ORIGINAL ARTICLE

The effect of taekwondo training on physical fitness and the allergic response factor of hypersensitive obese children

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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ABSTRACT

Background and Study Aim: Allergies can lead to the development of sleeping disorders and impede normal growth in children. Therefore, it is necessary to act on allergies by improving lifestyles through non-pharmacologic treatments. The aim of this study was knowledge about the effects of taekwondo training on physical fitness and allergic responses in obese male children with allergic diseases.

Material and Methods: Fourteen children with allergic rhinitis, atopic dermatitis, and with more than 20% body fat, aged 11.5 ±0.58 years, were randomly assigned to taekwondo training group (n = 7) and control group (n = 7). Taekwondo training was conducted 60 min a day, 5 days per week for 12 weeks. Body compositions, blood pressure, allergic response factor (IgE, IL-4, histamine) were measured. Physical fitness including muscle strength, muscle endurance, flexibility, balance, agility, isokinetic muscle function and cardiorespiratory fitness ware measured.

Results: Taekwondo training significantly increased lean body mass ($p<0.05$), knee extension at 60°/sec ($p<0.01$), knee extension at 180°/sec ($p<0.05$), grip strength ($p<.05$), vertical jump ($p<0.01$), sit-up ($p<0.05$) and VO2max ($p<0.01$). IgE was decreased, and IL-4 ($p<0.05$) significantly was decreased in Taekwondo training group.

Conclusions: Regular taekwondo training improved the body composition of all obese children with allergic rhinitis and atopic dermatitis, developed cardiovascular fitness and leg strength further, and reduced allergic responses, demonstrating that it is an effective method to improve allergic diseases of growing children with allergies.

Keywords: body composition • immunoglobulin • interleukin • non-pharmacologic treatments

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INTRODUCTION

Globally, allergies are described as chronic inflammatory diseases in childhood [1], and overweight or obese children display a higher incidence of allergic disease than normal-weight equals [2, 3].

The precise mechanisms underlying obesity and allergies are unclear, but in the case of children, overweight and obesity have been linked to allergic rhinitis [4, 5]. Also, children who are at the same time obese and allergic have been reported to be less physically active than those who are not [6]. In particular, allergies can lead to the development of sleeping disorders and impede normal growth in children and adolescents. Therefore, it is necessary to act on allergies by improving lifestyles through non-pharmacologic treatments [7, 8].

For instance, prior studies have demonstrated that physical exercise protects the body against diseases associated with chronic inflammations, that it increases anti-inflammatory cytokines, and that it reduces pro-inflammatory ones through the release of cytokine inhibitors [9]. With regular physical exercise, the incidence of infections is lower than for completely sedentary behaviours [10]. However, a high-intensity physical exercise that lasts for more than one week can result in long-term immune function impairments, with an increased risk of infections by 100 to 500% [11, 12].

The IgE (immunoglobulin E) level is one of the major indicators of allergic diseases. It has been reported that IgE levels are higher in obese children than in those with normal weight [13]. Additionally, IL-4 (interleukin-4) induces B-cell differentiations in the production of antibodies and inhibits the generation of type-1 helper T-cell cytokines. Therefore, physical exercise is needed to prevent inflammatory diseases, including allergies.

Taekwondo is one of the most popular sports practised by people of all ages in more than 200 countries [14, 15]. In this martial art, the hands and feet are used for the skills of attack and defence; both high-intensity and intermittent trainings are featured, including a variety of basic actions such as jumps, steps, punches, and kicks [16]. In addition, a 20-minute taekwondo training session consumes 300 kcal, the recommended level of daily physical activity suggested by the American College of Sports Medicine (ACSM) [17].

This study is the first approach of its kind to investigate the effects of taekwondo training on allergic responses of obese children. Previous research on taekwondo has been examined it as a type of physical exercise with a focus on the performance of elite and adult athletes in competitions [18], although most participants of taekwondo sessions are children and adolescents.

The aim of this study was knowledge about the effects of taekwondo training on physical fitness and allergic responses in obese male children with allergic diseases.

MATERIAL AND METHODS

Subjects

Twenty children with allergic rhinitis, atopic dermatitis, and with more than 20% body fat at the Sacheon City Youth Culture Center in Gyeongsangnam-do, South Korea, were recruited. The study was approved by the Ethics Committee of Dong-A University (2-104709-AB-N-01-201703-HR-008-02).

The sample consisted of 12- to 13-year-old boys. Six of them were excluded from the study for personal reasons. The final study sample comprised a taekwondo training group and a control group (n = 7 each), 14 subjects in total. The participants' physical characteristics are shown in Table 1.

Procedures

Body composition and blood pressure

The subjects were instructed to maintain fasting for eight hours and to wear comfortable clothing. The measurement points were before (baseline) and after the taekwondo training. Body height, body weight, body fat percentage, fat mass and lean body mass were measured using the InBody 470 body composition analyser (InBody Co., Ltd., Seoul, South Korea).

The blood pressure was measured three times (both systolic and diastolic), using a CK-E301 mercury blood pressure monitor (Chin Kou Medical Instrument Co., Ltd., Taiwan).

Fitness measurement

Physical fitness was measured using Helmas (Health management system, O2 Run, Korea) [19]. Muscle strength was measured with a digital grip dynamometer (Takei Kiki Kogyo Co.,

Immunoglobulin E (IgE) – IgE is the antibody that causes acute allergic reactions; it is measured to detect allergic conditions [39].

Interleukin-4 (IL-4) –is a pleiotropic cytokine produced in response to receptor activation by TH2-type CD4+ T cells, basophils, and mast cells [40].

Hypersensitivity – the state where even a tiny amount of allergen can cause severe allergic reactions [39].

Chronic – *adjective* **1.** used for describing a disease or condition that lasts for a long time. Compare **acute 2.** used for describing severe pain [41].

Muscle endurance – *noun* the capacity of muscles to sustain prolonged aerobic activity [41].

Baseline – *noun* **1.** a boundary line at each end of a court that marks the limit of play in tennis, badminton or basketball **2.** on a baseball field, a line running from home plate to first base and from home plate to third base, and extending into the outfield as foul lines **3.** in baseball, the area within which a base runner must stay when running between bases **4.** the point from which change can be measured [41]: in this work in the sense of **4**.

Poomse (kata in karate) – it is traditionally understood as the style of conduct which expresses directly or indirectly mental and physical refinements as well as the principles of offence and defence resulting from cultivation of taekwondo spirit and techniques. Nowadays, poomse is involved in competition in the taekwondo technique modality [42].

Taegeuk – in the context of **taekwondo** refers to a set of ***pumsae*** (also known as ***poomsae*** or ***poomse***) or forms used to teach taekwondo. A form or ***pumsae*** is a defined pattern of defence-and-attack motions. Outside of the context of taekwondo, the word ***taegeuk*** refers to the **Taoist** principle of the "unity of opposites" (***yin*** **and** ***yang***). ***Taegeuk*** is also the name of the red and blue circular symbol used in the **flag of South Korea** [Wikipedia].

Neurotrophic – adjective relating to the nutrition and maintenance of tissue of the nervous system [41].

Table 1. The characteristics of study subjects.

Variables	Taekwondo (n = 7)	Control (n = 7)
Age (years)	11.50 ±0.41	11.70 ±0.61
Body height (cm)	150.04 ±2.63	149.83 ±11.64
Body weight (kg)	50.06 ±8.20	48.87 ±14.00
Body fat (%)	30.03 ±7.05	28.33 ±9.95
Fat mass (kg)	15.51 ±5.90	14.23 ±8.21
Lean body mass (kg)	34.40 ±2.79	34.27 ±7.99
Systolic blood pressure (mmHg)	106.57 ±11.09	106.29 ±15.99
Diastolic blood pressure (mmHg)	58.43 ±7.32	62.14 ±10.09

Ltd., Tokyo, Japan): The legs are slightly spread and the arms opened in a natural way. After straightening the arms at about 15° and keeping the torso upright, the dynamometer can be grabbed. The maximum value is measured by two trial grips. Muscle endurance was assessed using a sit-up measuring device (NH-3000 N, 0811059) with both hands crossed over the chest and the abdominal strength used to raise the upper body. Flexibility was evaluated by a sit-and-reach measuring instrument (NH-3000 G, 0811054) with a posture of 90 degrees at the waist and the knees bent forward without reaching the bend. The distance (cm) at which the fingertip was pushed out was measured. The higher of the two values was recorded. The balance was defined as the time standing with one foot on the base of the measuring instrument on one leg and with a closed eye or with closed eyes while bending the knee of the opposite foot at 90 degrees. The left and right were measured once each and the longer standing times were recorded. An improvisation was performed with a vertical jump-measuring instrument (NH-3000 F-B, 0811055) on a mat, taking a ready position and jumping with the start. At that time, the knee was not lifted into the air, and the highest value from two trials was recorded. Agility was measured with a side step meter (NH-3000 J, 0811058), with both feet spread out around the centre line. We moved to the step with the start at both sides at a 100 cm interval, and one foot returned to the first posture beyond the right (or left) line. The number of times when both feet moved around the centre line for 20 seconds was measured.

Isokinetic muscle function test

To measure lower-limb isokinetic muscular functions, the knee's isokinetic muscle strength was measured using a Cybex 770 Norm (Lumex Inc., Ronkonkoma, NY, USA). The subject was seated in a chair and fastened firmly by a belt to the upper body and the hip. For the maximum muscle strength, three times at 60°/sec and three times at 180°/sec with a high-speed load to evaluate muscle endurance. The knee joint torque measurements were performed according to our previous studies [20]. Both the flexor and extensor muscle strengths were measured.

Maximum oxygen uptake test

Cardiorespiratory fitness testing was performed on a treadmill. The oxygen uptake and heart rate during physical exercise were analysed with Quark CPET, a fully automatic metabolism analyser (Cosmed Srl, Rome, Italy). After stabilisation for three minutes, the speed was increased by 1.0 km/h and the slope gradually increased by 1%, starting at 4.0 km/h and a 2% slope. The peak VO2 was determined when the participants met at least two of three criteria: (a) showing signs of intense effort (heavy breathing, facial flushing, unsteady gait, or sweating), (b) over 90% of the maximum heart rate according to the subject's age, and (c) a respiratory exchange ratio ≥1.0 [21].

Blood analysis

The participants' blood samples were collected between 8 am, and 10 am before and after the intervention. Eight-hour fasting prior to testing and limiting intense physical activities during 24 hours was recommended to the subjects. Blood in the amount of 10 ml was collected from the forearm with a cannula, using a disposable syringe

Table 2. The changes in body composition between baseline and 12-week taekwondo.

Variables	Group	Baseline	12 week	p-value
Body height (cm)	Taekwondo	150.04 ±2.63	**152.60 ±2.33****	0.443
	Control	149.83 ±11.64	**151.96 ±11.76****	
Body weight (kg)	Taekwondo	50.06 ±8.20	**52.24 ±8.98***	0.532
	Control	48.87 ±14.00	50.43 ±13.88	
Body fat (%)	Taekwondo	30.03 ±7.05	29.39 ±7.23	0.193
	Control	28.33 ±9.95	28.94 ±9.85	
Fat mass (kg)	Taekwondo	15.5 ±5.90	15.86 ±6.21	0.035
	Control	14.23 ±8.21	**15.57 ±8.44****	
Lean body mass (kg)	Taekwondo	34.40 ±2.79	**36.39 ±3.23***	0.21
	Control	34.27 ±7.99	35.14 ±8.34	

analysed by paired t-test: *p<0.05, **p<0.01; p-value was calculated by repeated Two-way ANOVA.

(Bom Medrea Co., Ltd.). Blood samples were centrifuged at 3,000 rpm for 10 minutes and stored at –80° C. IgE was analyzed by Phadia 1000 FEIA (fluorescence enzyme immunoassay) (Phadia AB, Uppsala, Sweden) and IL-4 as well as histamines were measured with a VersaMAX Microplate Reader (Molecular Devices, LLC., Sunnyvale, CA, USA) and analyzed by an ELISA (enzyme-linked immunosorbent assay).

Taekwondo training program

The taekwondo training program was conducted in program A (Monday, Wednesday, and Friday) and in a program B (Tuesday and Thursday) for 60 minutes, five times a week for 12 weeks. Warm-ups were performed for 10 minutes with static and dynamic stretching. Considering that the subjects were beginners, the sessions consisted of poomsae movements from the taegeuk chapters 1 to 3, basic movements such as steps, and kyorugi (sparring or competition). A cool-down was performed with stretching for the last 10 minutes.

During physical exercise, the heart rate was measured by wearing the portable wireless heart rate meter POLAR RS-400™ (Polar Electro Co., Finland). The intensity of the taekwondo training was 50-75% of the heart rate reserve (HRR), and the ratings of the perceived exertion (RPE) ranged from 12 to 17. The control group did not participate in personal exercise programs during the study period.

Statistical analysis

The similarities of the taekwondo and control groups were verified using SPSS 22.0 for Windows. The descriptive statistics of all variables were calculated as means and standard deviations. A two-way repeated ANOVA was calculated to determine group differences. Independence and response t-tests were performed when the effects of group and time were statistically significant. Pearson's correlation coefficients were calculated to identify associations among variables and the statistical significance was set at p<0.05.

RESULTS

Body composition

The height was increased in both the taekwondo training (p<0.01) and control groups (p<0.01). The controls showed a significant increase in fat mass (p<0.01) and a group by a time difference (p<0.05). Body weight (p<0.05) as well as lean body mass (p<0.05) were significantly increased in the taekwondo training group (Table 2).

Physical fitness and lower-limb isokinetic muscular functions

The knee extension at 60°/sec and 180°/sec was significantly increased in the taekwondo group (p<0.01, p<0.05) and there was also a significant group x time difference (p<0.01). Grip strength

Table 3. The changes of lower limb isokinetic function and physical fitness between baseline and 12-week taekwondo.

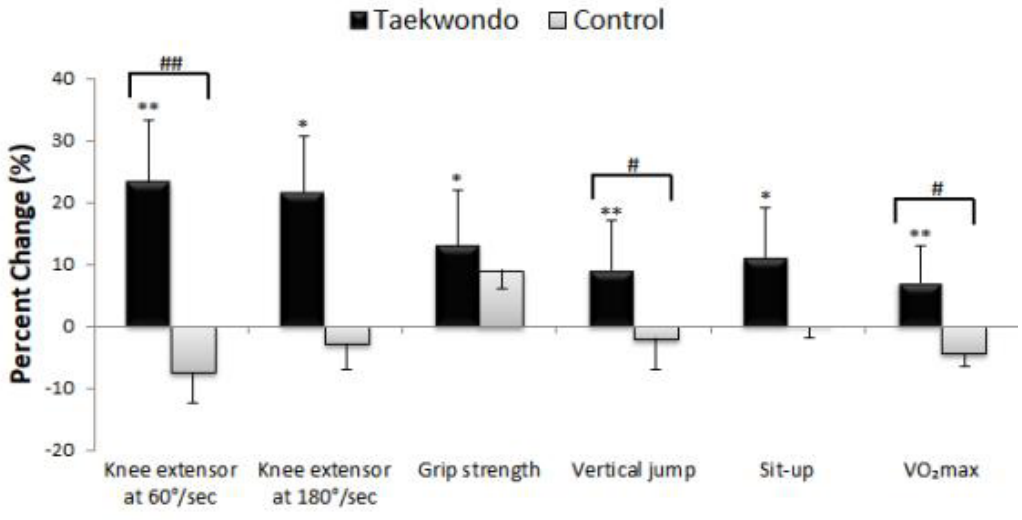
Variables	Group	Baseline	12 week	p-value
Knee flexor at 60°/sec (Nm)	Taekwondo	61.71 ±15.36	68.71 ±8.94	0.519
	Control	65.71 ±27.89	67.43 ±15.00	
Knee extensor at 60°/sec (Nm)	Taekwondo	86.43 ±17.27	**112.71 ±21.48****	0.001
	Control	94.86 ±23.87	88.29 ±12.79	
Knee flexor at 180°/sec (Nm)	Taekwondo	52.43 ±13.14	55.86 ±10.17	0.253
	Control	54.86 ±17.77	52.14 ±14.54	
Knee extensor at 180°/sec (Nm)	Taekwondo	57.14 ±8.13	**72.86 ±13.63***	0.053
	Control	57.43 ±22.60	55.71 ±16.14	
Grip strength (kg)	Taekwondo	16.06 ±2.71	**18.26 ±4.03***	0.451
	Control	16.17 ±4.22	17.61 ±3.60	
Sit-and-reach (cm)	Taekwondo	6.63 ±5.66	7.40 ±5.84	0.112
	Control	4.31 ±3.46	1.26 ±7.28	
Vertical jump (cm)	Taekwondo	30.43 ±4.08	**33.43 ±5.56****	0.019
	Control	34.00 ±7.85	33.57 ±5.94	
Sit-up /30sec (frequency)	Taekwondo	16.57 ±3.65	**18.57 ±3.60***	0.12
	Control	17.00 ±5.29	17.00 ±4.93	
Side-step /20sec (frequency)	Taekwondo	28.29 ±4.15	29.14 ±4.30	0.623
	Control	28.57 ±3.87	28.57 ±2.82	
Closed eyes one leg standing (sec)	Taekwondo	24.14 ±15.39	26.00 ±20.03	0.48
	Control	22.57 ±29.67	21.29 ±18.66	
VO_2 max (ml/kg/min)	Taekwondo	37.75 ±4.42	**39.55 ±4.65****	0.034
	Control	39.58 ±8.89	37.99 ±6.22	

analyzed by paired t-test: *p<0.05, **p<0.01; p-value was calculated by repeated Two-way ANOVA.

significantly increased in both the taekwondo and control groups (both p<0.05). The vertical jump was significantly increased in the taekwondo group (p<0.05), and there was a group by time effect (p<0.05). In addition, the sit-up performance significantly increased in the taekwondo group (p<0.05). VO2max also increased in the taekwondo group (p<0.01), indicating significant differences (p<0.05) between groups and time (Table 3 and Figure 1).

Allergic response factor

The taekwondo group sharply decreased in IgE levels which conversely increased in the control group, and there was a significant (p = 0.022) difference between groups and time (p<0.05). While IL-4 (p<0.05) diminished in the taekwondo group (p = 0.049, p = 0.018). Changes in allergic responses are shown in Table 4 and Figure 2.



Significantly different from baseline: *p<0.05, **p<0.01.

Significant interaction between groups and period: # p<0.05, ## p<0.01.

Figure 1. The comparison of isokinetic lower limb strength and physical fitness between baseline and 12 weeks intervention.

Correlations

IL-4 was negatively correlated with the knee extensor at 60°/sec (r = −0.598, p<0.05) and at 180°/sec (r = −0.570, p<0.05). The knee extensor at 180°/sec was positively correlated with the knee extensor at 60°/sec (r = 0.692, p<0.01) and with sit-ups (r = 0.648, p<0.05). The vertical jump showed a significant positive correlation with sit-ups (r = 0.808, p<0.001), while the VO2max revealed positive correlations with the knee extensors at 60°/sec and at 180° (r = 0.549, p<0.05; r = 0.601, p<0.05; r = 0.688, p<0.01; r = 0.717, p<0.05) (Table 5).

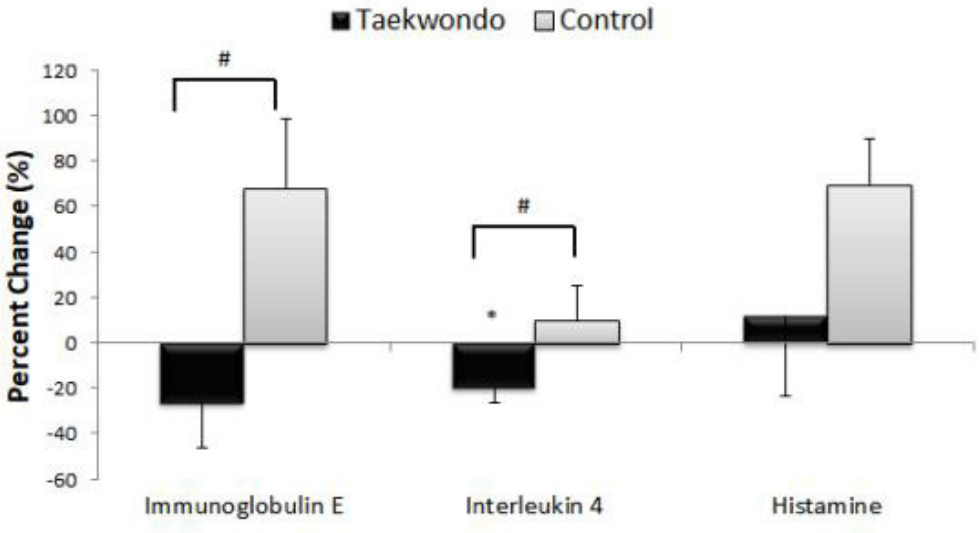
DISCUSSION

After 12 weeks of taekwondo training, physical fitness levels improved. Statistically significant increases were observed in limb isokinetic muscular strength, grip strength, vertical jumps, sit-ups, and the maximal oxygen uptake. Taekwondo

Table 4. The changes in allergy-related factors between baseline and 12-week taekwondo.

Variables	Group	Baseline	12 week	p-value
Immunoglobulin E (KU/L)	Taekwondo	445.40 ±464.64	258.61 ±317.81	0.022
	Control	187.50 ±104.28	339.71±271.58	
Interleukin 4 (pg/mL)	Taekwondo	0.118 ±0.037	**0.107 ±0.035***	0.018
	Control	0.114 ±0.035	0.122 ±0.041	
Histamine (ng/mL)	Taekwondo	0.698 ±0.358	0.599 ±0.235	0.216
	Control	0.707 ±0.41	1.052 ±0.489	

analysed by paired t-test: * p<0.05; p-value was calculated by repeated Two-way ANOVA.



Significantly different from baseline: *p< 0.05; Significant interaction between groups and period: # p<0.05.

Figure 2. The comparison of inflammatory cytokine and IgE between baseline and 12 weeks intervention.

is effective in improving physical activities through various body movements and in elevating the maximum muscular strength that occurs once muscles or muscle tissues contract. Kicks activate the flexors and extensors of the abdominal muscles, gluteal muscles, and knees [22-24].

The lower-limb isokinetic strength of the taekwondo group was increased in this study. Taekwondo kicks increased the knee extensors significantly at 60°/sec and 180°/sec after training because of their ability to stretch the lower limb muscles using the knee-flexing force. According to Blimkie et al. [25] and Froberg et al. [26], changes in the muscle development of children are associated with an increase in both testosterone levels and muscle mass, due to the acceleration of muscle strength as boys enter puberty. This study showed that the grip strength, vertical jumps, and sit-ups significantly increased in the taekwondo group. In particular, the vertical jump is an item that can be used to evaluate lower-limb strength. Previous studies have reported that the strength of the thigh's quadriceps muscle is positively correlated with grip strength and vertical jumps [27].

Maximal oxygen uptake is an indicator of aerobic capacity, which can be used as an evaluation basis for individuals' abilities to perform endurance exercises [28]. During rest, the liver, lungs, kidneys, and the brain consume the most energy, but during physical exercise, musculi skeleti consume the metabolic activity's majority [29]. The maximal oxygen uptake significantly increased in the taekwondo group and tended to decrease in the control group. Studies of adults have demonstrated that cardiovascular endurance tended to be relatively low in allergy patients compared to healthy individuals [30, 31], whereas a study with children reported a maximal oxygen uptake of 40.1 ml/kg/min at the ages of 11 to 13 years [32] which was 37.75 ml/kg/min before and 39.55 ml/kg/min after the taekwondo training in this study, although the latter value was not statistically different from the normal children's in the study by Carrel et al. [32]. In addition, other investigations have demonstrated that physical exercise improves the cardiorespiratory functional capacity of adult allergy patients [33], so taekwondo training does not only maintain cardiopulmonary functions in obese children with allergic diseases but also affects cardiovascular endurance, even after adulthood.

The root cause of allergies lies in the ingestion or inhalation of one or more allergens that initiate an IgE induction process [34]. In many studies, IgE has been demonstrated to be a mediator of allergies [35]. Interleukin 4 is known to be mainly

Table 5. Correlations coefficients between allergic response factor and fitness in obese children (n = 14).

Indicator	IgE	IL-4	EX 60°	EX 180°	Vertical jump	Sit-up	VO_2 max
IgE	-	.517	–.433	–.178	–.131	.112	.043
IL-4	.517	-	**–.598***	**–.570***	–.149	–.161	.102
EX 60°	–.433	**–.598***	-	**.692****	.254	.357	**.549***
EX 180°	–.178	**–.570***	**.692****	-	.491	**.648***	**.601***
Vertical jump	–.131	–.149	.254	.491	-	**.808*****	**.688****
Sit-up	.112	–.161	.357	**.648***	**.808*****	-	**.717****
VO_2 max	.043	.102	**.549***	**.601***	**.688****	**.717****	-

IgE immunoglobulin E; IL-4 interleukin 4; EX extensor; analysed by paired t-test: *p<0.05, **p<0.01, ***p<0.001.

produced by activated T cells, Th2, mast cells, and neutrophil spheres. In this study, IL-4 was significantly decreased, confirming the improvement of inflammations. The decrease of IL-4 seems to play a role in improving immunity and in reducing the production of allergy antibodies.

According to Tu et al. [36], serum IgE level cut-offs served optimally regarding atopy, allergic rhinitis, and eczema in 77.7 KU/L for Asian children with or without allergic diseases. The subjects in this study exhibited 445.40 ±464.64 KU/L in the Taekwondo group with atopic dermatitis or allergic rhinitis but decreased to 258.61 ±317.81 KU/L after training. According to Oh et al. [37], IgE levels were decreased in both 12 week aerobic and resistive exercises for middle school students with type-1 hypersensitivity reactions and depression. Although taekwondo training did not reach 77.7 KU/L, it was conducted in the group of obese children with allergic diseases (allergic rhinitis, atopic dermatitis), considering that allergies are chronic illnesses and decrease after taekwondo training, since the improvement of physical fitness and the reduction of inflammatory cytokines are expected to ameliorate allergic reactions.

The rate of change in correlations between physical fitness and allergic responses before and after taekwondo training displayed a positive correlation (r = 0.596) between IgE and IL-4. Previous studies have shown that people with allergies display higher IgE levels, suggesting that IL-4 stimulates the allergy antibody production [38]. In the taekwondo group of this study, IL-4 and IgE decreased, while IL-4 and IgE displayed a significant positive correlation (r = 0.596, p<0.05). Such changes are assumed to be effective in reducing inflammatory cytokines through taekwondo training.

In addition, a correlation between physical fitness and allergic response factors indicates that an increase in lower-limb strength affects the reduction of IL-4, thereby decreasing the IgE production. Conversely, lowering the lower-limb strength may increase allergic responses.

This study also revealed that improvement of leg strength decreased cytokine levels and that allergy antibody IgE levels were decreased by the improvement of leg strength, although physical exercise interventions for children with allergic diseases have not been extensively researched.

CONCLUSIONS

Regular taekwondo training improved the body composition of all obese children with allergic rhinitis and atopic dermatitis, developed cardiovascular fitness and leg strength further, and reduced allergic responses, demonstrating that it is an effective method to improve allergic diseases of growing children with allergies.

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