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The Effects of a Circuit Training Program on Muscle Strength, Agility, Anaerobic Performance and Cardiovascular Endurance

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Abstract**—**This study aimed to examine the effects of a circuit training program on muscle strength, agility, anaerobic performance and cardiovascular endurance. The study involved 24 freshmen (age 18.87±0.68 yr.) male students of the Faculty of Sport Science, Burapha University. They sample study were randomly divided into two groups: Circuit Training group (CT; n=12) and a Control group (C; n=12). Baseline data on height, weight, muscle strength (hand grip dynamometer and leg strength dynamometer), agility (agility T-Test), and anaerobic performance (Running-based Anaerobic Sprint Test) and cardiovascular endurance (20 m Endurance Shuttle Run Test) were collected. The circuit training program included one circuit of eight stations of 30/60 seconds of work/rest interval with two cycles in Week 1-4, and 60/90 seconds of work/rest interval with three cycles in Week 5-8, performed three times per week. Data were analyzed using paired t-tests and independent sample t-test. Statistically significance level was set at 0.05. The results show that after 8 weeks of a training program, muscle strength, agility, anaerobic capacity and cardiovascular endurance increased significantly in the CT Group ($p < 0.05$), while significant increase was not observed in the C Group ($p < 0.05$). The results of this study suggest that the circuit training program improved muscle strength, agility, anaerobic capacity and cardiovascular endurance of the study subjects. This program may be used as a guideline for selecting a set of exercise to improve physical fitness.

Keywords**—**Cardiovascular endurance, circuit training, physical fitness, anaerobic performance.

I. Introduction

NOWADAYS, people pay more attention to their health care. This has resulted in the rapid growth of the health industry and the establishment of the exercise businesses, which has increased steadily as well. According to a survey in 2009, the numbers of health and fitness establishments worldwide were more than 128,000, but in 2015, the number increased to more than 186,000 [1]. In addition, it is undeniable that fitness trainers in the workplace are extremely important because, for one thing, they have to recommend exercise program guidance to their fitness members. The Exercise for Health Division, Department of Health, Ministry of Public Health of Thailand recommends that an exercise program in a health club requires skillful health personnel in many aspects such as basic knowledge about health, exercise testing, programming to ensure success and safety to exercisers [2]; therefore, institutions that produce graduates to enter a career in fitness and sports science need to prepare them as technicians for the job.

The Faculty of Sport Science, Burapha University is an educational institution that produces graduates in the field of exercise and sports science to serve the labor market of this field more than 10 years. This is in accordance to the goal of our faculty to produce skilled graduates in the field. Furthermore, graduates need to have the right personality and physical traits; in other words, they must be positively focused and look healthy and strong.

During recent years, the circuit training program is a form of exercise that has become widely used. David et al. [3] studied the effects of a circuit training program, with and without motivational interviewing behavioral therapy, on reducing adiposity and type 2 diabetes risk factors in Latina teenagers. As part of the study, subjects participated in a training program twice a week for 16 weeks. The results show that cardiorespiratory fitness and leg strength increased significantly, while waist circumference, subcutaneous adipose tissue, visceral adipose tissue, and fasting insulin and insulin resistance decrease significantly when compared to the control group. The study concluded that the circuit training program may be an effective starter program to reduce fat depots and to improve insulin resistance in overweight/obese individuals. In accordance with another study to evaluate the effects of a circuit training program with a maintenance program on muscular and cardiovascular endurance in children, results showed that the circuit training program was effective in increasing and maintaining both muscular and cardiovascular endurance in school children [4].

Finally, the advantage of a circuit training program which combines aerobic exercise and a weight training was proved to take less time to yield a better fitness result [5]. It is well accepted that circuit training in general could develop physical fitness in a diverse group. The aim of the present study was to examine the effects of a circuit training program on the muscle strength, agility, and anaerobic performance and cardiovascular endurance of freshmen students of the Faculty of Sport Science, Burapha University.

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II. Materials and Methods

A. Participants

Participating in the study were 24 healthy male freshman students with a mean age, height and weight of 18.87±0.67 yrs., 173.95±5.36 cm, and 64.62±9.42 kg, respectively. All were not currently involved in any form of physical training. Tests of muscle strength, agility, anaerobic performance, and aerobic performance were done at pre- and post-training program. The participants were randomly assigned into two groups - the Circuit Training Group, CT (n = 12) and the Control Group, C (n = 12).

B. Circuit Training Program

The experimental group was trained three times a week on Monday, Wednesday and Friday for eight weeks. The exercise training program was developed based on the ACSM recommendation [6]. Briefly, training protocol included a five-minute warm-up and two rounds - in 28 min - of eight station circuit training with 30 sec exercise and 60 sec rest at each station. The circuit stations include battle rope, single-leg hop, leg raise, barbell squat (22 kg), jump squat, shoulder press (15 lbs dumbbell), triceps dips, and bear crawl, respectively. In the last four weeks, subjects were trained three rounds of the same circuit in 42 min, however, with increase rest period to 90 sec in each station. The training sessions in this phase ended with a five minutes cool down. The control group maintained their normal routine, however, and was not involved in any physical training. Training and data collection were done at the Fitness Room of Burapha University's Faculty of Sport Science.

TABLE I
Circuit Training Program and Equipment

Exercise	Equipment
Battle rope	Battle rope
Single-leg hop	-
Leg raises	-
Barbell squat	Barbell (22 kg)
Jump squat	-
Shoulder press	Dumbbell (15lbs.)
Triceps dips	-
Bear crawl	-

TABLE II
Number of Cycles, Exercise Duration, Rest Period between Stations, Rest Periods between Cycles and Total Duration of the Circuit Training Program

Weeks	Cycles	Exercise duration (seconds)	Rest period between stations (seconds)	Rest period between cycles (seconds)	Total duration (minutes)
1-4	2	30	60	2	28
5-8	3	60	90	2	42

C. Pre-Post Testing

1. Muscle Strength Assessment

Grip and leg strength were measured using digital handgrip dynamometer (Takei T.K.K. 5401 Grip-D Tokyo, Japan) and digital leg dynamometer (Takei T.K.K. 5402 Back-D Tokyo, Japan), respectively. The participants perform two maximum efforts of the dominant hand in the standing position, with the arms extended by the side of the body with 1-minute rest between efforts and use the result to be an average [7]. For measuring leg strength, participants stood with their legs placed shoulder-width apart on the base of the dynamometer. The chain on the dynamometer was set with the participants maintaining a squat position with the knee bent at about 110 degrees, which would mean that their thighs are slightly higher than parallel to the floor. Reaching down and gripping the bar, the participants pull the bar up as hard as possible while trying to extend their legs, while the arms should remain straight throughout the entire test.

2. Agility Assessment

Agility T-Test was used to measure agility. The participant stands at the Cone A at the base of the "T". The researcher gives the signal to 'Go', and starts the stopwatch and the test commences. The participant runs to and touches Cone B, side steps to Cone C and touches it, again side steps to Cone D and touches it, side steps back again to the Cone B and touches it, and then runs backwards to the Cone A. The researcher stops the stopwatch and ends the experiment when the participant completes the full circuit, and records the time. The participants perform two maximum efforts (Fig. 1).

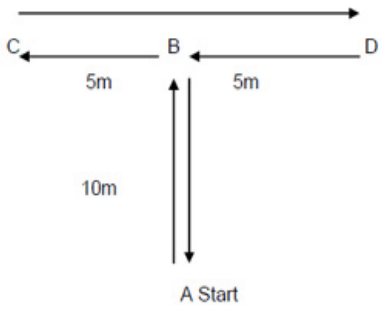

Fig. 1 Position and direction of Agility T-Test

3. Anaerobic Performance Assessment

The RAST test was used on the athletic track to assess anaerobic performance. The test includes six sprint-runs at maximum speed at a distance of 35 m, with 10 sec rest periods between each sprint. Prior to commencement of the test, the participants perform a warm up jog of approximately 10 min at low intensity, followed by leg stretching. The time is manually recorded by the researcher and two assistant researchers, who are positioned at the endpoint of the test in order to control the recovery time (10 sec). Participants walk to cool down for 2 min after finishing the test [8]. The anaerobic power and anaerobic capacity are relevant to the body mass (W/kg^{-1}) that are assessed from the test.

4. Cardiovascular Endurance Assessment

Cardiovascular endurance was assessed with the 20-meters shuttle run test. In this particular test, the participant performs the test in groups of eight and instructed to run back and forth on a 20 m course at the same time. A sound signal is emitted from a prerecorded tape. The speed starts at 8.5 km/h^{-1} and is then slowly increased at 0.5 km/h^{-1} each minute. The test finishes when the participant is unable to maintain a running

speed to match the pace of the 'beep' sound; the number of completed stages is used to predict the maximal rate of oxygen uptake [7].

D.Statistical Analysis

Descriptive statistics (mean and standard deviations) for age, height, body weight, muscle strength, agility, anaerobic performance and aerobic performance were calculated. Dependent samples t-test was used to study the differences of the before and after training variables in both groups (experimental group and control group) and the independent sample t-test was used to study the differences of the variables between groups. All statistical analyses were performed by using the statistical package for social sciences (SPSS for windows version 20.0). The level for statistical significance was set at $P<0.05$ in all test.

III. Results

All data are reported as mean ± SD. Pre- and post-descriptive values of muscle strength, agility, anaerobic performance and aerobic performance of experimental group and control group are shown in Table III. All the parameters at pre-training showed no significant differences between the experimental group and control group.

TABLE III
MUSCLE STRENGTH, AGILITY, ANAEROBIC PERFORMANCE AND AEROBIC PERFORMANCE OF CIRCUIT TRAINING GROUP (N=12) AND CONTROL GROUP (N=12)

Variables	Circuit training group	Control group
Muscle Strength		
-Hand Grip (kg/w^{-1})		
Pre-training	0.63±0.10	0.60±0.10
Post-training	0.71±1.07#*	0.61±1.21
-Leg Strength (kg/w^{-1})		
Pre-training	2.47±0.48	2.30±0.61
Post-training	3.01±0.54#*	2.30±0.78
Agility		
-Agility T-Test (sec)		
Pre-training	12.15±0.93	11.72±0.69
Post-training	10.97±1.19#*	11.96±0.94
Anaerobic Performance		
-Anaerobic Power (Watts)		
Pre-training	8.24±1.47	8.74±2.05
Post-training	8.31±1.75	6.93±1.97*
-Anaerobic Capacity (Watts)		
Pre-training	5.90±1.05	5.99±1.66
Post-training	6.82±1.45#*	4.50±1.16*
Cardiovascular Endurance		
-VO2 max (ml/kg^{-1}/min^{-1})		
Pre-training	46.46±5.55	45.79±5.69
Post-training	55.09±6.63#*	43.84±5.57

#significantly different between Pre-training and Post-training
*significantly different between CT and C Group

After eight weeks of the circuit training program, muscle strength (handgrip strength and leg strength) increased significantly from 0.63+0.10 kg/w-1 to 0.71+1.07 kg/w-1 only in the experimental group, and the increase was significantly higher than the control group; the anaerobic capacity increased significantly from 5.90+1.05 to 6.82+1.45 watts and the increase was significantly higher than the control group. The post-training value of aerobic performance (VO2 max) in the experimental group was significantly higher than the pre-training value (46.46+5.55 ml/kg-1/min-1 to 55.09+6.63 ml/kg-1/min-1). The agility score of the experimental group was lower pre-training (from 12.15+0.93 sec to 10.97+1.19 sec), which signified the improvement. Such improvement was significantly higher than the control group ($p< 0.05$).

IV. Discussion

Results showed that after eight week of circuit training program designed for this study, muscle strength (grip and leg strength) increased significantly from 0.63±0.10 to 0.71±1.07 kg/w^{-1}, $p<0.05$ and from 2.47±0.48 to 3.02±0.54 kg/w^{-1}, $p<0.05$, respectively. Such increase of both was significantly higher than the values found in the control group ($p<0.05$). The increase in strength was expected since the exercise in many stations involved resistance such as barbell, dumbbell and body weight of the subjects. The research yielded a similar result with that of the study of Schmidt et al. [9]. In that study, low intensity circuit training plus a high resistance exercise for 12 weeks in women significantly increased scores for bench press, knee extension, and muscle endurance of the subject. Similarly, in the very recent study of Giannaki et al. [7], teenage boys underwent interval circuit training twice a week as part of a physical education class and reported significant increase in muscle strength and high jump ability.

In the experimental group of this study followed by eight weeks of circuit training, agility, as reflected by running times, decreased from 12.15±0.93 to 10.97±1.19 sec; the decrease was statistically significant ($p< 0.05$). Such improvement in agility was significant when compared to the score (time) of the control group. It appears that the circuit training program, designed in this study, not only increased the muscle strength, but also the agility of the subjects. Along the same line, Taskin [10] studied the effects of an eight-station circuit training session conducted three times per week for 10 weeks on speed, agility, and aerobic capacity. The results showed significant improvement for all the parameters studied. Furthermore, study of Kumar [11] reported a significant increase in the leg muscle strength and agility of subjects participating in six station circuit training (exercise for 25 - 35 sec with 20 - 30 sec rest at each station, 2 - 4 sets with a 2 - 3 min rest period between each set for a duration of eight weeks). The findings of studies suggest there is no doubt that interval circuit training focusing on agility training will lead to an increase in agility [11].

The circuit training program in this study appeared to have no effect on the anaerobic power of the subjects in the experiment the group (pre-training was 8.24±1.47 and 8.31± 1.75 watts for post-training). However, the anaerobic power of the experimental group was significantly higher than the value for the control group (8.31±1.75 vs. 6.95±1.97 watts, $p<0.05$). Anaerobic capacity of the experiment group increased significantly from 5.90±1.05 to 6.82±1.45 watts ($p<0.05$). The experimental group showed a significantly higher anaerobic capacity than the control group (6.82±1.45 vs. 4.50±116 watts, $p<0.05$). These results imply that the circuit training program designed in this study was responsible for an increase in an

anaerobic capacity found in participants and that an increase in muscle strength may be responsible for the increase in anaerobic capacity.

The circuit training program of this study led to a significant increase in VO_2 max of the experimental group (increase from 46.46±5.55 to 55.09±6.63 $ml/kg^{-1}/min^{-1}$, $p<0.05$), while in the control group, VO_2max showed a small drop at post-training; however, the drop was not statistically significant.

Even though the training activity at each station was primarily anaerobic exercise, increased aerobic performance was recorded. The results support the theory that repeated anaerobic training over a period of time (in this study - 8 weeks) could result in an increase in aerobic performance as reflected by the increase in VO_2 max value found in this study. Furthermore, repeated anaerobic exercise could lead to a reduction in fat deposits. These findings yielded similar results with many studies [5], [7], [9], [12]. Finally, the findings in this study imply that interval circuit training, involving work and rest interval with a focus on anaerobic training with resistance, i.e. with resistance and done repeatedly for a long period of time, is an effective way to improve both aerobic and anaerobic performance that form the foundation of health-related physical fitness.

V. Conclusion

It may be concluded from the existing data that the circuit training program of this study improved some physical fitness parameters, i.e., muscle strength, agility and cardiovascular endurance of the young college students. The training program could be used to improve physical fitness of the young college students.

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