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High intensity interval and moderate continuous cycle training in a physical education programme improves health-related fitness in young females

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ABSTRACT: The aim of the study was to investigate the effects of eight weeks of regular physical education classes supplemented with high intensity interval cycle exercise (HIIE) or continuous cycle exercises of moderate intensity (CME). Forty-eight collegiate females exercising in two regular physical education classes per week were randomly assigned to two programmes (HIIE; n=24 or CME; n=24) of additional (one session of 63 minutes per week) physical activity for 8 weeks. Participants performed HIIE comprising 2 series of 6x10 s sprinting with maximal pedalling cadence and active recovery pedalling with intensity 65%–75% HR_{max} or performed CME corresponding to 65%-75% HR_{max}. Before and after the 8-week programmes, anthropometric data and aero- and anaerobic capacity were measured. Two-way ANOVA revealed a significant time main effect for VO_2max ($p<0.001$), similar improvements being found in both groups (+12% in HIIE and +11% in CME), despite body mass not changing significantly ($p=0.59$; +0.4% in HIIE and -0.1% in CME). A significant main time effect was found for relative fat mass (FM) and fat-free mass (FFM) ($p<0.001$ and $p<0.001$, respectively). A group x time interaction effect was found for relative FM and FFM ($p=0.018$ and $p=0.018$); a greater reduction in FM and greater increase in FFM were noted in the CME than the HIIE group. Improvements in anaerobic power were observed in both groups ($p<0.001$), but it was greater in the HIIE group (interaction effect, $p=0.022$). Weight loss is not mandatory for exercise-induced effects on improving aerobic and anaerobic capacity in collegiate females. Eight weeks of regular physical education classes supplemented with CME sessions are more effective in improving body composition than physical education classes supplemented with HIIE sessions. In contrast to earlier, smaller trials, similar improvements in aerobic capacity were observed following physical activity with additional HIIE or CME sessions.

Key words:
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INTRODUCTION

Systematic physical activity is necessary to maintain good health and prevent the development of civilization diseases. Numerous studies have proved that insufficient physical activity increases the risk of developing obesity, diabetes mellitus type 2, cardiovascular diseases including hypertension and coronary heart disease, locomotor system disorders and emotional disorders [1,2]. Physical activity based on exercise of continuous or changing intensity, practised systematically, favourably affects the physiological indices, including anthropometric, fitness and biochemical parameters [3,4].

A study performed in European Union (EU) countries in 2009 indicated that 60% of EU citizens never or very seldom practice sport, 9% do so regularly and 31% with some regularity. In Polish society 6% reported regular sport practice, 19% with some regularity, 24% seldom and 49% never [5]. Systematic physical exercises based on high intensity with interval elements appeared to be more effective in improving anaerobic and aerobic capacity and in favourably modifying anthropometric and biochemical indices compared to endurance exercises of stable and moderate intensity [6,7].

One form of physical activity performed within the framework of the physical education programme in Maria Curie-Skłodowska University (UMCS) is exercising on spinning bicycle ergometers with the load adjusted to heart rate with accompanying music for coordinated exercise. In this form of exercise all participants performed with very similar character of movement structure.

Health and exercise professionals need precise data on optimal exercise volume and intensity to prescribe high-intensity interval exercises as safe and effective intervention. Although studies on high-intensity interval exercises have been conducted extensively in athletes, far fewer studies have investigated the impact of performing high-intensity interval exercises, one session per week, with the combination of regular physical activity on cardiorespiratory fitness. There are not enough data in the literature on the effectiveness of high-intensity interval exercises for sedentary academic populations, limiting implementation of this kind of intervention in regular academic courses.

Objectives

The aim of the study was to investigate the effects of eight weeks of regular physical education classes supplemented with high intensity interval exercise (HIIE) training or continuous cycle exercises of moderate-intensity (CME) sessions. The results of previous studies led to the hypothesis that regular physical fitness classes complemented with HIIE are more effective in improving body composition and cardiorespiratory fitness than continuous moderate exercise [8].

MATERIALS AND METHODS

Subjects. Forty-eight collegiate female participants (20.9 ± 0.94 years, body mass 60.5 ± 8.3 kg, height 166.6 ± 5.2 cm) were recruited from the University of Maria Curie-Skłodowska in Lublin, Poland. All participants were considered non-athletic, as they were not involved in athletic training within the previous 6 months. All participants were obligated to participate in 45-min regular physical education classes twice a week, as part of an academic programme. The course was conducted by the one skilled physical education teacher. Participants were encouraged to fully participate in their group programmes. Subjects were instructed about the aim and methods of examination and were recommended to continue their normal dietary and physical activity practices throughout the study, but to refrain from alcohol and exercise for 48 h before each trial.

Participants were instructed not to change diet or typical daily physical activities during the intervention. Written informed consent was obtained from all subjects before the study began.

Exercise intervention

After initial measurement, the participants were randomized to two subgroups: a) subgroup of high intensity interval exercise training (HIIE), n=24 and b) subgroup of continuous moderate exercise (CME), n=24.

Intervention groups received one additional 63-min session per week for 8 weeks of regular HIIE or continuous cycle exercises of moderate intensity (CME). All exercise training in the intervention groups was supervised by a skilled exercise physiologist. Heart rate and exercise discomfort symptoms were continuously monitored throughout training. The exercise programme was performed on mechanically braked cycle ergometers (HESS Co., Poland). The magnitude of the load was adjusted to the heart rate taken from a heart rate monitor (Polar Electro Inc, Lake Success, NY). A training session started with a 5-min warm-up and finished with a 10-min cool-down. The HIIE training protocol consisted of units composed of two bouts of 6 series of 10 s sprints with maximal speed of pedalling separated by 1 min active recovery with intensity adjusted to 75% HR_{max}, i.e. about 150 beat·min^{-1}. The CME training protocol consisted of exercises with constant moderate intensity at the level of 75% HR_{max}, i.e. about 150 beat·min^{-1}.

The study protocol was approved by the Ethic Committee at the University of Maria Curie-Skłodowska, and the study conformed to the Declaration of Helsinki.

Measurements

Somatic features. Anthropometric measurements included: body mass, body height, body composition, waist and hip circumferences. Body mass (BM) was measured with a weight scale to the nearest 0.1 kg and body height with a stadiometer to the nearest 0.1 cm. Body composition: fat mass (FM) and fat-free mass (FFM) were assessed with a stand-on hand-to-foot 8-electrode body composition analyser (model: BC 418MA, Tanita Co., Tokyo, Japan), according to the manufacturer's instructions. Normal, non-athletic body type was chosen for the manufacturer's in-built predictive algorithm. Standard positioning was used as described in the instruction manual in all measurements, and skin-to-skin contact was avoided. Participants were asked to stand with bare feet on the electrode panel and hold electrodes in both hands; arms were extended and hung down in a natural standing position with the electrodes in contact with the thumb and the palm during the measurements. Body mass index (BMI) was calculated.

Exercise capacity

Aerobic capacity

Aerobic capacity was expressed as estimated maximal oxygen uptake (VO_2max), which was obtained using the cycle ergometer test and the Åstrand-Rhyming nomogram from the steady state heart rate (HR) and the work load. The test was conducted on a Monark bike ergometer, model 874E (Monark Exercise, Vansbro, Sweden). Prior to testing participants were fitted with a heart rate monitor (Polar Electro Inc, Lake Success, NY) that linked the HR response to the ergometer using a telemetry system. The pedal rate was set at 50 revolutions per minute. The test was initiated from a 1 W·kg^{-1} load and continued for 6 minutes to reach a target rate of 135-150 bpm. If HR was lower or higher than the target rate, the workload was adjusted to bring the HR into the desired range, and an additional 6 minutes of cycling was performed [9].

Anaerobic capacity

Participants performed the anaerobic test (AnT) on a mechanically braked cycle ergometer (Ergomedic 874E, Monark, Sweden) according to the procedures of the Quebec test [10]. The testing session started with a standardized 5-minute warm-up of cycling and after a 5-minute rest the AnT began with a load of 7.5% body mass (BM). The participants were instructed to accelerate to their maximal pedalling rate and were verbally encouraged to maintain this pedalling cadence as long as possible throughout the 10-second test. The computer software (MCE, JBA Staniak, Poland) automatically calculated peak power (PP), defined as the highest mechanical power expressed in W·kg^{-1} of body mass as well as total work (W_{tot}) and time to peak power output (T).

Statistics

Two-factor (2-group × 2-time) repeated measures ANOVAs were performed to detect whether training-induced changes depended on the kind of training. The main effects for the group were not of interest; only the main effect for time and the interaction between group and time were analysed. Effect sizes (ES) were reported as partial eta-squared (η^2_p). The data are presented as mean (± SD) unless otherwise stated. Data processing and statistical evaluations were completed using SPSS version 20.0 for WINDOWS (SPSS Inc, Chicago, IL). The level of statistical significance was set at $p<0.05$.

RESULTS

At baseline, body mass and height and all physiological attributes were similar ($p > 0.05$) across groups. The initial percentage of fat mass was significantly higher in the CME group than in the HIIE group, but there was no difference in absolute fat free mass between training groups.

Somatics

The results of two-factor ANOVA for absolute and relative fat mass (FM) revealed a significant ($p<0.001$ and $p<0.001$, respectively) main time effect; FM was reduced significantly after the intervention. A significant group x time interaction effect was found for relative FM and FFM ($p=0.018$ and $p=0.018$); a greater reduction in FM and greater increase in FFM was noted in the CME than the HIIE group. No significant group x time interaction effect ($p=0.295$) was found for absolute vales of FFM, expressed in kg. Also, no significant time effect or group x time interaction effect was found for BM and BMI (Table 1).

Aerobic and anaerobic capacity

Two-factor ANOVA for VO_2max showed a significant time effect of the intervention ($P<0.001$). No significant time x group interaction effect for VO_2max was observed ($p=0.863$) (Table 2).

TABLE 1. Pre- and post-training mean (±SD) values of selected somatic variables in subjects from HIIE and CME groups.

	PE+CME		PE+HIIE			Effects	
	pre	post	pre	post		Time	Time*group
BM [kg]	62.3 ± 7.9	62.3 ± 7.4	58.7 ± 8.6	59 ± 8.5	p	0.590	0.277
					η^2_p	0.006	0.026
FM [%]	27.0 ± 6.1	26.1 ± 5.5	22.3 ± 5.8	22 ± 5.6	p	0.001	0.018
					η^2_p	0.323	0.116
FFM [%]	73.0 ± 6.1	73.9 ± 5.5	77.7 ± 5.8	78.0 ± 5.6	p	0.001	0.018
					η^2_p	0.323	0.116
FM [kg]	17.3 ± 6.2	16.7 ± 5.6	13.5 ± 5.5	13.4 ± 5.4	p	0.001	0.012
					η^2_p	0.240	0.129
FFM [kg]	45 ± 2.4	45.6 ± 2.6	45.2 ± 3.7	45.6 ± 3.9	p	0.001	0.295
					η^2_p	0.340	0.024
BMI	22.5 ± 2.8	22.4 ± 2.6	21.2 ± 2.6	21.2 ± 2.5	p	0.700	0.226
					η^2_p	0.003	0.032

Note: : PE+CME – physical education classes supplemented with session of continuous moderate exercises, PE+HIIE – physical education classes supplemented with session high intensity interval exercises, pre – pre-training measurements, post-training measurements, BM – body mass, FM – fat mass, FFM – fat-free mass, BMI – body mass index, EE – energy expenditure, MET – metabolic equivalent of task unit.

TABLE 2. Pre- and post-training mean (±SD) values of selected aerobic and anaerobic indices in subjects from HIIE and CME groups.

	PE+CME		PE+HIIE			Effects	
	pre	post	pre	post		Time	Time*group
VO_2max [ml·kg^{-1}·min^{-1}]	37.1 ± 7.9	41.2 ± 9	35.7 ± 3	40.1 ± 6	p	0.001	0.863
					η^2_p	0.359	0.001
P_{max} [W]	7.52 ± 0.73	7.71 ± 0.82	7.49 ± 0.46	7.86 ± 0.51	p	0.001	0.022
					η^2_p	0.550	0.109
W_{tot} [J/kg]	63.0 ± 7.5	65.6 ± 7.6	62.8 ± 5.9	66.8 ± 5.1	p	0.001	0.145
					η^2_p	0.510	0.046

Note: : PE+CME – physical education classes supplemented with session of continuous moderate exercises, PE+HIIE – physical education classes supplemented with session high intensity interval exercises, VO_2max – maximal oxygen uptake, P_{max} – power output, W_{tot} – total work.

Significant time main effects were found for P_{max} and W_{tot} ($p<0.001$ and $p<0.001$, respectively). P_{max} and W_{tot} were significantly improved after the intervention. A significant group x time interaction effect was found only for P_{max}, whereas for W_{tot} it was not significant ($p=0.022$ and $p=0.145$). A greater increase in P_{max} was noted in the HIIE than in the CME group (Table 2).

DISCUSSION

The main finding of this study is that eight weeks of only two physical education classes supplemented with an HIIE or CME session once a week provide similar, but significant improvements in aerobic capacity. Secondly, regular physical education classes supplemented with CME sessions are more effective in improving body composition than physical education classes supplemented with HIIE sessions in collegiate females. It was also observed that weight loss is not mandatory for exercise-induced effects on improving aerobic and anaerobic capacity. To date, most studies have focused on the effectiveness of high-intensity interval training. This study is one of the few that provide supporting data on how combining a single session of HIIE or CME with regular physical education classes results in effectiveness of the academic programme in improving health-related physical fitness.

Appropriate doses of physical activity apart from rational nourishment are necessary to maintain an optimal level of physiological indices characterizing health condition, particularly body composition, physical fitness and lipid profile [1,11,12]. An insufficient level of physical activity is a real problem of public health in Europe and worldwide. Inadequate doses of physical activity are connected with increased risk of developing civilization diseases and risk of death from all causes and especially from cardiovascular causes [13,14].

WHO recommendations for adults aged 18-64 years advise 150 minutes of aerobic exercises of moderate intensity per week or 75 minutes of vigorous exercises or an equivalent amount of exercises combining vigorous and moderate intensity.

It was underlined that additional health benefits could be obtained by increasing aerobic moderate physical activity above 300 minutes per week or aerobic vigorous physical activity above 150 minutes per week [15]. Moreover, recommendations include resistance and stretching exercises twice weekly or more frequently. Similar recommendations were presented by the American College of Sport Medicine and the Polish Forum for Prevention Guidelines on physical activity [12,13]. One method of developing and maintaining a high level of aerobic and anaerobic capacity is high-intensity interval training [6,7].

We found that CME-induced improvements in body composition were higher than changes observed in HIIE for the same time spent on organized physical activity. This is in contrast to our primary hypothesis. To date, many reports have shown that high-intensity interval training has been effective for management of body composition. We have provided evidence that CME training could provide an even stronger effect in female students. This conclusion confirms some recent reports on CME vs. HIIE effects in a wide range of populations. In overweight adults, 3 sessions per week of high-intensity interval training performed for 12 weeks did not confer the same benefit for body fat levels as continuous exercise training [16]. Keating et al. [16] concluded that exercising with continuous moderate-intensity but not high-intensity interval training improves fat distribution in overweight adults. It was also reported that high-intensity interval training and endurance training were equally effective in improving body mass and health-related fitness and important for health metabolic parameters in obese youth [17].

Recently, Kemmler reported that although 16-week high-intensity interval training impacted cardiometabolic health more favourably than a moderate-intensity continuous endurance exercise protocol, the reduction of fat mass was greater in moderate-intensity continuously exercising untrained male adults [18]. After the 4-week exercise intervention in obese men, Alkahtani [19] found significant increases in fat oxidation after moderate-intensity interval training and high intensity interval training, but with no effect of training intensity and with lack of significant improvements in body composition. Unfortunately, interval training was not compared with continuous training. The lack of significant body fat reduction in HIIE could be partially explained by the findings of Larsen et al. [20] showing that within 6 weeks of high-intensity interval training mitochondrial fat oxidation was not improved in either skeletal muscle or adipose tissue. Mitochondrial content and mitochondrial oxidative phosphorylation capacity were increased in skeletal muscle, but not in adipose tissue [20]. On the other hand, an increased rate of fat oxidation has been widely reported to occur during continuous exercise [21]; this effect depends on exercise duration [22].

The results of the present study suggest that CME and HIIE are effective in increasing cardiorespiratory fitness. Estimated VO_2max increased on average by 12% in HIIE and 11% in CME. Similar effects of interval training on both aerobic and anaerobic performance have been observed by other authors [23,24]. In the present study no effect of training kind was found. In other studies, it was found that CME supplemented with bouts of high-intensity exercise and CME alone are beneficial training strategies for improving cardiorespiratory fitness [25].

In young individuals, the sprint interval training could be a time efficient strategy allowing to maintain cardiorespiratory fitness [26] or to improve body composition, aerobic and anaerobic capacity with similar or greater effects compared to standard physical education classes or CME [27]. This is an important effect as cardiorespiratory level is inversely associated with all-cause and cardiovascular disease mortality in men and women below 60 years of age [28,29]. Also, higher levels of cardiorespiratory fitness are associated with lower cancer mortality risk in women and attenuate the risk of cancer mortality in overweight women [30]. Furthermore, Farrel et al. [30] found that using adiposity measures to estimate cancer mortality risk in women can be potentially misleading unless cardiorespiratory fitness is considered. In the present study we did not observe significant weight reduction, but in line with recent findings it could be assumed that reducing body mass is not mandatory for exercise-induced health benefits if the cardiorespiratory fitness level is increased [31–33].

We also found that two sessions of regular physical education classes supplemented with one session of CME or HIIE training for 8 weeks significantly improved anaerobic capacity. We noted significantly increased anaerobic power and total work in the 10-s Quebec test, but the significant power output increase depended on the kind of training. HIIE provided a superior effect in improving anaerobic power than CME. The other authors also reported that high-intensity interval training could result in significantly enhanced VO_2max and power output in active men and women, even after a 3-week training period [34]. Our results are also in compliance with data provided by Ziemann et al. [35], who also noted significant improvement in aerobic and anaerobic capacity after 6-week high-intensity interval training in collegiate adults. Previously it was also observed that 6-week moderate-intensity aerobic training on a mechanically braked cycle ergometer that improved the maximal aerobic power did not change anaerobic capacity and that adequate high-intensity intermittent training may improve both anaerobic and aerobic energy supplying systems significantly [36]. Recently, Nedrehagen and Saeterbakken reported that 8-week regular soccer training supplemented with 3-4 sets of 4-6 repeated sprints (30 m with 180° directional changes) weekly improved repeated sprint ability greater that regular training of equal volume and intensity [37]. It was also shown that, physical activity basing on recreational soccer game could be more effective in improving body composition than a continuous running [38]. Physiological adaptation mechanisms to HIIE are not clear in detail; most often improved lactate metabolism in working muscle is mentioned as the main factor [39]. It is worth mentioning that HIIE and CME could also equally affect left ventricular structure and function, suggesting central cardiac adaptation [40]. In the study based on the animal model, Toti el al. [41] demonstrated that high-intensity training, in addition to metabolic changes consisting of a decrease in blood lactate and body weight, induced an increase in the mitochondrial enzymes and slow fibres in different skeletal muscles of mice, which indicates an exercise-induced increase in the aerobic metabolism.

Still a large percentage of the population fails to meet the minimum exercise guidelines. The academic environment could be an appropriate place to implement an optimal and cost-effective exercise-based strategy for reducing cardiovascular problems. The results of this study support the idea of supplementing regular physical education classes with even one supervised training session, based on either CME or HIIE, for health benefits, although in this population HIIE did not confer the same results in reducing body fat as CME. The obtained data are provocative but should encourage larger multicenter studies.

Limitations

This study also has several limitations that need discussion. The relatively small sample size may have resulted in bias in detecting differences in the effect between the two exercise interventions on measured variables. Also, participants were instructed to maintain nutritional habits during the study, but diet was not strictly controlled and measured. Similarly, physical activity outside the intervention was not controlled and limited. It is likely that changes in patterns of participating in physical activity within the investigation could have influenced the obtained results. Lastly, cardiorespiratory fitness was measured via an indirect method that limits the interpretation and possibility of comparison with data from other investigations.

The optimum dosage of HIIE or CME in an academic programme still needs to be established. Future research aimed at identifying the optimal frequency, intensity, time and type of exercise is warranted.

CONCLUSIONS

Eight weeks of regular physical education classes supplemented with CME sessions are more effective in improving body composition than physical education classes supplemented with HIIE sessions in collegiate females. In contrast to earlier, smaller trials, similar improvements in aerobic capacity were observed following physical activity with additional HIIE or CME sessions.

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