37	1.18 ± 0.36	1.43 ± 0.38	1.43 ± 0.31‡	–0.4 ± 0.12	–0.0 ± 0.27	0.54
	$\dot{V}O_2$ peak (ml)	15.46 ± 3.93	14.95 ± 3.72	18.61 ± 4.82#	19.24 ± 4.25‡	–0.51 ± 1.85	0.62 ± 3.77	0.20
	$HR_{Max.}$	130.17 ± 15.64	131.04 ± 24.59	127.57 ± 14.52	124.78 ± 16.69	0.87 ± 15.91	–2.78 ± 12.90	0.39
	VT-1 (L)	0.87 ± 0.34	0.83 ± 0.32	0.95 ± 0.30	1.09 ± 0.27*‡	–0.04 ± 0.15	0.13 ± 0.21#	0.02
	VT-1 (ml)	11.36 ± 3.14	13.91 ± 14.45	12.42 ± 3.35	14.43 ± 3.18*	2.54 ± 13.40	2.01 ± 2.83	0.85
	VT-1 HR	107.65 ± 13.27	107.83 ± 18.84	102.65 ± 16.81	109.83 ± 15.52*	0.17 ± 9.93	7.17 ± 11.43#	0.03
	VE (L)	49.24 ± 17.11	46.70 ± 15.74	54.93 ± 14.24	56.14 ± 11.15‡	–2.54 ± 6.87	1.21 ± 10.51	0.15
	Threshold Workload (watts)	50.00 ± 16.85	53.26 ± 15.63	50.35 ± 26.89	98.91 ± 31.51*‡	3.26 ± 11.44	48.57 ± 22.40#	0.001

* Student t-test for dependent samples, significant results for the same group, $p \leq 0.05$.
\# Student t-test for independent samples, significant results for the pre-intervention condition, $p \leq 0.05$.
‡ Student t-test for independent samples, significant results for the post-intervention condition, $p \leq 0.05$.
Legend: $\dot{V}O_2$ – oxygen consumption; HR – heart rate; VT – ventilatory threshold; VE_{max} – maximum ventilation; peak – maximum condition reached.

TABLE 4
Biochemical analysis results

Variables	Control (n = 23)			Experimental (n = 23)			Δ (Post-Pre)		
	Before	After	p	Before	After	p	Control	Experimental	p
T3 (ng/dL)	105.75 ± 27.83	97.93 ± 31.16*	0.02	106.27 ± 17.53	91.45 ± 12.84*	0.001	–7.81 ± 14.43	–14.81 ± 18.04	0.17
T4 (ug/dL)	7.97 ± 1.74	7.38 ± 1.96*	0.005	8.07 ± 1.34	6.57 ± 1.07*	0.001	–0.59 ± 0.84	–1.50 ± 1.12*	0.05
TSH (uIU/mL)	3.83 ± 4.20	3.67 ± 4.09	0.53	2.53 ± 1.96	2.33 ± 1.21	0.47	–0.15 ± 1.09	–0.19 ± 1.25	0.91

* Student t-test for dependent samples, significant results for the same group, $p \leq 0.05$.



* Student t-test for dependent samples, significant results for the same group, $p \leq 0.05$.
‡ Student t-test for independent samples, significant results for the post-intervention condition, $p \leq 0.05$.

***Fig. 1** – Basal metabolic rate*

ty of VT-1 ($p \leq 0.001$ and $p \leq 0.005$, respectively) in the maximum ventilation ($p \leq 0.02$) and in final posttest diastolic pressure ($p \leq 0.04$). The ANOVA analysis detected differences to peak $\dot{V}O_2$ relative: group effect [$F_{(1,44)} = 4.81$; $p = 0.03$] and no significant differences to time effect [$F_{(1,44)} = 0.38$; $p = 0.53$]; to peak $\dot{V}O_2$ absolute: group effect [$F_{(1,44)} = 10.25$; $p = 0.002$] and no significant differences to time effect [$F_{(1,44)} = 0.017$; $p = 0.89$]; to threshold workload: group effect [$F_{(1,44)} = 12.61$; $p = 0.0009$], time effect [$F_{(1,44)} = 97.62$; $p = 0.00001$] and interaction [$F_{(1,44)} = 74.59$; $p = 0.00001$]. No significant alterations were observed in the other variables.

Table 4 shows the results of biochemical analyses. Significant T3 and T4 reductions were observed in both groups ($p \leq 0.05$). The ANOVA analysis detected differences in time factor for the variables T3 [$F_{(1,44)} = 19.89$; $p = 0.00006$] and T4 [$F_{(1,44)} = 45.55$; $p < 0.00001$]. The other analyses did not show significant differences.

DISCUSSION

Comparing pre- and post-intervention periods, our study found no significant alterations in body composition in the experimental or control groups. This was unexpected, since there are reports in the literature on substantial alterations in this variable after aerobic exercise programs as well as equally substantial alterations in individuals remaining sedentary[16]. However, since the characteristics of the group studied must be taken into account; we used healthy sedentary seniors who had been sedentary for at least 40 years. It seems unlikely that the relatively short intervention period (six months) would have an effect given the lengthy period of inactivity reported by the subjects. For safety reasons, it would not be appropriate to raise the intensity of the exercise very much unless there were longer intervention periods to allow this to be done gradually. A further issue that must be considered is that this age group in general has diminished ability to adapt to physiological stimuli[24-26]. Other studies, however, have demonstrated the ability of adults in this age range to adapt to exercise training[27,28]. Moreover, it is important to consider the differences found in fat mass (higher in the control group) and oxygen uptake (lower in the control group), and the absence of modification on diet. The lack of these observations is the main limitation of our study.

On the other hand, a significant reduction in basal metabolism was observed in both groups. In the experimental group, this may be at least partly due to the type of exercise prescribed (subjects used cycle ergometer with their body weight supported), and there was no specific strength work to stimulate protein synthesis, and consequently change in the lean mass alteration and possibly raise in the basal metabolism. The decrease in BMR could be considered a functional adaptation for preserving body mass by reason of an increase in energy expenditure. Perhaps we would have seen different BMR results with higher workloads, or if the subjects had done interval training appropriate to their physiological states. The reduction observed in the control group may be related to factors such as lower active cellular mass[8], less food intake[5], reduced maximum oxygen consumption ($\dot{V}O_2max$)[29] or to aging itself[30].

Associated with the reduction in BMR, another factor that may assist our understanding of the data observed is the significant decrease in thyroid hormones T3 and T4 that we saw in both control and experimental groups. According to Poehlman *et al.* (1993)[2], the thyroid hormones may act as modulators of BMR decline with age by intervening in thermogenesis and metabolic rate regulation.

The improvement in the aerobic power of the experimental group was seen in their oxygen use and heart rate parameters at aerobic ventilatory threshold I intensity, and particularly in their higher workloads at threshold intensity. Although the exercise prescription was set at a relatively low intensity, there was a significant improvement in the cardiovascular apparatus. According to Ready and Quinney (1982)[31] and Bosquet *et al.* (2002)[32], the variation in the intensity of physical exercise in relation to anaerobic ventilatory threshold leads to beneficial alterations on some physiological parameters. The prescription of more intensive exercise leads to a better response to training, thus suggesting that the adaptative response may be intensity-dependent. However, the state of the subjects' physical fitness prior to prescription has to be taken into account, particularly for seniors. Long-term sedentary seniors should start with a low intensity exercise program.

Another important aspect observed in this investigation was the adherence to the exercise program; the fact that there were no dropouts neither in experimental nor in control group showed the fidelity of this specific population. This is surely quite an important datum in that this age group shows fidelity, dedication, responsibility and determination. This suggests that regular physical exercise may so be effective in maintaining functional skill sets and promoting enhanced feelings of well-being in seniors. It is a relatively low-cost method and may be adopted by large number of people.

CONCLUSION

The data suggest that an endurance-based physical exercise program prescribed at VT-1 intensity using cycle ergometer for six months is not sufficient to bring about significant favorable modifications in the body composition of male seniors reporting lengthy periods of sedentary lifestyle or even reduce BMR, although such a program is capable of substantially improving cardiopulmonary condition.

The use of an interval program that integrates four weekly sessions, using a preliminary aerobic component followed by an anaerobic one (hypertrophic, more specifically), might be a good alternative to revert this condition.

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