Effect of accumulated vs continuous exercise on excess post-exercise oxygen consumption

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Abstract

Background: A continuous aerobic exercise program is an effective method of improving calorie consumption on the metabolism of skeletal muscle. However, studies report that accumulated exercise of 30 minutes divided into three sessions of 10 minutes is as effective as one continuous exercise session for 30 minutes. As yet, no study has compared the excess post-exercise oxygen consumption associated with accumulated exercise and continuous exercise over these timeframes.

Objective: The primary purpose of this study was to compare the excess post-exercise oxygen consumption associated with performing continuous exercise for 30 minutes and three sessions of accumulated exercise for 10 minutes at the same intensity of 60% VO_2max.

Method: Posters about the study were posted on the February 2019 Konkuk university homepage and bulletin board, and a total of 34 college students (males, n=18; females, n=16) volunteered to participate. Using a balanced repeated measures crossover design, the subjects randomly took two exercise: continuous exercise (1 x 30 minutes) or accumulated exercise (3 x 10 minutes), and the washout period between the two exercises was a week. All exercises were performed using an ergometer at 60% maximal oxygen consumption. Oxygen consumption and heart rate were monitored and measured during exercise and after exercise. Lipid profile and lactate acid were measured at rest, exercise end, exercise end plus 30 minutes, and exercise end plus 60 minutes. IBM SPSS Statistics 23 was used to perform paired t-test, and the statistically significant difference was set at <.05.

Results: Excess post-exercise oxygen consumption parameters (e.g., total oxygen consumption, total calorie, and summation of heart rate) were higher in accumulated exercise than in continuous exercise (p<.05). No significant difference in calorie of during exercise between CEx and AEx (p = .140). No significant difference was observed in the lipid profile between accumulated exercise and continuous exercise (p>.05). No significant differences were observed at rest, exercise end plus 30 minutes, exercise end plus 60 minutes in lactic acid in the blood (p <.05). However, at exercise end, it was significantly higher in the accumulated exercise (p<.01).

Conclusions: This study confirmed that after equalizing energy expenditure for continuous exercise and accumulat ed exercise in participants in their 20s, accumulated exercise results in higher excess post-exercise oxygen consum ption than continuous exercise. The data suggests that accumulated exercise may be more effective in reducing bo dy fat than continuous exercise for a given amount of energy expenditure. [*Ethiop.J. Health Dev.* 2020;34(Special issue-3):84-90]

Key words: Continuous exercise, accumulated exercise, excess post-exercise oxygen consumption

Introduction

In modern society, mechanized and automated conveniences are reducing the amount of physical activity done by people of all ages. The increase in sedentary lifestyle promotes the deterioration of physical function in various respects (1). Additionally, unbalanced diets and excessive stress threaten people's health (2). In Korea, the proportion of obese adults is about 33.6%, i.e., one in every three is obese, and over 50% are overweight (3,4). The increase in obesity due to a lack of physical activity and poor eating habits leads to various lifestyle-related diseases and a range of socio-economic problems (5,6).

Exercise programs are reported to be the most effective method of preventing health problems, such as obesity and lifestyle-related diseases, and improving health status (7). To promote health, the American College of Sports Medicine (ACSM) recommends regular weekly exercise and physical activity for a minimum of 75 minutes at high intensity, 150 minutes at moderate intensity, or 150 to 250 minutes at light intensity (8). Regular exercise and physical activity have a positive effect on increasing the secretion of energy metabolism hormones, such as epinephrine, norepinephrine, growth hormone, insulin and cortisol in the blood, and enhancing the use of fat as an energy source (9,10). In addition, regular exercise and physical activity have been reported to improve cardiopulmonary endurance to prevent obesity and various diseases associated with obesity (11). Despite the positive effects of exercise, most people today are reported to be busy, and the lack of time is cited as the main reason for not being able to exercise and carry out physical activity regularly (12). As such, people need a more accessible and practical exercise and physical activity program that they can integrate into their busy daily lives.

In recent years, instead of continuous exercise (CEx) that need to be performed for a long time due to busy schedules and lack of workout time, accumulated exercise (AEx) in which the total workout time is divided into several times are recommended (8). According to recent guidelines issued by the American College of Sports Medicine (ACSM), because continuous exercise (CEx) has a large time constraint, accumulated exercise (AEx), covering much shorter exercise periods, is recommended. In ACSM's guidelines, the traditional CEx program for over 30 minutes was used as an effective method for solving calorie consumption and obesity. Recently, AEx that incorporates three 10-minute sessions of exercise was reported to be as effective as a single 30-minute session of CEx (13). Darling *et al.* (14) report that CEx for 30 minutes at 70% exercise intensity showed more energy consumption than AEx for 3 x 10-minute workouts. Cunha *et al.* (15) reported a higher excess post-exercise oxygen consumption (EPOC) in AEx than CEx when

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exercising with the same energy consumption at 75% intensity of VO_2R (oxygen consumption reserve). On the other hand, Schaun *et al.* (16) reported no difference in EPOC between CEx and AEx, indicating the same momentum, and no effect on the total energy consumption. In another previous study, the EPOC of 70% maximal oxygen consumption (VO_2max) was similar in both CEx and AEx (17), and no significant difference was observed in energy consumption between CEx and AEx under the same conditions of exercise intensity and time (14). Other studies have reported that fat metabolism during exercise and post-exercise recovery is different between CEx and AEx of the same amount of exercise (18,19). Gayda *et al.* (18) and Goto *et al.* (19) report that despite the similarity in fat metabolism between the two exercise methods at moderate intensity, AEx showed a greater fat oxidation during post-exercise recovery.

Objective

Previous studies (8,13-17) do not produce clear results on calorie consumption and EPOC with respect to CEx and AEx under the same momentum conditions. Moreover, various studies have recently been carried out to compare the EPOC with respect to the exercise method (CEx vs AEx) under the same exercise calorie conditions, however they are insufficient to clarify the results. Therefore, it is important to verify the exercise effect of both CEx and AEx through the difference in EPOC when exercising using the same amount of calories. Based on this, the objective of this study was to investigate the difference in EPOC in CEx (30 minutes, one time) and AEx (10 minutes, three times) with 60% VO_2max in male and female college students.

Methods

Participants: Posters about the study were posted on the February 2019 Konkuk university homepage and bulletin board, and 34 healthy college students (mean ages = 23.65 ± 2.17, 18 men, 16 women) who did not exercise regularly, volunteered to participate. To select the number of subjects, 16 people were required under the effect size = .25, a = .05, power = .95, and r = .80, using G-power 3.1.3 program. In addition, a normality test confirmed the randomness of sampling and normality through Shapiro-Wilk. All the participants answered the Physical Activity Readiness Questionnaire (PAR-Q+) and the American Heart Association (AHA) Preparticipation Screening Questionnaire. The following exclusion criteria were used: unstable angina, recently cardiac infarction (four weeks), uncompensated heart failure, severe valvular illness, pulmonary disease, uncontrolled hypertension, kidney failure, orthopedic/neurological limitations, cardiomyopathy, planned surgery during the research period, reluctance to sign the consent form, drug or alcohol abuse, and involvement in another study.

Next, participants underwent anthropometric examinations. All participants were fully acquainted with the nature of the study and informed of the experimental risks before signing a written consent form to participate. It was explicitly stated to the participants that they could withdraw from the study at any point. All of the participants completed the pre-test questionnaires and provided their voluntary consent to participate.

Experimental design: To test EPOC and energy expenditure during and after CEx and AEx, a balanced repeated measures crossover design was used. The examiner performed gas analyzer calibration (Quark CPET, Cosmed, Italy) an hour before the participants arrived, to prevent the occurrence of errors during the actual measurement, and the same examiner performed all the measurements. Each participant visited the laboratory three times. On the first visit, the following tests were performed: body composition tests (InBody 770, Biospace Ltd, Seoul, Korea), maximal cardiopulmonary exercise test (CPET, Quark CPET, Cosmed, Italy), and a test for determining the maximal values of VO_2 (VO_2max). After performing the maximal CPETs on the second visit at least 72 hours later, a continuous cycle ergometer exercise was performed at 60% of VO_2max (1 x 30 minute), and after at least one week after the second visit, accumulated cycle ergometer exercise at 60% of VO_2max (3 x 10 minutes) were performed. As soon as both the CEx and AEx sessions ended, participants came down from the cycle ergometer and, while sitting on chairs, the EPOC was measured for 60 minutes.

Pre-testing measurements phase: The participants went through a maximal aerobic exercise test using a cycle ergometer (Aerobike, Combi 75 XL, Tokyo, Japan) in order to determine VO_2max. The work rate at 50 rpm was 50W for males and 25W for females for the first 2 minutes, and increased by 25W for males and 12.5W for females every 2 minutes until exhaustion, or until participants were unable to maintain 50 rpm. The criteria used for achieving VO_2 max are plateau in oxygen consumption as workload increases, a respiratory exchange ratio (RER) of greater than above 1.15, and maximal HR within 10 b/min of the age-predicted maximum (220–age). All participants met the first two criteria. Participants' heart rates were measured using a Polar V800 monitor (Polar Electro, Kempele, Finland).

Exercise training protocol phase: The participants came to the laboratory at 08:00 for a standardized breakfast, after having fasted for 12 hours and restraining from vigorous physical activity for 48 hours. Breakfast consisted of two loaves of bread (200 kcal), one boiled egg (80 kcal), one glass of orange juice (120 kcal) and one glass of water. Participants rested in a comfortable posture after breakfast and participated in the experiment after two hours. Ambient room temperature was maintained at 23 ± 1°C. After 10 minutes of quiet sitting, VO_2, ventilation and RER were measured for 5 minutes, with the average used as baseline.

The participants performed continuous or accumulated exercise on the cycle ergometer. For both CEx and AEX, after entering the speed according to the participant's exercise intensity on the bicycle, a gas analyzer was worn. CEx was performed at 60% of VO_2max for 1 x 30 minutes; AEx was performed for 10 minutes. AEx was measured three times in a day, at

10:00, 13:00 and 16:00. After exercise, while sitting on a chair wearing the gas analyzer, EPOC measurement was performed for 60 minutes. When the measurement was finished, all equipment was removed. When participants completed each AEx morning session, they laid down to rest until the next exercise session and measurement time.

EPOC measurement phase: Immediately after the exercise, participants sat in chairs while relative VO_2, absolute VO_2, kilocalorie, heart rate (HR), and duration were monitored continuously for the first 60 minutes of recovery. The criterion for determining EPOC values was when VO_2, HR, and RER values returned to the resting baseline. The collection and analysis of lipid profile and lactic acid were done at rest, end exercise, exercise end plus 30 minutes and exercise end plus 60 minutes. Total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL) cholesterol, and low-density lipoprotein (LDL) cholesterol were measured using a portable digital lipid analyzer (SD LipidoCare, SD Biosensor, Inc., Seoul, Korea). Blood lactate acid concentration was determined using a Lactate Pro 2 analyzer (Arkray Inc., Kyoto, Japan).

Measurements: All statistical analyses were done using IBM SPSS Statistics 23 (SPSS Inc., Chicago, IL, USA). Data normality was verified using the Shapiro-Wilk test and descriptive data presented as means ± standard deviations. The difference between the two protocols was compared using a paired t-test. Where the main effects were statistically significant, *post hoc* pairwise comparisons were performed with Sidak-adjusted p-values. Model fit was evaluated using Hurvich and Tsai's Criterion. All statistical assumptions were checked using standard graphical procedures. Statistical significance was accepted at $p<0.05$.

Results

Socio-demographic characteristics: Thirty-four healthy college students were recruited for the study. The mean age of the study participants was 24.28 ± 2.49 in males and 22.94 ± 1.53 in females. The mean height (cm) was 177.43 ± 7.78 for males and 159.48 ± 4.30 for females. The mean weight (kg) was 75.38 ± 9.98 for males and 53.88 ± 6.10 for females. The mean body mass index (BMI) (kg/m^2) was 23.86 ± 2.04 for males and 21.19 ± 2.28 for females, and the lean body mass (kg) was 61.11 ± 8.14 for males and 37.17 ± 2.84 for females. Percentage fat mass was 18.74 ± 5.71 for males, and 30.01 ± 6.06 for females (Table 1).

Table 1: Participants' characteristics

Variables	Total (n=34)	Men (n=18)	Women (n=16)	P-value
Age (years)	23.65±2.17	24.28±2.49	22.94±1.53	.072
Height (cm)	168.98±11.06	177.43±7.78	159.48±4.30	<001
Weight (kg)	65.26±13.67	75.38±9.98	53.88±6.10	<001
BMI (kg/m^2)	22.61±2.52	23.86±2.04	21.19±2.28	.001
Lean body mass (kg)	49.84±13.60	61.11±8.14	37.17±2.84	<001
Fat mass (kg)	15.41±4.99	14.27±5.30	16.71±4.42	.158
% fat mass (%)	24.05±8.13	18.74±5.71	30.01±6.06	<001
VO_2max (mL/min/kg)	36.84±6.16	41.08±4.49	32.08±3.86	<001

Note: Data are means (± SD); SD = standard deviation, BMI = body mass index

Excess post-exercise oxygen consumption (EPOC): The variables related to EPOC were as shown in Table 2, which showed higher values in AEx than in CEx in all variables: VO_2 total (p-value < .001, Men, p-value < .001, Women, p-value = .001), VO_2/kg total (p-value <. 001, Men, p-value < .001, Women, p-value = .001), Kcal total (p-value < .001, Men, p-value < .001, Women, p-value = .001) and HR sum (p-value < .001, Men, p-value = .002, Women, p-value = .003). When the results of oxygen deficiency were examined, all variables (p-value < .001, Men, p-value < .001, Women, p-value < .001) showed higher values in AEx than in CEx. Also, the results for men and women all variables showed higher values in AEx than in CEx. Figure 1 shows the homogenization of energy consumption during exercise. There was no significant difference in calorie consumption during exercise between CEx and AEx (p-value = .140).

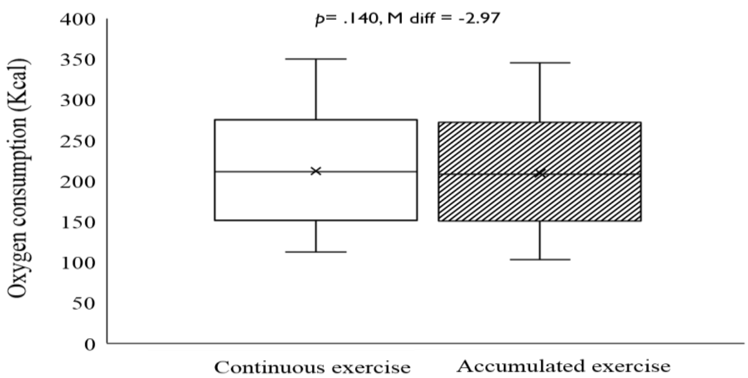

Figure 1: **Comparison of oxygen consumption exercise**

Table 2: **Comparison of EPOC in CEx and AEx (± SD)**

Variables		EPOC				O_2 deficit		
		VO_2_total (mL/min)	VO_2/kg_total (mL/min/kg)	Kcal_total (kcal/min)	HR_sum	VO_2_total (mL/min)	Kcal_total (kcal/min)	HR_sum
	CEx	11992.4 ±6481.05	185.42 ±98.94	58.14 ±31.42	2931.64 ±1560.92	594.11 ±242.10	3.39 ±1.35	28.98 ±8.17
	AEx	22101.61 ±12117.68	339.26 ±163.46	108.96 ±58.97	4988.83 ±2521.68	1627.22 ±596.59	9.38 ±3.50	85.35 ±22.22
	Δ% Sig (p-value)	84.30 <.001*	82.96 <.001*	87.42 <.001*	70.17 <.001*	173.84 <.001*	176.93 <.001*	194.51 <.001*
Men	CEx	14980.78 ±6529.74	204.83 ±103.40	72.80 ±31.82	3026.21 ±1346.65	729.80 ±194.71	4.19 ±1.06	29.00 ±8.74
	AEx	26742.27 ±13741.16	360.56 ±184.25	132.18 ±66.55	5012.70 ±2719.93	1971.44 ±595.86	11.50 ±3.38	84.28 ±21.78
	Δ% Sig (p-value)	78.51 <.001*	76.03 <.001*	81.57 .<.001*	65.64 .002*	170.13 <.001*	174.53 <.001*	184.71 <.001*
Women	CEx	8630.48 ±4616.70	163.59 ±91.98	41.65 ±21.82	2825.24 ±1811.68	441.71 ±197.76	2.48 ±1.04	28.28 ±7.74
	AEx	16880.86 ±7357.47	315.29 ±138.39	82.84 ±35.44	4961.97 ±2367.21	1239.97 ±280.19	6.98 ±1.58	86.55 ±23.36
	Δ% Sig (p-value)	95.60 .001*	92.73 .001*	98.90 .001*	75.63 .003*	180.72 <.001*	181.48 <.001*	206.05 <.001*

SD = standard deviation, CEx = continuous exercise, AEx = accumulated exercise, EPOC = excess post-exercise oxygen consumption, O_2 = oxygen, VO_2 = oxygen consumption, HR = heart rate, Sum = summation
* p<.01 significant

Lipid profile and lactate acid: Figure 2 shows the comparison of lipid profile on EPOC in CEx and AEx. No significant difference was observed in total cholesterol, triglyceride, HDL cholesterol, and LDL cholesterol in all variables (p-value > .05).

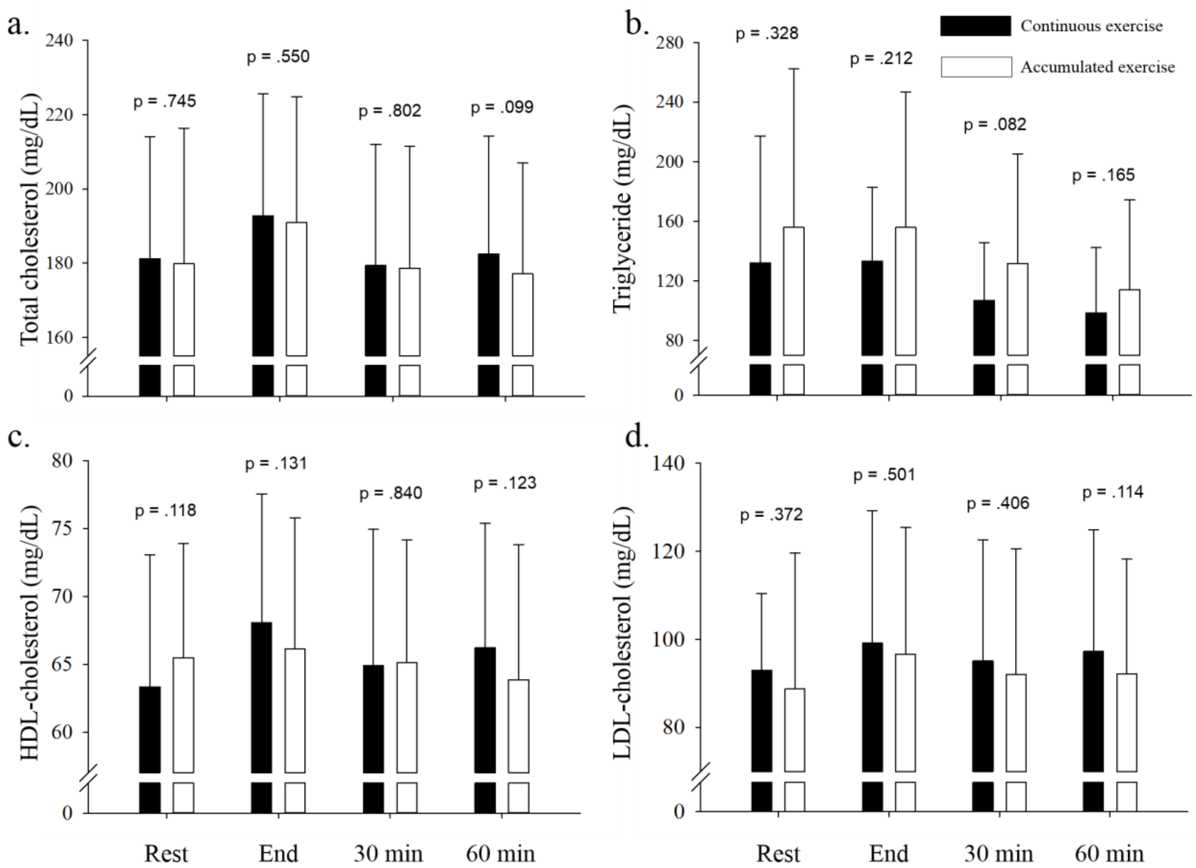

Figure 2: **Comparison of lipid profile in EPOC between CEx and AEx**

Figure 3 shows the comparison of lactic acid in the blood. No significant difference was observed at rest, exercise end plus 30 minutes and exercise end plus 60 minutes, however at exercise end, it was significantly higher in the AEx.

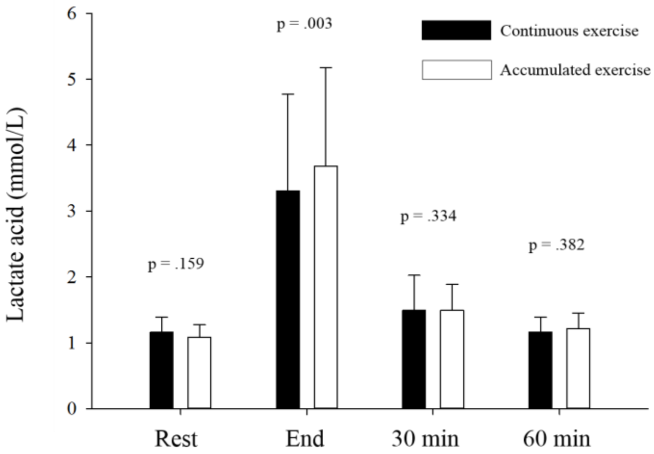

Figure 3: **Comparison of lactate acid in EPOC between CEx and AEx**

Discussion

Energy expenditure during exercise: No significant difference was observed in energy expenditure during exercise between CEx and AEx. These results indicate that the exercise program in this study was properly configured, such that there was no difference in the amount of exercise between the AEx and CEx, and that the measurement was performed correctly. Peterson *et al.* (17) and Goto *et al.* (19) also reported no significant difference in energy consumption during exercise between 30 minutes of CEx and 3 x 10 minutes of AEx.

Excess post-exercise oxygen consumption (EPOC): The changes in EPOC parameters in both AEx and CEx were examined. All EPOC parameters (e.g., total oxygen consumption, total oxygen consumption per weight, total calorie, and summation of heart rate) were significantly higher in AEx than in CEx. AEx showed a greater EPOC response than CEx, which is consistent with various previous reports (20-22). Despite the same exercise intensity and exercise volumes in CEx and AEx, significant differences in the EPOC parameters can be interpreted as differences in oxygen deficit. Oxygen deficit refers to the difference between oxygen uptake of the body during the early stages of exercise and during a similar duration in a steady state of exercise, and it usually occurs for one to four minutes after the start of exercise until the aerobic metabolism goes completely to equilibrium (23). Generally, the oxygen deficit is the same between 30 minutes and 10 minutes of aerobic continuous exercise. However, as shown in this study, 3 x 10 minutes of exercise results in three oxygen-deficit cycles, which can induce an increase in EPOC based on more oxygen deficit (24). Increasing oxygen deficit and EPOC by AEx activates the sympathetic nervous system, leading to more oxidation of fats and energy consumption, which is similar to interval exercise effects (20,25). Also, explained by the energy cost of glycogen synthesis from lactic acid, synthesis of adenosine triphosphate and phosphocreatine (ATP-PC), and changes in cytokine release (26,27).

EPOCs are manifested by exercise for the following reasons. First, an increase in EPOC appears to replenish the muscles with myoglobin to resynthesize the depleted ATP-PC and to supply dissolved oxygen in the blood (28). Second, due to an increase in mitochondrial oxygen consumption, the respiratory muscles and heart rate are maintained at high levels during the exercise (29,30). Finally, due to increased secretion of epinephrine and thyroid hormones, oxygen consumption increases due to the increase in oxidative phosphorylation (ATP generation) of mitochondria substrates is stimulated until the hormones are restored in the circulating blood (30). These three reasons result in the continued increase in oxidative metabolism to replenish energy after exercise, leading to the appearance of EPOC (31,32). Although the EPOC mechanism was not confirmed in this study, the increase in oxygen deficiency in AEx is thought to increase EPOC by inducing more oxidative metabolism to compensate for post-exercise energy consumption (33).

Based on the previous studies and this study's results, AEx may be seen to increase energy consumption during the EPOC period after exercise and may support the claim of higher total calorie consumption than CEx. Therefore, when performing the same calorie exercise at the same exercise intensity, the total energy consumption and EPOC is greater in AEx than in CEx, which is believed to have a variety of physiological and clinical benefits, such as the treatment of obesity. In this regard, various studies comparing the effects of AEx with CEx in various metabolic disorders also demonstrates the effectiveness of AEx. Murphy *et al.* (33) and Goto *et al.* (34) verified that long-term AEx helps with regulating blood pressure, blood sugar, blood cholesterol and blood lipid concentrations based on larger EPOC than long-term CEx. Since AEx is more effective in fat metabolism than CEx, it is recommended for people with time constraints who want to prevent health problems and improve health status.

Limitations of this study

The main limitation of this study was that the study participants were exclusively college students in their 20s. Various age groups were not considered. There will be limits in grafting data from participants in their 20s and applying it to different age groups. Also, the study did not control extra variables, such as participants' diet, exercise and supplement intake.

Conclusions

The objective of this study was to compare the effects on EPOC of the same amount of exercise performed in 1 x 30-minute CEx session and 3 x 10-minute AEx sessions. Our study provided that when homogenizing the energy expenditure of CEx and AEx on a cycle ergometer, EPOC was higher in AEx than CEx in both male and female participants in their 20s, suggesting that AEx may be a more effective strategy than CEx in using body fat for energy expenditure. Therefore, when performing the same calorie exercise at the same exercise intensity, the total energy consumption and EPOC are greater in AEx, which is believed to have a variety of physiological and clinical benefits, such as the treatment of obesity. Also, it is recommended that AEx may be a more effective strategy in using body fat for energy expenditure for those who do not exercise due to a lack of time.

Ethical clearance

All procedures of the study were approved by the Institutional Review Board of Konkuk University (7001355-201903-HR-305) in Korea and were conducted according to the Declaration of Helsinki.

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