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EFFECT OF SIXTEEN WEEKS OF COMBINED EXERCISE ON BODY COMPOSITION, PHYSICAL FITNESS AND COGNITIVE FUNCTION IN KOREAN CHILDREN

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ABSTRACT

This study examined the effects of 16-week combined exercise programme on body composition, physical fitness and cognitive function of Korean children. The 20 participants were randomly assigned to the Combined Exercise Training (CET) (resistance exercise and aerobics) group (n=10) or a control group (CG, n=10). The CET group performed 90-min exercise sessions twice per week for 16 weeks, including 40min of resistance exercise, 40min of aerobic exercise and 10min warm-up and cool-down. The CG did not participate in any exercise or physical activity. Body composition variables (weight, body mass index, fat-free mass, per cent body fat, and basal metabolic rate) were measured using bio-electrical impedance analysis. Subjects underwent a physical fitness test consisting of sit-ups, grip strength, sit-and-reach, standing long jump, side-steps and isokinetic leg extension strength. The cognitive function test consisted of electro-encephalography (EEG) activation and the Stroop test. Significant interaction effects (time x group) on EEG activation (brain activity) in the Fp1 (p=0.034), F3 (p=0.028), and C4 (p=0.013) areas and Stroop test (cognitive function) (p=0.005) were observed in the CET group compared to the CG. There were no interaction effects (time x group) on body composition or physical fitness variables. The CET affected the cognitive function of Korean children positively.

Key words*:* Body composition; Cognitive function; Combined exercise; Electro-encephalography activation; Physical fitness; Youth.

INTRODUCTION

The World Health Organisation (WHO) reports that there are 42 million overweight children worldwide, implying that childhood overweight and obesity are increasing and becoming one of the most serious public health problems (WHO, 2013). Ogden *et al*. (2012) reported that in 2010 in the US over one-third of children and adolescents were overweight or obese. In Korea in 2012, the prevalence of obesity in boys and girls was 13.1% and 6.2%, respectively (Ministry of Education, Science and Technology, Ministry of Health and Welfare, Korea Centres for Disease Control and Prevention, 2013).

The US Centres for Disease Control and Prevention reported that childhood mental disorders, such as substance-use disorders, attention-deficit/hyperactivity disorder (ADHD), behavioural disorders, Tourette syndrome, mood and anxiety disorders, and autism spectrum disorders are additional public health problems (US Centres for Disease Control and Prevention, 2013). As mental health is important to overall health and chronic health conditions, these health problems can affect individuals throughout life (Herpertz-Dahlmann *et al*., 2013). Therefore, public health management strategies targeting institutions such as schools (through physical education), hospitals, and community centres are important for managing weight and mental disorders in children and adolescents (Showell *et al*., 2013; Wathen & Macmillan, 2013; Wolfenden *et al*., 2014).

Physical activity is an excellent method for promoting physical health, including weight management and preventing various diseases in clinical practice (Orrow *et al*., 2012; Vuori *et al*., 2013). Moreover, physical activity positively affects psychological and social health, including the improvement of aspects, such as self-esteem, social interactions, anxiety, mood, and depression (Brown *et al*., 2013; Eime *et al*., 2013).

Furthermore, physical activity is reported to improve cognitive and memory functions (Ploughman, 2008; Flöel *et al*., 2010), which can consequently improve academic performance in adolescents (So, 2012). Ha and So (2012) found that a 12-week combined exercise programme for 80 min/day, three days/week resulted in a decrease in per cent body fat and waist circumference in 20 Korean female college students. According to the findings of Shin *et al*. (2009), after eight weeks of physical exercise muscular strength improved in elderly Korean women, while acute physical exercise around the anaerobic threshold in healthy subjects improved cognitive function (Kashihara *et al*., 2009).

One method to assess neuropsychological function is the Stroop test, which was introduced by Stroop (1935) and has become widely used (Pachana *et al*., 2004). Its validity and reliability have been confirmed (Franzen *et al*., 1987), and many versions, including Korean and Asia versions, have been developed and their validity and reliability was confirmed (Kim *et al*., 2004; Qian & Wang, 2007). A relationship between aerobic fitness and the Stroop test has been reported (Buck *et al*., 2008; Yanagisawa *et al*., 2010).

AIM OF THE STUDY

To our knowledge, no studies on types of exercise, particularly combined exercise, have focused on Korean children. Therefore, the present study examined the effect of a 16-week combined exercise training programme on body composition, physical fitness and cognitive function of Korean children.

METHODOLOGY

Participants

A repeated-measures 2 x 2 analysis of variance (ANOVA), with an anticipated statistical power of 0.80, α error probability of 0.05, and effect size of 0.4, predicted that the appropriate sample size for the present study was 16 participants (G-power programme 3.1.3, Germany). To take into account the possibility of subjects dropping out, a sample size of 22 participants was used. The subjects were 22 elementary school students aged 8-11 years from the Mokdong children's fitness centre in Y-gu, Seoul, Korea. Participants were randomly divided into 2 groups, namely the Combined Exercise Training (CET; *n*=11) and control (*n*=11) groups. There were 5 boys and 6 girls in each group.

None of the children exercised regularly or had any health problems. The children and their parents were requested to maintain typical dietary and activity patterns throughout the study period. Compliance was assessed by physical activity and food-frequency questionnaires at the beginning and end of the study. One girl each in the CET and control groups was excluded because they did not attend all exercise sessions or did not complete the final evaluation, respectively. Therefore, 10 participants each in the CET and control groups (4 boys and 6 girls in each) completed all pre- and post-exercise assessments. All participants and their parents provided written informed consent prior to participation. The characteristics of the participants are shown in Table 1.

TABLE 1. **CHARACTERISTICS OF SUBJECTS**

Characteristics	**Control group** (*n*=10)	**Exercise training group** (*n*=10)	***t***	**p-value**
Age (years)	9.20±1.40	8.30±0.48	1.924	0.080
Height (cm)	131.21±5.87	124.88±4.52	2.703	0.015*
Weight (kg)	27.85±3.76	26.83±4.75	0.530	0.603
BMI (kg/m^2)	16.13±1.51	17.10±2.16	-1.162	0.260
Fat-free mass (kg)	22.68±2.72	21.35±2.09	1.229	0.235
Body fat (%)	18.35±5.57	19.28±9.00	-0.279	0.784
Basal metabolic rate (kcal)	859.97±58.80	831.19 ±45.08	1.229	0.235

t= Independent *t*-test value * p<0.05

Experimental design

The CET group participated in a 16-week supervised combined resistance and aerobic exercise programme. One 90-min exercise session consisted of the following four phases: a warm-up phase; resistance exercise at 50–70% of one repetition maximum; aerobic exercise at 60-80% of heart rate reserve; and a cool-down. Exercises were performed twice per week for 16 weeks. In contrast, children in the control group were instructed to maintain their normal sedentary lifestyle.

Measurements

Body composition variables included weight, body mass index (BMI), fat-free mass, percentage body fat, and basal metabolic rate. *Physical fitness* variables included sit-ups, grip strength, sit-and-reach, standing long jump, side-steps and isokinetic leg extension strength. Finally, *cognitive function* was assessed by electro-encephalography (EEG) activation (Niedermeyer & Da Silva, 2004) and the Stroop test (Stroop, 1935). The Stroop test has been widely used to test for cognitive function (Bench *et al*., 1993; Douglas & Sharon, 2009; Yanagisawa *et al*., 2010; Palmer *et al*., 2014). All variables and parameters were measured 2 days before and after the intervention.

Body composition

Body composition variables, including weight, fat-free mass, percentage body fat, and basal metabolic rate, was assessed with an 8-polar electrode impedance instrument (InBody 720, Biospace, Seoul, Korea). This instrument measures the resistance of the arms, trunk, and legs at 1, 5, 50, 256, 512, and 1024kHz through 8 tactile electrodes, 2 on the palm and thumb of each hand and 2 on the anterior and posterior aspects of the sole of each foot (Jensky-Squires *et al*., 2008).

According to the protocol of Heyward and Wagner (2004), participants were prohibited from urinating just before impedance measurement, consuming anything in the previous 4 hours, and performing any exercise in the previous 12 hours. Each participant wore light clothing and removed all metal items, which can interfere with measurements. Body composition was assessed in accordance with established recommendations (Heyward & Wagner, 2004). The Body Mass Index (kg/m^2) of each participant was calculated from weight and height.

Physical fitness variables

The *sit-up* test was used to measure muscular endurance. Participants were instructed to lie on a sit-up board (PB-160, Proteus, Korea), bend their knees 90°, and raise the upper body and bend forward using only their abdominal muscles. The number of sit-ups completed in 60s was recorded. The *grip strength* test was used to measure muscular strength. The control lever of a grip strength machine (TKK5401, Takei, Japan) that contains a potentiometer control system was adjusted so that the second knuckle of the fingers was at the bottom of the grip bar. The participants flexed maximally during three trials, and the average strength (kg) of the three trials was recorded. For the *sit-and-reach* test, which measures flexibility, participants sat on a flexibility-measuring instrument (Sit-and-Reach Board, Shinasports, Seoul, Korea). They spread their heels approximately 5cm apart and to the edge, straightened their knees, bent the trunk forward, and naturally made the measuring instrument board move forward. The average of 3 trials was recorded.

The *standing long jump* test is a measure of power. The participants jumped forward as far as possible from a standing jump platform. The distance was measured in centimetres, and the average of 3 trials was recorded. For the *side-step* test, which measures agility, participants stood on the centre line of a long board that had 80cm parallel lines on both sides. The participant was instructed to cross the line on the right, return to the line, cross the line on the left, and finally return to the original position on the centre line. The total number of times the participant crossed the line in 30s was recorded. Isokinetic *leg extension strength* was assessed using an ergonomic hand-held dynamometer (01163, Lafayette, LA, USA), to measure the muscle strength at the left and right knee joints individually. The participants sat on a chair adjusted so that the centre of the knee joint was aligned with the dynamometer's axle. To avoid measuring joints besides the knees, the femur and chest were stabilised, the lengths of the distal femur and axle were anatomically equalised, and the ankles were subsequently strapped in place. The average strength score (kg) of 3 trials was recorded.

Cognitive function

EEG activation was measured by the monopolar derivation method at 20 points on the surface of the head using a Neuromics-32 device (32ch Digital QEEG, Juwon Medical, Seoul, Korea). Twenty gold-coated plate-shaped disc electrodes were attached according to the International 10/20 electrode system. The reference electrode A1 was attached behind the right earlobe, and the ground electrode was attached behind the left earlobe. The signal was recorded, when the signals were stable without any interference, for more than 10s. For all electrodes, a glass resistance measurement device (EZM 5AB) was used to maintain the resistance at <5kΩ. To minimise contact resistance with the skin, the attachment area was swabbed with alcohol. The plate electrodes were attached using electrode glue (ElefixZ-401CE, Nihon Kohden, Japan) and subsequently covered with gauze to allow the glue to affix the electrodes to the surface of the head.

EEG data were collected using the Brain Mapping System for real-time data collection and time-series analysis. In addition, the EEG was amplified 50 000-fold using an EEG amplifier (EEG100B, Biopac System Inc., Korea). EEG signals from 20 channels were saved to computers at a sampling frequency of 256Hz through a 0.5-50Hz pass filter and 12-bit analogue-digital converter. The relative α power of the collected data were calculated by Telescan 2.0 software (Laxtha Inc., Daejeon, Korea), using EEG data from 4 areas: Fp1, F3, F4, and C4. The relative α power was analysed by calculating the relative ratios of the appearance of α rhythms to θ, α, β, and γ rhythms and excluding the δ rhythm. The α waves were investigated in the present study, because mental concentration can be observed as α waves among various EEG wave types during exercise (Kamp & Troost, 1978; Boutcher & Landers, 1998).

In addition, the *Stroop test* was performed to assess cognitive function (Stroop, 1935). During the Stroop test, the participants were instructed to identify verbally the colour of a written word, and not the word itself, as quickly as possible. The Stroop test contains 100 items arranged in 20 rows and 5 columns. The number of correct answers given in 2 minutes was recorded.

Exercise programme

The CET group performed 10min of whole-body stretching as a warm-up and a cool-down at each training session. The main 80-min exercise programme consisted of 40min of treadmill running at 60-80% of heart rate reserve, followed by 40min of resistance training, which included squats, leg press, leg curl, bench press, lat pull-down, seated cable row, shoulder press, bicep curls, triceps extensions, and sit-ups. The resistance exercise portion of the session involved 2 sets of 50-70% 1 repetition maximum for each exercise. Exercise intensity during the aerobic exercise training sessions was monitored using a Polar real-time system (Polar-S610, Kempele, Finland).

Statistical analysis

The mean and standard deviation were computed for each test item. Differences in the baseline characteristics between groups were assessed by independent *t*-tests. In addition, 2-way repeated-measures ANOVA was used to determine significant changes in the dependent variables for pre- and post-exercise compared to the control group. All analyses were performed using SPSS version 18.0 (SPSS, Chicago, IL, USA). The level of significance was set at $p<0.05$.

RESULTS

There were no significant differences between groups at baseline except for height. Changes in body composition, physical fitness variables, and cognitive function after combined exercise training for 16 weeks for a group of Korean children are shown in Table 2, 3 and 4. There were significant interaction effects (time x group) on EEG activation at Fp1 (p=0.034), F3 (p=0.028), and C4 (p=0.013) and the Stroop test (p=0.005) (Table 2). However, there were no significant interaction effects (time x group) on body composition (Table 3) or physical fitness variables (Table 4).

TABLE 2. **CHANGES IN COGNITIVE FUNCTION VARIABLES**

Variables		Group	Pre-exercise	Post-exercise	Interaction F	Interaction p-value
Electro-encephalo-graphy activation for brain areas:	Fp1	Control	0.70±0.24	0.78±0.46	5.297	0.034*
		Combined	0.69±0.29	1.38±0.87		
	F3	Control	1.07±0.35	0.91±0.27	5.744	0.028*
		Combined	0.99±0.39	1.74±1.40		
	F4	Control	1.03±0.42	1.27±1.00	1.271	0.274
		Combined	1.02±0.38	1.70±1.17		
	C4	Control	2.54±2.08	1.42±0.60	7.550	0.013*
		Combined	1.69±0.68	2.63±1.90		
Stroop test (counts/2min)		Control	54.70±16.97	58.60±18.23	10.234	0.005**
		Combined	47.90±10.41	57.00±12.74		

Interaction= (Group X Time) *p< 0.05 and **p< 0.01 (Repeated-measures ANOVA)

TABLE 3. **CHANGES IN BODY COMPOSITION**

Items	Group	Pre-exercise	Post-exercise	Interaction F	Interaction p-value
Weight (kg)	Control	27.85±3.76	29.46±4.12	0.026	0.873
	Combined	26.83±4.75	28.52±5.14		
BMI (kg/m^2)	Control	16.13±1.51	16.53±1.83	0.009	0.925
	Combined	17.10±2.16	17.53±2.09		
Fat-free mass (kg)	Control	22.68±2.72	23.65±2.94	0.266	0.612
	Combined	21.35±2.09	22.15±2.47		
Body fat (%)	Control	18.35±5.57	19.44±6.39	0.949	0.343
	Combined	19.28±9.00	21.44±7.42		
BMR (Kcal)	Control	859.97±58.80	880.84±63.60	0.266	0.612
	Combined	831.19±45.08	848.39±53.41		

Interaction= (Group X Time) p< 0.05

TABLE 4. **CHANGES IN PHYSICAL FITNESS**

Items	**Group**	**Pre-exercise**	**Post-exercise**	**Interaction F**	**p**
Sit-ups (reps/60s)	Control	21.30±12.31	20.50±16.50	0.409	0.531
	Combined	27.10±10.41	28.00±9.78		
Grip strength (R) (kg)	Control	10.60±2.85	10.81±3.13	0.001	0.990
	Combined	9.69±2.87	9.91±3.36		
Grip strength (L) (kg)	Control	9.88±3.73	11.36±3.07	0.361	0.555
	Combined	9.22±3.17	10.17±3.68		
Sit-and-reach (cm)	Control	10.66±4.94	11.15±4.84	0.472	0.501
	Combined	9.31±3.14	10.60±3.07		
Stand. long jump (cm)	Control	125.50±24.79	127.35±19.70	0.717	0.408
	Combined	124.40±14.10	122.60±16.37		
Side-steps (reps/30s)	Control	35.70±8.43	39.80±6.65	0.281	0.603
	Combined	35.90±6.17	38.80±5.88		
Isok. leg ext. strength (R) (kg)	Control	13.60±4.83	14.00±4.48	0.016	0.900
	Combined	10.17±3.81	10.30±3.77		
Isok. leg ext. strength (L) (kg)	Control	11.48±5.60	12.41±3.79	0.415	0.527
	Combined	7.91±3.93	10.20±3.87		

Interaction= (Group X Time) $p < 0.05$

DISCUSSION

This study investigated the effects of a 16-week combined aerobic and resistance exercise programme on body composition, physical fitness, and cognitive function in a group of Korean children. The combined aerobic and resistance exercise programme significantly improved cognitive function as measured using EEG activation and the Stroop test. However, no significant improvements were observed in any body composition or physical fitness variables.

Several studies indicate that exercise intervention can positively affect body composition in obese children, including increasing fat-free mass and decreasing body fat (McGuigan *et al.*, 2009; Alberga *et al.*, 2011; Alberga *et al.*, 2013; Kelley & Kelley, 2013). However, in the present study, there were no significant differences in body composition after the exercise intervention. This might be because the subjects in the present study were non-obese children aged 8-11 years who were undergoing rapid growth, and exercise may have had only a relatively small effect on body composition compared to obese children. In particular, because normal non-obese children of these ages are generally in very good physical condition, relative to that in other stages in life, regular combined exercise does not significantly affect their body composition condition compared to controls. Nevertheless, additional well-designed studies are necessary to determine the effect of long-term (>6 months) exercise interventions on body composition.

The meta-analysis of Dobbins *et al.* (2013) indicates physical activity programmes help increase VO_{2max}, a measure of aerobic physical fitness. Several previous studies investigated only VO_{2max} as a measure of physical fitness (Pedersen 2007; Lee *et al*., 2010; Dobbins *et al*., 2013). Although VO_{2max} is the gold standard for assessing physical fitness per se, it is also a component of health-related physical fitness, which also includes cardio-respiratory endurance, muscular endurance, muscular strength and flexibility. Other exercise measures include motor-related physical fitness components, such as power, agility, and balance (Vivian, 2010).

In the present study, neither health- nor motor-related physical fitness variables differed significantly between the exercise and control groups post-intervention. As mentioned above, normal non-obese children have relatively good physical fitness, indicating regular exercise is unlikely to affect significantly health- or motor-related physical fitness compared to controls. Exercise is strongly associated with changes in brain function and activity (Ogoh *et al*., 2005; Helena *et al*., 2007). Moreover, it has psychological and social benefits, such as improved self-esteem, social interactions and mood, as well as decreased anxiety and depression (Brown *et al*., 2013; Eime *et al*., 2013). In addition, exercise improves cognitive and memory functions and academic performance (Ploughman, 2008; Flöel *et al*., 2010; So, 2012). Thus, although the exercise intervention had little or no effect on body composition or physical fitness in the case of the normal non-obese children in the present study, the results strongly corroborate previous findings that exercise positively affects the psychological and cognitive functions of the brain. Additional well-designed studies are required to determine the extent to which exercise affects specific brain areas, as well as psychological and cognitive functions.

This study has some limitations. Because the participants were recruited from a single children fitness centre in Korea and the sample was small, the results are not representative of all Korean children. In addition, this study entails a relatively short intervention and a lack of follow-up testing to investigate the long-term effects of the intervention. However, this study consisted of a 16-week intervention and included complicated measurements, such as cognitive function. Moreover, the number of subjects in the present study was similar to those of more advanced studies. The validity and reliability of the Stroop test have been confirmed in studies with a similar sample size to the present study. Regardless, the major strength of this study is that it focused on normal non-obese children performing a combined exercise programme.

CONCLUSION

A 16-week supervised combined exercise programme positively affected the cognitive function in this group of Korean children. However, it did not affect body composition or physical fitness. Thus, such programmes may benefit the cognitive function of children.

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The authors declare that there is no conflict of interest.

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