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Taekwondo training improves CVD risk factors in obese male adolescents

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Abstract

Background & Study Aim: Prevalence of obesity during growth periods has been increased remarkably worldwide. We placed special emphasis on after-school taekwondo training programs to prevent obesity. The aim of this study was knowledge about the effects of taekwondo training on cardiovascular disease risk factors in obese male adolescents.

Material & Methods: Twenty three obese male adolescents who were above the 95th percentile for body mass index: 29.7±2.26 kg·m^{-2}, aged 14.0±0.90 years, were randomly assigned to taekwondo training group (TTG, n = 12) and control group (CON, n = 11). Taekwondo training was conducted 60 min a day, 3 days per week for 16 weeks. Blood lipids, blood pressure, and arterial stiffness were measured as cardiovascular disease risk factors. health-related fitness including flexibility, muscle strength, muscle endurance, and cardiorespiratory fitness were measured.

Results: Taekwondo training significantly decreased body weight ($F=8.667$, $p<.01$), body mass index ($F=9.261$, $p<.05$) and improved right brachial-ankle pulse wave velocity ($F=5.707$, $p<.05$). The values of sit and reach ($F=9.436$, $p<.01$), standing long jump ($F=11.465$, $p<.01$), sit-ups ($F=7.429$, $p<.01$), and peak VO_2 ($F=4.513$, $p<.05$) were significantly increased in TTG after 16 weeks of taekwondo training.

Conclusions: Our study revealed that taekwondo training improves arterial stiffness as well as health-related fitness. Taekwondo training may be recommended as a sports-based physical activity program for improving cardiovascular health in obese male adolescents.

Keywords: arterial stiffness • cardiovascular disease • health-related fitness • obese adolescents • taekwondo

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Taekwondo – an Olympic sport which is originated from Korean martial art. Taekwondo training comprise of various movements such as kicking, punching, and stepping.

CVD risk factors – cardiovascular disease are caused by various risk factors such as high blood pressure, abnormal blood lipid profiles

Health-related fitness – the components of health-related fitness involve cardiovascular fitness, muscular strength and endurance, flexibility, and body composition that helps you to stay healthy.

Poomse – it is traditionally understood as the style of conduct which expresses directly or indirectly mental and physical refinements as well as the principles of offense and defence resulting from cultivation of taekwondo spirit and techniques. Nowadays, poomse is involved in competition in the taekwondo technique modality [31].

Introduction

Obesity has become one of the major risk factors for conditions inducing hypertension, metabolic syndromes, atherosclerosis, and cardiovascular diseases (CVD) [1]. The prevalence of obesity during adolescence has been increasing gradually worldwide, despite various intervention efforts to reduce the rate of increase [2].

Physical inactivity is associated with fat accumulation and metabolic dysfunctions. A recent study reported that the level physical activity during adolescence gradually declines by average 7.0% per year [3]. Adolescents who spent more hours watching TV are at greater risk of being overweight, high abdominal fat, and low HLD-C [4]. This sedentary lifestyle and physical inactivity during adolescence may carry over into adulthood [5].

Various forms of physical activity have been implemented to improve CVD risk factors and health-related fitness without dietary intervention [6-8]. The major effects of aerobic exercise are the reduction of fat mass and blood lipids [6]. while resistance exercise enhances muscle mass and strength [7]. Recent study reported that a combination of aerobic and resistance exercise is more efficient than a single exercise alone to prevent CVD risk factors [8]. However, a previous study reported that it is difficult to manage exercise interventions in adolescents compared with young children and adults [2]. Monotonous movements such as running on the treadmill or lifting weights even can deter obese adolescents from exercise. Physical activities during adolescence should be pleasurable and sustainable. For this reason, sport-based activities (i.e. football, basketball, and volleyball) are often applied to increase their motivation. According to a longitudinal study, sports participation from childhood to adolescence is associated with decreasing fat and developing health-related behaviours [9].

Taekwondo is a popular martial art and Olympic combat sport originated in Korea. Many people worldwide practice taekwondo since childhood, because it enhances their self-discipline, self-confidence, and physical fitness while providing self-defence techniques [10-12]. A previous study reported that taekwondo training reduced fat mass and improved physical fitness in untrained female adolescents [11]. Taekwondo training is also characterized by high intensity and intermittent activities including various basic movements of jumping, stepping, punching, and kicking [13]. A pervious study showed that 20 minutes of taekwondo training can burn up to 300 kcal in adult males which meets the recommended level of daily physical activity based on American College of Sports Medicine (ACSM)'s guideline [14]. Therefore, taekwondo training is a reasonable option for a sports-based physical activity program in obese adolescents.

To the best of our knowledge, this is the first approach that investigates the effect of taekwondo training on CVD risk factors in obese adolescents. Most previous studies used taekwondo as an exercise intervention recruited adult athletes as a participant and focused on exercise performance [13]. However, a large portion of trainees who participate in regular taekwondo training are children and adolescents.

Thus, the aim of this study was knowledge about the effects of taekwondo training on cardiovascular disease risk factors in obese male adolescents.

Material and methods

Participants

The participants were recruited by flyers and oral presentations during an after school activity program in a local middle school. Thirty obese male adolescents aged 13-15 years. old who had over 95 percentile of body mass index (BMI) in the CDC growth reference chart [15], voluntarily participated in the study. All participants were not taking any medical medications related with CVD and were able to participate the physical activity program. Participants were randomly assigned to taekwondo training group (TTG) or control group (CON). None of them had taekwondo experience within the last two years. During the study period, seven participants dropped out from the study due to personal reasons. Therefore, twenty-three participants (TTG; n = 12, CON; n = 11), aged 14.0±0.90 years and BMI 29.7±2.26 kg/m^2, completed this study.

Written informed consent was obtained from participants and their parents. This study was approved by the Institutional Review Board of the University.

Measures

All variables were measured the before and after intervention at the same time of day. Body height was measured with barefoot on the stadiometer (STDK Model 1, HD, Japan). Body weight was measured with minimal clothing on a digital weight scale (CAS, Korea). BMI was also calculated before and after the intervention periods. Blood pressure was measured with an automatic device (VP-1000; Omron Healthcare, Japan). Participants were sitting in a silent room for five minutes prior to measure right forearm blood pressure.

Blood samples from all participants were collected between 9 and 10 a.m. before and after the intervention periods. They were instructed to fast for 12 hours prior to the test and limit intense physical activity for the last 24 hours. Venous blood samples (4 ml) were taken from the antecubital vein and separated into SST tube. The samples were centrifuged with 3,000 rpm for 10min and stored at –80°C. Total cholesterol (TC), high density lipoprotein cholesterol (HDL-C), and low density lipoprotein cholesterol (LDL-C) levels were analysed using a Colorimetry assay (AU680, Beckman coulter, USA).

Arterial stiffness was measured using the oscillometric technique (VP-1000; Omron Healthcare, Japan). Before the test, participants were prohibited from consuming caffeine and energy drinks which may affect cardiovascular function.

The test was performed in a silent and temperature controlled room. Participants lay in the supine position with electrocardiogram electrodes placed on both wrists. The cuff was connected to a plethysmographic sensor and an oscillometric pressure sensor was wrapped around both arms and ankles. Heart sounds were monitored by a microphone on the left edge of the sternum at the third intercostal space. Pulse wave velocity (PWV) was calculated by transmission time between two arterial recoding sites.

Average health-related physical fitness components including flexibility, muscle strength, muscle endurance, and cardiorespiratory fitness were measured before and after the intervention periods. The sit and reach test was used as a marker of flexibility. Participants sat with their leg fully extended and pushed a ruler as far as possible on a calibrated box. Muscle strength was evaluated using a hand dynamometer (Takei, TKK5101). Hand grip span was adjusted according to participants' hand size and maximal isometric strength generated by the dominant hand was recorded. The number of sit-ups with correct form within 60 seconds were recorded for measuring muscle endurance. Cardiorespiratory fitness was assessed on the graded exercise treadmill test with the Bruce protocol. Briefly, participants walked on the treadmill at a speed of 2.7 $km \cdot h^{-1}$ and at a 10% grade. Speed and grade were gradually increased every 3 min by 1.3 $km \cdot h^{-1}$ and 2% until participants were exhausted.

Peak VO_2 was determined when the participants met at least two of three criteria (a) showing signs of intense effort (heavy breathing, facial flushing, unsteady gait and sweating), (b) over 90% of their age-related maximum heart rate, and (c) a respiratory exchange ratio ≥1.0 [16]. Oxygen uptake was measured using a Quark b^2 (Cosmed, USA). Additionally, participants' standing long jumps were measured to evaluate the explosive power of lower limb. Participants stood on horizontal lines on the landing-mat. The distance was measured from the take off point to the landing point of the back of the heel.

Taekwondo training program

The TTG group performed 60 minutes taekwondo training 3 days per week for 16 weeks as an after-school activity program at an indoor gym. Participants first performed warm-up exercises for 10 minutes that included jogging, static stretching, and sports specific movements. The taekwondo training program was consisted of basic components of taekwondo movements including punching, kicking, stepping, sparring, and *poomsae*. For the last 10 min, participants performed a cool down program with meditation and muscle stretching. The intensity of taekwondo training was set at average 60-80% of their heart rate reserve (HRR). Once a week, five participants were randomly selected to monitor the intensity of taekwondo training by using a heart rate monitor (Polar, 5610i, USA) during the intervention periods. Meanwhile, the control group did not participate in any after-school activity program or private physical activity program during the intervention periods. All participants in TTG and CON participated regular physical education classes (2 times/wk) as a part of their school curriculum.

Questionnaires

Physical activity level was assessed by *Physical activity questionnaire for adolescents* (PAQ-A) before and after the intervention periods [17]. The questionnaire is designed for adolescent with a 7-days recall instrument which consisted of 9 items with 5-point scale. The mean score of 9 items indicates the physical activity level. A score of 1 indicates low physical activity, whereas a score of 5 indicates high physical activity. Dietary record for 3 days were collected before and after the intervention period. These dietary data were transferred to nutritional computer program (CAN pro. 4, KOREA) which base on Korean foods and analysed for total caloric intake, and for carbohydrate, protein, and fat.

Statistical analysis

All data were expressed as mean and standard deviation. Two-way repeated ANOVAs were used to analyse interaction effect between the groups and time. Independent t-test (between group effect) and paired t-test (within group effect) were also applied to compare the main effect. Pearson-correlation analysis was used to examine the relationship between percent change of baPWV and other variables. significant level was set at .05.

Results

The height increased both in TTG ($p<.01$) and CON ($p<.01$) during the intervention periods. Body weight ($F=8.667$, $p<.01$) and BMI ($F=9.261$, $p<.01$) were significantly decreased in TTG while CON did not show any changes. For arterial stiffness, right baPWV ($F=5.707$, $p<.05$) was significantly improved in TTG while CON did not show any changes during intervention periods (Table 1).

The percent changes of CVD risk factors are reported in Figure 1. Negative percent changes in total cholesterol (TTG; –5.8% vs CON; +8.5%, $p<.05$), LDL-C (–8.3% vs +3.8%, $p<.05$), systolic blood pressure (–3.2% vs +3.8%, $p<.05$), right (–6.4% vs 4.5%, $p<.05$) and left baPWV (–5.1% vs +3.4%, $p<.05$) were observed only in TTG indicating the improvements of CVD risk factors.

The effects of taekwondo training on health-related fitness are presented in Table 2. Taekwondo training significantly enhanced the value of sit and reach ($F=9.436$, $p<.01$), standing long jump ($F=11.465$, $p<.01$), sit-ups ($F=7.429$, $p<.05$), and peak VO_2 ($F=4.513$, $p<.05$) while CON did not show any changes from the baseline except for standing long jump ($p<.01$) during intervention periods.

Discussion

The primary findings of this study were that taekwondo training improved arterial stiffness and health-related fitness in obese adolescents. Body weight and BMI also decreased as a result of taekwondo training in the present study. Increasing

Table 1. Changes of anthropometric characteristics and arterial stiffness during 16 weeks of taekwondo training in obese adolescents.

Variable (indicator)	TTG (n = 12)		CON (n = 11)	
	Pre	Post	Pre	Post
Body height (cm)	**170.6 ± 8.90**	**172.3 ± 8.25****	**167.7 ± 7.62**	**169.4 ± 6.70****
Body weight (kg)	**84.6 ± 13.91**	**80.7 ± 14.88****	86.4 ± 10.09	86.9 ± 8.91
Body mass index (kg/m^2)	**28.9 ± 2.38**	**27.0 ± 3.03***	30.6 ± 1.78	30.2 ± 1.64
Systolic BP (mmHg)	128.9 ± 11.07	124.2 ± 8.07	123.1 ± 9.95	127.3 ± 9.92
Diastolic BP (mmHg)	66.9 ± 9.15	64.6 ± 7.39	62.9 ± 6.63	65.8 ± 8.14
Right baPWV (m·s^{-1})	**995.0 ± 147.59**	**922.1 ± 97.30***	912.5 ± 110.06	949.5 ± 129.71
Left baPWV (m·s^{-1})	993.0 ± 144.66	930.5 ± 97.89	934.7 ± 112.47	962.3 ± 116.40

baPWV brachial-ankle pulse wave velocity; **BP** blood pressure; **TTG** taekwondo training group; **CON** control group; ***p<.05,** ****p<.01** indicates significant time effect within group

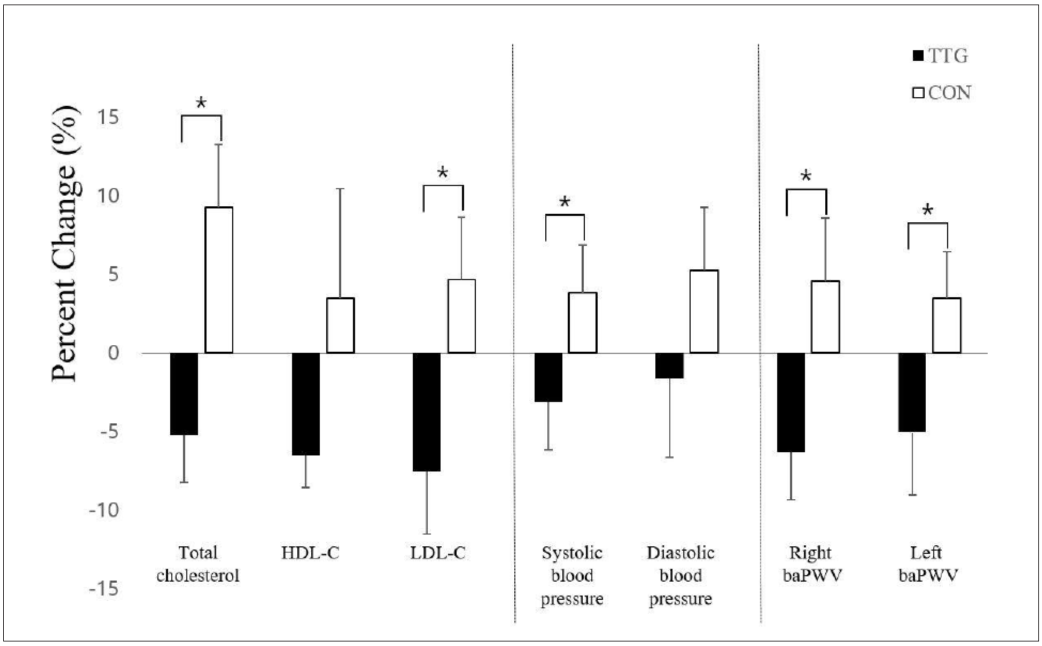

Figure 1. Percent changes of CVD risk factors during 16 weeks of taekwondo training in obese male adolescents.

baPWV brachial-ankle pulse wave velocity; **TTG** taekwondo training group (n = 12); **CON** control group (n = 11); **HDL-C** high density lipoprotein cholesterol; **LDL-C** low density lipoprotein cholesterol; * (indicates significant difference between TTG and CON at p<.05)

Table 2. Changes of health-related fitness (mean and SD) during 16 weeks of taekwondo training in obese adolescents

Variables (indicator)	TTG (n=12)		CON (n=11)	
	Pre	Post	Pre	Post
Sit and reach (cm)	**2.3 ±7.35**	**9.5 ±5.34****	2.0 ±8.38	4.0 ±6.38
Grip strength (kg)	**30.1 ±7.31**	**32.4 ±7.91***	28.0 ± 7.67	29.0 ±6.49
Standing long jump (cm)	**149.3 ±20.84**	**175.1 ±14.58****	**151.2 ± 29.42**	**162.6 ±28.0****
Sit-ups (reps·min^{-1})	**21.8 ±9.53**	**33.4 ±7.97 ****	19.2 ± 14.39	23.5 ±12.40
Peak VO_2 (ml·kg·min^{-1})	**42.0 ±5.32**	**46.8 ±6.64***	38.6 ± 4.29	39.0 ±5.12

***p<.05, ** p<.01** indicates significant effect within group

physical activity with intervention programs were proven to reduce body weight and percent body fat in obese adolescents, especially during aerobic type exercise compared to resistance type exercise [6]. A previous study demonstrated that taekwondo training decreased fat mass and percent body fat in female adolescents [11]. Our study showed a greater reduction of body weight compared to previous study [11]. We assumed that different gender (male vs female), higher intensity (60-80% vs 60%), more frequency (3 times/week vs 2 times/week), and longer duration (16 weeks vs 12 weeks) as well as growth effect may result in greater reduction in body weight and body composition in our study compared to previous studies. However, another exercise training study using martial art did not show significant changes in body weight and composition.

Tsang et al. [18] reported that 6 months of *kung fu* training did not change body composition in obese adolescents. They assumed that intermittent low intensity of *kung fu* training with longer rest time may not provide enough stimulation for changes of body composition. Therefore, it is important to note that sports-based exercise program should consider the appropriate intensity and frequency for changing body weight and composition in obese adolescents. Our study confirmed that 16 weeks of taekwondo training could be an effective intervention program for weight control in obese adolescents.

The blood lipids profiles in obese children and adolescents should be closely monitored to prevent development of CVD in adulthood [19]. Up to 50% of obese children who had dyslipidemia accumulated the fatty steaks in the endothelium, which could lead to atherosclerotic CVD [20]. Our study demonstrated that the percent changes of total cholesterol (TTG; –5.8% vs CON; +8.5%) and LDL-C (–8.3% vs +3.8%) were significantly different between two groups during intervention periods. The effects of exercise interventions on blood lipid levels were different from study to study. Swimming or soccer training for 12 weeks increased HDL-C (swimming: +5.7%, soccer: +3.1%) but, reduction of LDL-C (–9.5%) was only shown in the soccer training group [21].

Another study reported that combined exercise (swimming, playing ball games, and walking) for 6 months reduced triglyceride (–26%) and LDL-C (–5.2%) without changing HLD-C in obese adolescents [22]. Many factors, including participants' characteristics (e.g. habitual physical activity level, percent body fat, and dietary intake) and intervention programs (e.g. exercise type, intensity, duration, and frequency), can influence the changes of blood lipids during adolescence [23].

Furthermore, the improvement of HDL-C was observed following a combination of resistance training with aerobic exercise, not aerobic exercise alone [8, 23]. Nevertheless, uncertain explanations remain as to why our participants in TTG decreased HDL-C level in the present study. In the present study, total cholesterol (+8.5%) and LDL-C (+3.8%) levels significantly increased in CON during intervention periods. These results suggested that regular physical education classes (2 times/wk) in school maybe insufficient to improve blood lipids profile in obese adolescents.

Obesity is associated with endothelial dysfunction during adolescence [24]. Arterial stiffness appeared to be an independent risk factor for developing CVD. Age, sex, lifestyle, and habitual exercise influence the changes of arterial stiffness [25]. Measurements of arterial stiffness in obese adolescents require careful design using non-invasive techniques. PWV commonly represents vascular function. In the present study, taekwondo training improved the right baPWV. A previous study indicated that performing jumping exercise for 12 weeks improved vascular compliance in obese adolescents [26]. Improvement of arterial stiffness through taekwondo training may be explained by several factors.

First, taekwondo training is composed of many stretching exercises, which continuously repeat short-length muscle movements. The large group of muscle is especially mobilized during kicking movements in taekwondo practice [27]. Therefore, great mechanical force on blood vessels might be occurring during taekwondo training.

Second, Taekwondo training may change the endothelial structure due to nitric oxide (NO)-mediated remodelling. Previous studies reported that exercise training improved endothelium function by up-regulating endothelial NO synthase expression [28]. We assumed that taekwondo training involving large muscle group increased the activation of the endothelial NO synthase via kinase AKt-dependent phosphorylation [28]. Therefore, endothelial structures might be adapted by taekwondo training.

Third, changing blood pressure and lipids through taekwondo training may lead to improved vascular function. A previous study reported that PWV is positively related with total cholesterol and triglyceride in hypertensive male adults [29]. The percent changes of baPWV was also positively related with systolic blood pressure ($r = .54$, $p<.01$), diastolic blood pressure ($r = .41$, $p<.05$), and LDL-C ($r = .35$, $p<.05$) in the present study. Although taekwondo training could not show significant change in blood pressure, the mean levels of systolic (–3.2%) and diastolic (–1.7%) blood pressure were decreased. Thus, decreasing blood pressure and lipids levels may play an important role in improving arterial stiffness in obese adolescents.

The findings of this study revealed that taekwondo training can improve health-related fitness. Increased flexibility (sit and reach) through taekwondo training was an expected result; as taekwondo training is comprised of many kicking techniques, which require a high level of lower extremity flexibility. Elite taekwondo athletes are also characterized by greater limb flexibility than other combat sports athletes [10, 13]. A previous study reported that sit and reach (12.3%) test score increased through 12 weeks of taekwondo training in female adolescent [11]. Taekwondo training may be a preventative program against a growth-related decrease in flexibility during adolescence [30]. Muscle fitness involved in standing long jump and sit-ups were enhanced by taekwondo training. Taekwondo training involves many twist movements between the upper and lower body, which stimulates the trunk and lower limbs muscles. For instance, basic kicking techniques such as the round house kick, side kick, back kick, and spin hook kick require twisting motions to generate power and maintain balance. These specific movements of taekwondo training may improve standing long jump and sit-ups scores in obese adolescents.

On the other hand, taekwondo training may not provide enough stimulation for improving upper limb strengths, such as grip strength. There was no improvement in grip strength in the present study. Previous study also showed that grip strength was not changed by taekwondo training, whereas lower limb muscle strength and endurance increased in female adolescents [11]. We confirmed that taekwondo training develops muscle fitness, especially in trunk and lower limbs in obese adolescents. Cardiorespiratory fitness was the primary variable of health-related fitness in our study because it is a powerful marker for predicting CVD in adulthood.

The present study showed that taekwondo training improved peak VO_2 (11.6%) in obese adolescents. A previous study reported that jumping exercise 3 days per week for 12 weeks (60-80% of HRR) improved aerobic fitness (14.3%) in obese adolescents [26]. However, taekwondo training 2 times a week for 12 weeks (60% of HRR) could not improve peak VO_2 in female adolescents [11]. Exercise type, intensity, and frequencies are major factors influencing cardiorespiratory fitness in obese adolescents. We suggest that increasing cardiorespiratory fitness through taekwondo training is required at least 3 times a week and over 60% of HRR intensity in general trainees including obese adolescents.

Conclusions

Four months of taekwondo training reduced body weight, BMI and improved arterial stiffness as well as health-related fitness in obese male adolescents. Also, positive changes of cholesterols and systolic blood pressure were observed through taekwondo training. Therefore, our study demonstrated that taekwondo training is beneficial for improving CVD risk factors in obese adolescents. Instructors and teachers may consider taekwondo training as a suitable sports-based physical activity program for obese adolescents. Additionally, we also found that regular physical education classes (2 times/week) in schools may not be sufficient to decrease the CVD risk factors in obese adolescents.

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