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■ Original Article

Association between Physical Fitness and Cardiometabolic Risk of Children and Adolescents in Korea

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Background: This study aimed to investigate the association between physical fitness and cardiometabolic health of Korean children and adolescents.

Methods: In total, 168 participants (89 boys and 79 girls) aged 10–16 years were recruited for the Intervention for Childhood and Adolescent Obesity via Activity and Nutrition Study in 2016. The subjects were categorized into two groups using the definition of metabolic syndrome by the International Diabetes Federation: metabolically unhealthy (with at least two of the five criteria) and healthy groups (with less than one criterion). Correlation analysis of the participants' general characteristics was performed. Odds ratios (ORs) of physical fitness for cardiometabolic risk were evaluated via logistic regression.

Results: Metabolically unhealthy children showed greater weight, height, and body mass index, higher Children's Depression Inventory score, and longer screen time than did the metabolically healthy children. Metabolically healthy children showed greater upper and lower extremity muscular strength than did the metabolically unhealthy children (P=0.04 and P<0.001, respectively). In the multiple logistic regression analysis, lower extremity muscle strength was inversely related to the clustered cardiometabolic risk of the children and adolescents with or without adjustment for confounders (OR, 4.32; 95% confidence interval [CI], 1.87–9.97; OR, 7.64; 95% CI, 1.55–37.74, respectively).

Conclusion: Physical fitness, especially lower extremity muscle strength, is significantly inversely associated with individual and clustered cardiometabolic risks in Korean children and adolescents.

Keywords: Cardiometabolic Risk; Physical Fitness; Cardiorespiratory Fitness; Child; Adolescent

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INTRODUCTION

Worldwide, cardiovascular diseases (CVDs) are the leading cause of both global mortality and disability.[1] Because the onset of atherosclerosis seems to occur in early childhood, it is currently recognized that CVDs are partly a pediatric problem.[2]

Several risk factors for CVDs have been identified in children and adolescents, such as abdominal obesity, elevated blood pressure, insulin resistance, elevated triglyceride (TG) levels, and reduced high-density lipoprotein (HDL) cholesterol levels.[3] These cardiometabolic risk factors during childhood tend to track into adulthood.[4] Accordingly, a global strategy based on knowledge of the importance of risk factors for CVDs for effective prevention is needed.[5]

A higher level of cardiorespiratory fitness and muscle strength independently reduce the risk of cardiometabolic risk in adults.[6] Further, several studies on physical fitness and health in childhood and adolescence have been conducted in the last years.[7]

Earlier studies suggest that a high level of cardiorespiratory fitness is associated with a healthier cardiovascular profile during childhood,[8] and muscle fitness has been recognized in the prevention of chronic diseases.[9] However, most of these preceding studies had been conducted predominantly in Western countries, and to our knowledge, there are a limited number of studies conducted on Asian children.

The primary aim of this study was to investigate the association between physical fitness and clustered cardiometabolic risk factors in Korean children and adolescents.

METHODS

1. Subjects

We conducted a cross-sectional analysis of the cardiometabolic health status of children and adolescents using data from the Intervention for Childhood and Adolescent Obesity via Activity and Nutrition (ICAAN) Study. The ICAAN Study is an intensive multidisciplinary intervention program including nutritional education, exercise education, and behavioral modification for children and adolescents with predominantly severe obesity in Korea. In this study, we used baseline data from 289 subjects aged 6–16 years who enrolled in the 16-week pilot study to test the feasibility of the ICAAN program. Children and adolescents without obesity were also included as active controls. Finally, a total of 168 participants (89 boys and 79 girls) were included in this study after excluding 121 participants who were younger than 10 years and whose data, such as laboratory test findings, survey data, and physical fitness test findings, were missing.

All subjects and their parents provided informed consents before participation in this study. All study protocols were approved by institutional review board and ethics committee in Hallym University Sacred Heart Hospital (IRB approval no., 2015-I134).

2. Definition of Cardiometabolic Health Status

To investigate the clustered cardiometabolic risk factors, we used the definition of metabolic syndrome by the International Diabetes Federation (IDF) in 2007.[10,11] We defined the metabolically unhealthy group (MUG) as children and adolescents having at least two of the following five criteria: (1) waist circumference (WC) of ≥90th percentile, (2) TG level of ≥150 mg/dL, (3) HDL cholesterol level of ≤40 mg/dL, (4) systolic or diastolic blood pressure (SBP or DBP, respectively) of ≥90th percentile, and (5) fasting plasma glucose level of ≥100 mg/dL. The cutoff values of the WC and blood pressure were based on the 2007 Korean growth charts for children and adolescents.[12] The rest of the participants who did not meet the criteria described above were classified into the metabolically healthy group (MHG).

3. Clinical Variables

The weight and height were measured using the body composite analyzer, InBody 720 (Biospace Co., Seoul, Korea). The WC was measured to the nearest 0.1 cm during exhalation at the midpoint between the lower border of the ribcage and the iliac crest using a measuring tape. The body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2). Blood pressure was measured twice using the DINAMAP DPC100X-EN automated blood pressure monitor (GE Medical System Information Technologies, Milwaukee, WI, USA) while the subjects were resting in a seated position; the two measures for each participant were averaged for the analysis.

Laboratory tests were performed only for the subjects whose parents had agreed to the performance of blood tests and provided written informed consent in advance. After at least 10 hours of fasting, blood samples were collected from the antecubital vein. The HDL cholesterol, TG, fasting serum glucose, and serum insulin levels were analyzed.

The homeostatic model assessment of insulin resistance (HOMA-IR) score was used as a measure of insulin resistance.[13] It was calculated by multiplying the fasting insulin level (μIU/mL) by the fasting glucose level (mg/dL) divided by 405.[14]

We performed three tests to evaluate the level of physical fitness. The arm curl test was used to measure the upper extremity muscle strength. The participants sat on a chair, held a dumbbell (4 kg for boys; 2 kg for girls) in their dominant hand and curled their hands up and lowered them down through the full range of motion. We counted the number of repetitions that they could perform in 30 seconds. The wall squat test was used to measure the lower extremity muscle strength. The participants stood comfortably with their feet approximately shoulder width apart and their back against the wall. They were asked to maintain a 90° angle between their hips and knees. The total time in seconds was recorded. The 3-minute step test was used to measure cardiorespiratory fitness. The participants alternated their steps to a 30-cm height step platform within 3 minutes. One step cycle comprised four stages in the metronome cadence set at the rate of 96 beats per minute. They stepped up to the platform with one foot (first stage), stepped up with the second foot (second stage), stepped down with one foot (third stage), and stepped down with the other foot (fourth stage). The total 3-minute post-exercise heart rate of the partic-

ipants was recorded.

4. Questionnaire-Based Survey

Some information on the factors that may influence metabolic syndrome in children and adolescents was obtained from the structured questionnaire completed by the participants and their parents. These factors included screen time, parents' educational level, monthly household income, and Children's Depression Inventory (CDI) score.[15]

5. Statistical Analysis

All data in this study were analyzed using STATA ver. 14.0 (Stata Corp., College Station, TX, USA). Using the Shapiro-Wilk test, categorical and continuous variables were checked for normality. The χ^2 test for parametric analysis and Fisher's exact test for nonparametric analysis were used for categorical variables. Continuous variables were analyzed using the t-test and Wilcoxon rank-sum test. Some variables, such as age, weight, CDI score, BMI, WC, DBP, HDL cholesterol level, TG level, fasting plasma glucose level, screen time, HOMA-IR score, and wall squat test findings, were analyzed using the nonparametric method because their distribution were skewed. Continuous data were expressed as means and standard deviations and categorical data as frequencies and percentages. Data in the nonparametric analysis were expressed as medians and interquartile ranges. Correlation analysis was used to examine the statistical relationship involving dependence between individual physical fitness components and cardiometabolic risks.

Logistic regression analysis was conducted to investigate the relationship between the independent components of physical fitness and clustered cardiometabolic risk factors in children and adolescents. All tests were two-sided, and the level of significance was set at P<0.05.

RESULTS

The general characteristics of the study subjects are shown in Table 1. We divided all study subjects into two groups: MHG and MUG (n=109 and n=59, respectively) according to the modified IDF criteria for defining metabolic syndrome in children and adolescents. The MUG showed greater weight, height, and BMI, higher CDI score, and longer screen time than did the MHG. However, there were no significant differences in the parents' educational level (P=0.280) and monthly household income (P=0.601) between the two groups. The MHG showed greater upper and lower extremity muscle strength than did the MUG (P=0.04 and P<0.001, respectively). However, there was no significant difference in the cardiorespiratory function.

Table 2 shows the correlation of the individual components of physical fitness with the single or clustered cardiometabolic risk factors. A

Table 1. General characteristics of the study subjects

Characteristic	Metabolically healthy group (n=109)	Metabolically unhealthy group (n=59)	P-value*
Age (y)[†]	11.07 (10.70–11.89)	12.49 (10.97–14.35)	<0.001
Sex			0.001
Boys	47 (43.1)	42 (71.2)	
Girls	62 (56.9)	17 (28.8)	
Weight (kg)[†]	44.4 (37.0–62.0)	79.2 (63.2–86.9)	<0.001
Height (cm)	148.54±8.25	159.11±9.08	<0.001
Body mass index (kg/m²)[†]	20.78 (17.97–26.21)	29.65 (27.28–34.19)	<0.001
Children's Depression Inventory score[†]	6.0 (4.0–12.0)	11.0 (5.0–16.0)	0.004
Screen time (h)[†]	3.0 (1.0–5.0)	5.0 (3.0–6.3)	<0.001
Parents' educational level			0.280
Low	37 (33.9)	25 (42.4)	
High	72 (66.1)	34 (57.6)	
Monthly household income (10⁴ Korean won/mo)			0.601
Low (<300)	19 (17.4)	14 (23.7)	
Middle (300–500)	44 (40.4)	23 (39.0)	
High (≥500)	46 (42.2)	22 (37.3)	
Arm curl test (attempts)	19.52±5.45	17.59±6.32	0.040
Wall squat test (s)[†]	65.0 (39.0–90.0)	35.0 (20.0–60.0)	<0.001
3-Minute step test (beats/min)	134.40±20.03	128.44±20.59	0.070
Waist circumference (cm)[†]	71.9 (63.0–85.4)	95.0 (90.5–102.2)	<0.001
Systolic blood pressure (mm Hg)	110.06±12.23	128.81±19.14	<0.001
Diastolic blood pressure (mm Hg)[†]	63.8 (58.5–70.0)	69.5 (64.5–75.0)	0.001
Triglyceride level (mg/dL)[†]	77.0 (59.0–93.0)	142.0 (92.0–183.0)	<0.001
High-density lipoprotein cholesterol level (mg/dL)[†]	57.0 (49.0–66.0)	41.0 (37.0–52.0)	<0.001
Glucose level (mg/dL)[†]	91.0 (87.0–95.0)	89.0 (85.0–95.0)	0.171
Homeostatic model assessment of insulin resistance score[†]	2.57 (1.43–3.89)	4.84 (3.82–8.19)	<0.001

Values are presented as mean (interquartile range) for nonparametric analysis data, number (%) for categorical variables, or mean±standard deviation for continuous variables.
*Analyzed using the t-test, chi-square test, or Wilcoxon rank-sum test. [†]Analyzed using the Wilcoxon rank-sum test and expressed as mean (interquartile range).

Table 2. Correlation analysis between each type of physical fitness and single components of cardiometabolic risks

Variable	Arm curl test		Wall squat test		3-Minute step test	
	r*	P-value[†]	r	P-value[†]	r	P-value[†]
Body mass index	-0.195	0.011	-0.478	<0.001	-0.091	0.239
Waist circumference	-0.248	0.001	-0.522	<0.001	-0.099	0.201
Systolic blood pressure	-0.218	0.005	-0.338	<0.001	-0.031	0.693
High-density lipoprotein cholesterol level	0.200	0.009	0.334	<0.001	0.128	0.097
Triglyceride G level	-0.160	0.038	-0.321	<0.001	0.004	0.962
Fasting blood glucose level	0.075	0.333	0.046	0.550	0.153	0.048
Homeostatic model assessment of insulin resistance score	-0.074	0.341	-0.260	<0.001	0.054	0.486
Age	-0.020	0.796	-0.224	0.004	-0.114	0.140

*Pearson's correlation coefficient. [†]Analyzed using Pearson's correlation.

Table 3. Odds ratios of physical fitness for cardiometabolic risks

Variable	Category	Unadjusted	Model 1	Model 2	Model 3
Muscle fitness (upper extremity)	Upper one-third	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
	Lower two-third	1.16 (0.57–2.39)	0.99 (0.43–2.28)	0.80 (0.30–2.11)	0.60 (0.0.17–2.06)
	P-value	0.676	0.978	0.655	0.417
Muscle fitness (lower extremity)	Upper one-third	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
	Lower two-third	4.32 (1.87–9.97)	6.81 (2.47–18.72)	3.85 (1.25–11.80)	7.64 (1.55–37.74)
	P-value	0.001	<0.001	0.019	0.013
Cardiorespiratory fitness	Upper one-third	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
	Lower two-third	1.11 (0.58–2.10)	1.03 (0.49–2.19)	0.79 (0.34–1.86)	0.58 (0.19–1.77)
	P-value	0.760	0.930	0.591	0.338

Values are presented as odds ratio (95% confidence interval). Model 1: adjusted for age and sex; model 2: adjusted for age, sex, and BMI; model 3: adjusted for age, sex, BMI, waist circumference, systolic blood pressure, high-density lipoprotein cholesterol level, homeostatic model assessment of insulin resistance score, screen time, monthly household income, and parents' educational level.
BMI, body mass index.

negative correlation was observed for the BMI, WC, SBP, and TG level; the only positive correlation was observed between the HDL cholesterol level and upper extremity muscle strength (P<0.05). However, there was no significant correlation with the fasting plasma glucose level and HOMA-IR score. A negative correlation was observed between lower extremity muscle strength and most of the cardiometabolic risk factors, including age (P=0.004). Conversely, a positive correlation with the HDL cholesterol level was observed (P<0.001); however, there was no significant correlation with the fasting blood glucose level. A negative correlation was observed only between the fasting blood glucose level and cardiorespiratory function (P=0.048), and there was no significant association between the rest of the cardiometabolic risk factors and cardiorespiratory function.

Table 3 shows the odds ratios (ORs) of physical fitness for cardiometabolic risk after sequentially adjusting for age, sex, BMI, WC, SBP, HDL cholesterol level, HOMA-IR score, screen time, monthly household income, and parents' educational level. Considering that physical fitness is particularly relevant to age and sex, we divided all the subjects by age (10–12 years or above) and by sex (boys or girls). Each type of physical fitness was divided into upper one-third and lower two-third using tertiles by age-sex group; we then merged them into each level of fitness (upper one-third and lower two-third). Upper extremity muscle strength and cardiorespiratory fitness were not associated with the clustered cardiometabolic risks regardless of any adjustment.

However, even when no adjustments were made, a significant association was observed between lower extremity muscle fitness and cardiometabolic risk (OR, 4.37; 95% confidence interval [CI], 1.87–9.97). After adjusting for age, sex, WC, SBP, HDL cholesterol level, HOMA-IR score, screen time, monthly household income, and parents' educational level, low level of lower extremity muscle fitness showed a stronger association with the cardiometabolic risks (OR, 7.64; 95% CI, 1.55–37.74).

DISCUSSION

This study was designed to investigate the association between the types of physical fitness and cardiometabolic risks in Korean children and adolescents. We found that the lower extremity muscle strength is inversely related to the clustered cardiometabolic risk of children and adolescents in Korea. In addition, there was a stronger association between lower extremity muscle strength and individual cardiometabolic risk factors than between the upper extremity muscle strength and cardiorespiratory fitness. In adults, it is widely known that a high level of muscle fitness reduces the risks for CVDs by decreasing the blood pressure, TG level,[16)] and incidence of abdominal obesity[17)] or increasing the HDL cholesterol level[18)] and insulin sensitivity.[19)] However, differing results on the association between physical fitness and cardiometabolic risks in children and adolescents have been reported. Although our results are not consistent with the following findings, some

authors found the association of cardiorespiratory fitness with clustered metabolic risks to be slightly stronger than that with muscle strength.[20] Other researchers suggested that muscle strength, especially that of the lower extremity, shows a stronger association with cardiometabolic risks,[21] and our finding was consistent with this conclusion. One possible explanation for this is the increase in fat-free mass. In obesity, a greater amount of adipose tissue is gained. Fat-free mass also increases as the amount of adiposity increases, and this supports the extra load.[22] For this reason, children with obesity tend to perform upper extremity muscle exercises more easily and their lower extremity muscle strength tends to be lower.[23]

In the present study, we also observed that insulin resistance measured using the HOMA-IR score was negatively related to the lower extremity muscle strength. Insulin resistance is characterized by a decrease in the ability of insulin to stimulate the use of glucose by the muscles and adipose tissue and to inhibit glucose production and output.[24,25] It can be influenced by both genetic and environmental factors, including obesity and sedentary lifestyle.[26] Obesity-mediated insulin resistance can result in some complications, such as dyslipidemia, impaired glucose tolerance or type 2 diabetes, hepatic steatosis, early atherosclerosis, and polycystic ovary syndrome.[27] Eventually, insulin resistance in childhood can track into adulthood.[28] Since it is not clear whether these effects are due to changes in muscle metabolism, insulin regulation, counterregulatory hormones, or adipose tissue induced by exercise, further study on this area is needed.

We also found no significant association with a low socioeconomic status (SES), including parents' educational level and monthly household income. Some previous studies have shown that the SES in childhood is inversely related to cardiometabolic risk factors and vascular structure and function.[29] The discrepancy in these results may originate from cultural differences. The proportion of the population with tertiary education among South Koreans aged 25 to 64 is the highest among the Organization for Economic Cooperation and Development countries.[30] The rate of tertiary educational attainment in the parents or sponsors of the subjects in this study was 63.1% (106 out of 168), which may act as one of the confounders.

Our study has three limitations. First, the study sample cannot represent all children and adolescents of our country because of the small sample size and the limited available region. Second, owing to the cross-sectional nature of the study, we could not determine the causality between increase in physical fitness and change in clustered or individual cardiometabolic risk factors. Third, sex and age could act as confounders; however, no definite standard reference values of each physical fitness are available. Therefore, we attempted to calibrate these variables using statistical analyses stratified by sex and age and adjusting for multiple confounding factors, including sex and age.

Despite these limitations, this is the first study that investigated the relationship between cardiometabolic risks and physical fitness in Korean children and adolescents to the best of our knowledge. In conclusion, physical fitness, especially lower extremity muscle strength, is significantly inversely associated with individual and clustered cardio-

metabolic risks in Korean children and adolescents. Therefore, lower extremity muscle fitness can be an important predictor of cardiometabolic risks in children and adolescents. Further studies are needed to investigate the cardiometabolic change in relation to increase in physical fitness.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGMENTS

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