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Effectiveness of a multi-faceted intervention among elementary school children

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Abstract

Childhood obesity has been shown to be closely related to future obesity and comorbidities. As its prevalence and impact has increased significantly worldwide, researchers have focused on prevention and intervention. This study assessed a multifaceted intervention for elementary school children.

A retrospective data collection with a cohort analysis was employed. A 16-week school-based intervention with nutritional intervention, physical activity, and behavioral education was designed and conducted by a multidisciplinary team for 1860 children aged 6 to 13 years. Basic information, anthropometrics, and physical fitness (PF) were recorded before and after the intervention. The differences compared with a reference group, and compared between subgroups, were analyzed.

Significant favorable changes in body weight and composition were found. Children's height, weight, and muscle weight increased, whereas BMI, BMI z-score (zBMI), waist circumference, hip circumference, waist-hip ratio, waist-height ratio, body fat percentage, and visceral fat area decreased. Sit-ups and 800-m run time significantly improved. Girls exhibited a greater reduction in body weight outcomes; boys improved more in body composition and PF. Students with higher zBMI had a greater reduction in all anthropometrics; students with lower zBMI showed greater PF improvement, except for the 800-m run.

The intervention improved weight measures, body composition, and PF. Subgroup differences suggested the need for sex- and weight-specific interventions.

Abbreviations: BF% = body fat percentage, BMI = body mass index, HC = hip circumference, PF = physical fitness, VFA = visceral fat area, WC = waist circumference, WHR = waist-hip ratio, WHtR = waist-height ratio, zBMI = BMI z-score.

Keywords: anthropometrics, childhood obesity, gender difference, physical fitness, school-based intervention

1. Introduction

1.1. Background

Childhood obesity is associated with adolescent and adult obesity,[1] and it plays an important role in the development of many disorders in adulthood.[2] Obese children are also prone to cardiovascular risk factors, type II diabetes, and some non-metabolic comorbidities, such as musculoskeletal and psychosocial problems during childhood and adolescence.[2,3]

While childhood obesity is becoming a worldwide public health issue, the prevalence of childhood obesity in Asian countries, including Taiwan, has also rapidly increased. According to data from Nutrition and Health surveys in Taiwan in 2001 to 2002, obesity prevalence has tripled for elementary

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school boys and doubled for girls in the past decade, with one-third of boys and one-quarter of girls either overweight or obese.

Among interventions to prevent or treat childhood obesity, combined behavioral and lifestyle interventions have been shown to lead to significant and clinically meaningful weight reduction in children and adolescents,[4] with diet, physical activity, and counseling the 3 most important factors for success.[5] In addition, these interventions might improve anthropometrics and physical fitness (PF), and could also consequently lower their future risk of metabolic syndrome and cardiovascular disease.[6]

1.2. Goals of the investigation

This investigation aimed to assess the effectiveness of a school-based, multifaceted intervention program on children's anthropometrics and PF, and to explore response differences among children with different baseline characteristics.

2. Participants and methods

2.1. Study design

A retrospective data collection with a cohort analysis was employed. The study was approved by the ethics committee of Chang Gung Memorial Hospital, Linkou, Taiwan, and the requirement to obtain informed consent was waived.

The intervention program was designed and conducted by a multidisciplinary team from February through May 2011 in response to the hospital policy on child health promotion. The team included family physicians, nurses, clinical dietitians, and social workers from the hospital and teachers, nurses, and administrative employees from the schools. Basic information, anthropometrics, blood pressure, and PF were assessed before and after the intervention. The research team obtained the study data from the database of the multidisciplinary intervention program after the ethics committee approved the design.

2.2. Participants

The stratum sample size was calculated at 99 based on a BMI change of −0.15 (95% confidence interval [CI]=−0.21 to −0.05) by an intervention under a type I error of 0.05 and a statistical power of 0.8. Considering a heterogeneity of response to an intervention across strata (eight different age groups and two sexes), a minimum of 1584 children were required.[7]

The program was conducted for all students from four elementary schools located in the Guishan District, a suburban city close to Taipei, with a population of almost 160 thousand. The primary economic drivers of Guishan are high-tech industry, manufacturing, and healthcare. The average income of the residents lies approximately in the first quintile of Taiwan. A total of 1860 children aged 6 to 13 years were included. In consideration of ethics and fairness, all students in the enrolled schools participated as intervention group. We adopted normative data for the external control group.

2.3. Intervention

The intervention to be assessed was school-based, multifaceted, and 16 weeks long, in accordance with the duration of 1 semester. It was designed by a multidisciplinary team based on essential principles of the theory of planned behavior.

2.3.1. Behavioral beliefs. This part of the intervention, conducted through lectures and group sessions, aimed to develop a more positive attitude in children toward staying fit by increasing their beliefs and skills in childhood weight management. For all children, a 50-minute lecture covering definition, causes, complications, and obesity treatment was provided at the beginning of the intervention. For the parents of overweight or obese children, a 50-minute small group consultation was provided covering the aforementioned topics plus an evaluation of the current weight status of their children. Next, there were three serial interactive group sessions on healthy diet provided by dietitians, and another 3 on simple at-home workouts provided by athletic trainers.

2.3.2. Normative beliefs. This part of the intervention aimed to create social pressures for children to act. It was conducted by integrating the programs into daily school routines, as well as intensive promotion of the importance and ways of staying fit. All the students participated in healthy gymnastics at school at least twice a week, for more than 15 minutes each time. Educational pamphlets on the importance and ways of staying fit were distributed to the students and their parents or guardians. The school lunch menu was evaluated and adjusted weekly by dietitians.

2.3.3. Control beliefs. This part of the intervention aimed to increase the self-efficacy of children in terms of performance attainment (mastery experience), vicarious experience, and verbal persuasion. If a participant achieved some preset goals on preferable behavioral changes, such as drinking fewer sweetened beverages, eating less fast food, or doing more after-school exercise, his/her effort were announced and praised publicly by a teacher, then rewarded with a small gift. Also, participants who attained preferable BMI changes were praised publicly and received a certificate for their accomplishment.

2.4. Measurements

2.4.1. Basic information. Basic information, including student profile, sex, and birth date was provided by the student and confirmed by a teacher.

2.4.2. Anthropometrics. Body height, body weight, waist circumference (WC), and hip circumference (HC) were measured and used to calculate the body mass index (BMI), waist/hip circumference ratio (WHR), and waist/height ratio (WHtR). Body composition was measured by means of bioelectrical impedance analyses, based on differences in conductivity of separate human components. Items recorded for the study included body fat percentage (BF%), muscle weight, and visceral fat area (VFA).

2.4.3. Bioelectrical impedance analyses (BIA). BIA was determined using the X-scan model (Jawon Medical, South Korea), which is a patented apparatus that reliably analyzes body composition with a tetra-polar 8-point tactile electrode system. By measuring segmental multifrequency impedance values at 1, 5, 50, 250, 550, and 1000 kHz, the system can analyze not only whole body composition but also segmental distribution.

2.4.4. Physical fitness. PF was tested with an 800-m run, 30-second and 1-minute sit-ups, standing long jump, and the sit-and-reach test to assess cardiorespiratory fitness (CRF), muscle endurance, explosive muscle strength of the lower limbs, and flexibility of the hamstring muscles, respectively. PF data were only available for students who were in the fourth to sixth grades, given such tests were required only for students in the fourth or higher grades according to the Sports Administration, Ministry of Education of Taiwan.

2.4.5. External validation of changes in measurements. Given there was no internal control group in the program, we adopted growth data from previous surveys in Taiwan as a reference group to compare with. The BMI growth chart data were from the Health Promotion Administration,[8,9] Ministry of Health and Welfare, and the PF growth chart data was from the Ministry of Education.[10]

2.5. Statistical analysis

Numerical variables were presented as mean ± standard deviation (SD), and the categorical variables were displayed as frequency and proportion. Changes in numerical variables between pre- and post-intervention were analyzed with a paired *t*-test. A *Z*-test was used to compare the changes in selected indicators between the intervention group and reference group. A two-sample *t*-test was used to compare the changes between subgroups. Numerical variables were checked for normality before statistical tests, in which logarithmic transformation was performed with right skewness. The multivariable-adjusted mean was calculated with a general linear model. All analyses were performed using SPSS Version 18.0 for Windows (SPSS Inc, Chicago, IL, USA). A two-sided *P* value less than .05 was considered statistically significant.

3. Results

3.1. Anthropometrics and PF before and after the intervention

Table 1 provides summary information of the demographic data, anthropometrics, and PF before and after the intervention.

3.1.1. Demographic data. A total of 1860 elementary school children were enrolled, including 810 boys and 1050 girls with a mean (SD) age of 9.19 (1.66) at entry and 9.45 (1.64) years after the intervention. The total number of students and the distributions of sex and grade remained the same throughout the program.

3.1.2. Anthropometrics. All anthropometric changes reached statistical significance when comparing before and after the intervention. Height and weight increased while BMI and BMI z-score (zBMI) decreased. Reductions in WC, WHR, WHtR, and an increase of HC were observed. Body fat percentage (BF%) and VFA were lower while muscle weight became higher.

3.1.3. Physical fitness. A reduction in sit-and-reach distance was observed, the number of 30-second sit-ups and 1-minute sit-ups

Table 1

Anthropometrics and physical fitness before and after the intervention.

Variables	Pre-intervention	Post-intervention	P
	Mean±SD or Frequency (%)	Mean±SD or Frequency (%)	
Demographic data			
Gender			
Boys	810 (43.5%)	810 (43.5%)	
Girls	1050 (56.5%)	1050 (56.5%)	
Age (years)	9.19 ± 1.66	9.45 ± 1.65	<.001
Grade			
1	192 (10.3%)	192 (10.3%)	
2	281 (15.1%)	281 (15.1%)	
3	321 (17.3%)	321 (17.3%)	
4	373 (20.1%)	373 (20.1%)	
5	342 (18.4%)	342 (18.4%)	
6	351 (18.9%)	351 (18.9%)	
Anthropometrics			
Height (cm)	137.94 ± 11.26	140.02 ± 11.31	<.001
Weight (kg)	36.96 ± 11.14	37.40 ± 11.33	<.001
BMI (kg/m^2)	19.03 ± 3.53	18.71 ± 3.59	<.001
zBMI	0.116 ± 1.01	0.005 ± 1.00	<.001
WC (cm)	63.26 ± 10.13	62.40 ± 9.57	<.001
HC (cm)	76.49 ± 9.07	77.28 ± 9.07	<.001
WHR	0.83 ± 0.006	0.81 ± 0.061	<.001
WHtR	0.46 ± 0.001	0.45 ± 0.001	<.001
BF% (%)	18.27 ± 6.72	15.55 ± 6.99	<.001
VFA (cm^2)	37.63 ± 20.82	33.56 ± 19.54	<.001
Muscle weight (kg)	27.55 ± 6.74	28.94 ± 7.12	<.001
Physical fitness.			
800-m run (seconds)	303.07 ± 60.79	288.36 ± 58.47	<.001
30-second sit-ups (times)	15.93 ± 5.15	19.26 ± 4.27	<.001
1-minute sit-ups (times)	26.11 ± 9.96	30.26 ± 9.59	<.001
Standing long jump (centimeters)	146.56 ± 21.60	147.41 ± 28.14	.307
Sit and reach (times)	26.96 ± 12.67	25.74 ± 9.35	.002

BF% = body fat percentage, BMI = body mass index, cm = centimeter, HC = hip circumference, kg = kilogram, SD = standard deviation, VFA = visceral fat area, WC = waist circumference, WHR = waist hip ratio, WHtR = waist height ratio, zBMI = BMI z-score.

Table 2

BMI and physical fitness changes between reference and subjects.

	Reference		Subjects			
	Mean	±SD	Mean	±SD	Z	*P*
BMI (kg/m²)						
6–13 year-old children	16.73	±1.56	19.03	±3.53	991.94	<.05
After 16 weeks	16.87	±1.58	18.71	±3.59		
Difference	−0.14	0.02	0.32	0.06		
800-m run (seconds)						
10 year-old children	307.58	±57.75	305.79	±60.82	98.05	<.05
After 16 weeks	301.78	±56.06	291.41	±63.06		
Difference	5.8	1.69	14.38	2.24		
1-minute sit-ups (times)						
10 year-old children	24.46	±8.12	25.75	±10.04	−484.12	<.05
After 16 weeks	25.07	±7.97	30.12	±9.26		
Difference	−0.61	0.15	−4.37	0.78		
Standing long jump (cm)						
10 year-old children	127.13	±20.83	137.73	±21.04	232.98	<.05
After 16 weeks	130.14	±21.46	133.14	±23.49		
Difference	−3.01	0.63	4.59	2.45		
Sit and reach (cm)						
10 year-old children	27.71	±7.70	26.78	±12.45	133.58	<.05
After 16 weeks	27.4	±7.82	25.64	±9.24		
Difference	0.31	0.12	1.14	3.21		

BMI = body mass index, cm = centimeter, kg = kilogram, m = meter, SD = standard deviation.
$P < .05$ performed by Z test

increased, and the length of the standing long jump increased. The time for an 800-m run after the intervention decreased. Except for the sit-and-reach and standing long jump, the children's PF indexes after the intervention were significantly improved.

3.2. BMI and PF changes between reference and participants

Table 2 presents the difference in changes between the study participants and the reference group. The study participants had a greater improvement in BMI, 800-m run, and 1-minute sit-ups compared with the reference group. A greater difference was observed in standing long jump and sit-and-reach.

3.3. Differences in anthropometric changes by sex and zBMI subgroup

Tables 3 and 4 present the anthropometric changes after the intervention in all samples and subgroups. The girls had a significantly greater reduction in WC, and WHtR than the boys did, whereas boys increased more in muscle weight. Students with higher zBMI had a larger reduction in all anthropometrics, including BMI, zBMI, WC, WHtR, BF%, and VFA, and showed a greater increase in muscle weight.

3.4. Differences in PF changes by sex and zBMI subgroup

Table 5 PF changes after the intervention in all samples and subgroups. There was no statistical significance among any measure. The boys changed in all PF indexes to a larger degree than the girls, meaning a larger regression in sit-and-reach, and a larger increase in 30-second sit-ups, 1-minute sit-ups, standing long jump, and 800-m run. The girls regressed slightly in standing long jump distance. The students with lower zBMI changed to a larger degree on almost all PF indexes than those with higher zBMI, meaning a larger regression in sit-and-reach, and a larger increase in 30-second sit-ups, 1-minute sit-ups, and standing long jump. The 800-m run was the only exception, for which students

Table 3

Differences[†] in anthropometric changes by gender and zBMI subgroups[‡].

Variables	BMI	zBMI	WC	WHtR
	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
Overall	−0.31 (−0.37,−0.24)	−0.11 (−0.13,−0.09)	−0.98 (−1.22,−0.74)	−0.01 (−0.015,−0.012)
Gender				
Girls	−0.37 (−0.46,−0.29)	−0.12 (−0.15,−0.10)	−1.58 (−1.90,−1.26)*	−0.02 (−0.019,−0.015)*
Boys	−0.25 (−0.35,−0.15)	−0.09 (−0.12,−0.07)	−0.38 (−0.75,−0.01)*	−0.01 (−0.012,−0.007)*
zBMI				
Median low (≤-0.091)	−0.12 (−0.22,−0.03)*	−0.04 (−0.14,−0.07)*	−0.33 (−0.68,0.02)*	−0.009 (−0.011,−0.006)*
Median high (>−0.091)	−0.50 (−0.59,−0.41)*	−0.18 (−0.20,−0.15)*	−1.63 (−1.97,−1.29)*	−0.018 (−0.020,−0.015)*

BF% = body fat percentage, BMI = body mass index, CI = confident interval, VFA = visceral fat area, WC = waist circumference, WHtR = waist height ratio, zBMI = BMI z-score.
* $P < .05$ between the two study groups.
† The difference of measures was calculated by post-intervention minus pre-intervention.
‡ Multivariable-adjusted mean with general linear model including independent variables of age, gender and zBMI.

Table 4

Differences† in anthropometric changes by gender and zBMI subgroups‡.

Variables	BF%	VFA	Muscle weight
	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
Overall	−2.70 (−2.85,−2.55)	−4.14 (−4.85,−3.43)	1.45 (1.29,1.61)
Gender			
Girls	−2.86 (−3.06,−2.66)	−3.74 (−4.68,−2.79)	1.17 (0.95,1.39)*
Boys	−2.54 (−2.76,−2.31)	−4.54 (−5.63,−3.46)	1.73 (1.48,1.98)*
zBMI			
Median low (≤-0.091)	−2.68 (−2.90,−2.46)	−3.69 (−4.73,−2.65)	1.08 (0.84,1.32)*
Median high (>−0.091)	−2.71 (−2.92,−2.50)	−4.59 (−5.59,−3.58)	1.82 (1.59,2.05)*

BF% = body fat percentage, BMI = body mass index, CI = confident interval, VFA = visceral fat area, WC = waist circumference, WHtR = waist height ratio, zBMI = BMI z-score.
* $P<.05$ between the two study groups.
† The difference of measures in this study was calculated by post-intervention minus pre-intervention.
‡ Multivariable-adjusted mean with gender linear model including independent variables of age, gender and zBMI.

with higher zBMI improved more than those with median-low zBMI.

4. Discussion and conclusions

In the present study, the overall intervention outcomes suggest that the program was effective in improving anthropometrics and PF. Within age groups, the children's body height and weight increased as would be expected; however, decreases in BMI and zBMI suggest a positive effect of the intervention on overweight. The data show a decrease in BMI among our 6- to 13-year-old intervention children, whereas the reference growth chart showed an increasing average BMI trend among children aged 6 to 13 years. Therefore, the BMI reduction was attributable to the intervention, rather than as a result of natural growth. Moreover, BF% decreased while muscle mass increased, suggesting a more favorable body composition after the intervention. Of most benefit, the reduction in WC, WHtR, and VFA suggested that the intervention directly diminished the degree of central obesity,[11,12] which is considered a predictor of cardiovascular and metabolic diseases in children.[11–13] WC has been closely related to the degree of central obesity and metabolic comorbidities in youth in previous studies.[11,14] WHtR, an age-independent measure, was also found to be strongly associated with the risk of cardiovascular and metabolic disease in the literature.[13,15,16] HC and WHR, which can be affected by sex, age, and other factors in children, were considered less practical for body fat distribution assessment.[14] As the literature has suggested, the positive anthropometric changes we observed here could be linked to a better metabolic profile and a lower cardiovascular disease risk for children in their future .[3,11,13,17,18]

Although the association between PF and future health in adults[19,20] has been widely accepted, the effects on youth health still await further study. Some research has found a weak association between PF and cardiovascular disease risk factors,[21] whereas other research has suggested it is a powerful health marker in childhood and adolescence,[22] as shown in favorable metabolic risk profiles,[18,23] cognitive control, and memory in children.[24] PF can improve alone or in conjunction with anthropometrics,[18] and has been identified as an important measure for assessing the effectiveness of an intervention. Significant improvements in PF were observed in this study. First, a time reduction in the 800-m run reflected an improvement in CRF, corresponding with previous studies in which there was a negative association between CRF and BMI, WC, and adipose mass.[25] Second, muscle endurance as tested by 30-second sit-ups and 1-minute sit-ups increased after the intervention. These 2 improvements in our participants were significantly greater than those of the reference group, suggesting the effectiveness of the intervention. Explosive muscle strength in the lower limbs, as tested by standing long jumps, increased without significance for the fourth-sixth graders, but significantly decreased for 10 year-old children compared with the reference group. A puzzle remained as to whether a reduction in BMI lead to a decrease in muscle strength for these children. A regression in flexibility of the hamstring muscles as tested by the sit-and-reach was observed

Table 5

Differences* in physical fitness changes by gender and zBMI subgroups†.

Variables	800-m run	30-second sit-ups	1-minute sit-ups	Standing long jump	Sit and reach
	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)	Mean (95%CI)
Overall	−18.46 (−23.49,−13.43)	2.61 (1.67,3.56)	4.04 (3.34,4.75)	2.39 (−2.60,7.37)	−2.19 (−3.21,−1.16)
Gender					
Girls	−17.82 (−26.18,−12.03)	1.86 (0.66,3.06)	3.67 (2.78,4.56)	−0.31 (−6.35,5.72)	−1.39 (−2.67,−0.10)
Boys	−19.11 (−24.24,−11.40)	3.37 (2.11,4.63)	4.42 (3.45,5.39)	5.09 (−1.85,12.03)	−2.98 (−4.38,−1.58)
zBMI					
Median low (≤-0.091)	−13.23 (−20.22,−6.25)	3.14 (1.92,4.37)	4.61 (3.66,5.57)	4.13 (−3.23,11.48)	−2.44 (−3.81,−1.06)
Median high (>-0.091)	−23.69 (−30.26,−17.13)	2.09 (0.85,3.33)	3.47 (2.56,4.38)	0.65 (−5.20,6.50)	−1.93 (−3.25,−0.62)

CI = confident interval, zBMI, BMI z-score.
$P<.05$ between the two study groups.
* The difference of measures in this study was calculated by post-intervention minus pre-intervention.
† Multivariable-adjusted mean with gender linear model including independent variables of age, gender and zBMI.

and found to be comparable to the documented standards for the same age groups.[26,27] However, this effect was greater in the intervention group than in the reference group. Further studies to understand the mechanism are warranted.

Anthropometric changes within subgroups corresponded to that of the overall participants, demonstrating that the intervention effect was universal and consistent, regardless of sex, age, and zBMI subgroup. However, interesting differences between these subgroups were observed. The intervention was more effective for girls in terms of weight outcomes, considering there were greater reductions in BMI, zBMI, WC, WHtR, and BF%. Conversely, the boys lost more VFA but gained more muscle weight than the girls, suggesting the positive changes in body composition were more significant in boys. Thus, findings from previous research suggesting a different degree of response to interventions between boys and girls were supported by the present study.[28–31] Most previous studies have suggested that obesity interventions are more likely to be effective for girls,[28–31] and one had found that boys lost more weight and body fat than girls.[29] In addition to baseline differences, there are a few possible explanations for the sex differences in intervention response. First, given some lifestyle behaviors are obesity-prone, baseline differences by sex for lifestyle and health behaviors could have caused different intervention responses. Second, boys and girls might differ in their compliance with interventions, which consequently could result in different outcomes. Third, hormones can play an important role in developing childhood obesity and the response to interventions. As a result, further research on both behavioral and biochemical mechanisms of sex differences are warranted.

Of note, children with higher zBMI had a greater reduction in all anthropometric indexes. Those with lower zBMI had smaller-scale changes that might not have significant clinical relevance. This suggests higher intervention effectiveness in children who were more overweight than their peers. Similar findings have been reported in previous studies.[30,31] Thus, it could be inferred that obesity interventions should be employed with overweight and obese children earlier than their peers, given limited resources. However, when we focus on long-term control of weight and related metabolic comorbidities at a public health level, rather than simply short-term weight reduction at an individual level, more research is needed to identify the ideal target population for intervention and prevention.

PF changes within the subgroups were consistent with those of the overall participants. Although not to a statistically significant degree, interesting differences were still of note. In contrast to the weight outcomes, the boys changed to a greater degree in PF than the girls, including a greater increase in CRF, muscle endurance, explosive strength, and a greater reduction in flexibility. These results are seemingly contradictory, yet reveal possible underlying mechanisms that subtly affect the responses of different sexes to given interventions. The literature suggests that boys have a more positive attitude toward and better perceptions of physical activities, are more likely to engage in them,[32,33] and have better responses to physical activity interventions.[34,35] Thus, a possible explanation is that boys responded to the intervention by increasing their physical activity to a larger degree than girls, whereas girls responded better in terms of diet modification. Consequently, boys might have improved more profoundly in body composition and PF than girls, whereas girls were more successful in gross weight control. Further research with more intricate control over the intervention program and assessment of behavioral changes would help to better understand the sex difference in intervention responses.

The students with a lower zBMI showed a greater change in PF than did the students with a higher zBMI. The 800-m run was the only exception, for which the students with higher zBMI showed a greater improvement. Previous studies have shown a negative association between CRF and BMI, WC, and adipose mass.[25] Although a larger anthropometric and body composition change was observed in the students with higher zBMI in our data analysis, we found it reasonable that this group also showed a greater CRF improvement.

The intervention program evaluated in this study was theory-based and multifaceted. The fact that it was designed and implemented by a multidisciplinary team also made it more practical, comprehensive, and culturally sensitive. Based on our results, this school-based intervention was effective, not only in weight outcomes, but also for improvements in body composition, fat distribution, and PF. Furthermore, given interesting response differences were observed between subgroups by sex and zBMI, further research on intervention response would help in the design of a more effective approach to prevent and treat childhood obesity in the future.

Among the advantages of this study are that it involved a comprehensive assessment of anthropometrics and PF, had a very large sample size, and included a wide age range of elementary school students. Thus, the integrity and value of this study in assessing the efficacy of the intervention is evident. However, there are also some limitations. First, there might be a selection bias, given the students who participated in the program were not selected randomly or with a stratified method from the correspondent population. This approach could limit the generalizability of this model regarding intervention effectiveness when applied to other ethnic groups. Second, we could only validate the changes with growth data from Taiwan as an external control group instead of an internal control group, given the school-based intervention program was applied to all students in considering ethics and fairness. Third, although significant efforts were made to standardize the intervention program, differences between schools and individuals could only be minimized and not eliminated completely. A future prospective cohort study with more precisely quantified interventions assigned to subgroups or in a stepwise manner would be of interest.

In conclusion, childhood obesity has been increasingly addressed due to its growing prevalence and impact on the global health burden. This study demonstrated a successful model implementing a school-based, multifaceted, and multidisciplinary intervention in childhood obesity with significant improvements in anthropometrics and PF. Research with a more intricate study design would be of interest to better understand the role that adiposity plays in youth, the factors affecting effectiveness of interventions, and sex differences in developing and treating obesity.

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References

[1] World-Health-Organization. Childhood overweight and obesity. http://www.who.int/dietphysicalactivity/childhood/en/, 2015.
[2] Daniels SR. Complications of obesity in children and adolescents. Int J Obes (Lond) 2009;33(Suppl 1):S60–65.
[3] l'Allemand-Jander D. Clinical diagnosis of metabolic and cardiovascular risks in overweight children: early development of chronic diseases in the obese child. Int J Obes (Lond) 2010;34(Suppl 2):S32–36.
[4] Oude Luttikhuis H, Baur L, Jansen H, et al. Interventions for treating obesity in children. Cochrane Database Syst Rev 2009.
[5] Richardson L, Paulis WD, van Middelkoop M, et al. An overview of national clinical guidelines for the management of childhood obesity in primary care. Prev Med 2013;57:448–55.
[6] Kriemler S, Meyer U, Martin E, et al. Effect of school-based interventions on physical activity and fitness in children and adolescents: a review of reviews and systematic update. Br J Sports Med 2011;45:923–30.
[7] Waters E, de Silva-Sanigorski A, Hall BJ, et al. Interventions for preventing obesity in children. Cochrane Database Syst Rev 2011;12:
[8] Chen W, Chang M-H. New growth charts for Taiwanese children and adolescents based on World Health Organization standards and health-related physical fitness. Pediatrics Neonatol 2010;51:69–79.
[9] Health Promotion Administration, Ministry of Health and Welfare. https://www.hpa.gov.tw/EngPages/Index.aspx [accessed August 16, 2018].
[10] Ministry of Education Republic of China (Taiwan). https://english.moe.gov.tw/ [accessed August 16, 2018].
[11] Lee S, Bacha F, Gungor N, et al. Waist circumference is an independent predictor of insulin resistance in black and white youths. J Pediatr 2006;148:188–94.
[12] Vorwieger E, Kelso A, Steinacker JM, et al. on behalf of the U-ICEsgCardio-metabolic and socio-environmental correlates of waist-to-height ratio in German primary schoolchildren: a cross-sectional exploration. BMC Public Health 2018;18:280.
[13] Kelishadi R, Gheiratmand R, Ardalan G, et al. Association of anthropometric indices with cardiovascular disease risk factors among children and adolescents: CASPIAN Study. Int J Cardiol 2007;117:340–8.
[14] Liu A, Hills AP, Hu X, et al. Waist circumference cut-off values for the prediction of cardiovascular risk factors clustering in Chinese school-aged children: a cross-sectional study. BMC Public Health 2010;10:82.
[15] Mokha JS, Srinivasan SR, Dasmahapatra P, et al. Utility of waist-to-height ratio in assessing the status of central obesity and related cardiometabolic risk profile among normal weight and overweight/obese children: the Bogalusa Heart Study. BMC Pediatr 2010;10:73.
[16] Arnaiz P, Grob F, Cavada G, et al. Waist-to-height ratio does not change with gender, age and pubertal stage in elementary schoolchildren. Revista médica de Chile 2014;142:574–8.
[17] Senechal M, Wicklow B, Wittmeier K, et al. Cardiorespiratory fitness and adiposity in metabolically healthy overweight and obese youth. Pediatrics 2013;132:e85–92.
[18] Ekelund U, Anderssen SA, Froberg K, et al. Independent associations of physical activity and cardiorespiratory fitness with metabolic risk factors in children: the European youth heart study. Diabetologia 2007;50:1832–40.
[19] Garcia-Hermoso A, Cavero-Redondo I, Ramirez-Velez R, et al. Muscular strength as a predictor of all-cause mortality in an apparently healthy population: a systematic review and meta-analysis of data from approximately 2 million men and women. Arch Phys Med Rehabil 2018.
[20] Davidson T, Vainshelboim B, Kokkinos P, et al. Cardiorespiratory fitness versus physical activity as predictors of all-cause mortality in men. Am Heart J 2018;196:156–62.
[21] Froberg K, Andersen LB. Mini review: physical activity and fitness and its relations to cardiovascular disease risk factors in children. Int J Obes (Lond) 2005;29(Suppl 2):S34–39.
[22] Ortega FB, Ruiz JR, Castillo MJ, et al. Physical fitness in childhood and adolescence: a powerful marker of health. Int J Obes (Lond) 2008;32:1–1.
[23] Steele RM, Brage S, Corder K, et al. Physical activity, cardiorespiratory fitness, and the metabolic syndrome in youth. J Appl Physiol 2008;105:342–51.
[24] Chaddock-Heyman L, Hillman CH, Cohen NJ, et al. The importance of physical activity and aerobic fitness for cognitive control and memory in children. Monogr Soc Res Child Dev 2014;79:25–50.
[25] Ortega FB, Tresaco B, Ruiz JR, et al. Cardiorespiratory fitness and sedentary activities are associated with adiposity in adolescents. Obesity 2007;15:1589–99.
[26] De Miguel-Etayo P, Gracia-Marco L, Ortega FB, et al. Physical fitness reference standards in European children: the IDEFICS study. Int J Obes (Lond) 2014;38(Suppl 2):S57–66.
[27] Catley MJ, Tomkinson GR. Normative health-related fitness values for children: analysis of 85347 test results on 9–17-year-old Australians since 1985. Br J Sports Med 2013;47:98–108.
[28] Brown T, Summerbell C. Systematic review of school-based interventions that focus on changing dietaryintake and physical activity levels to prevent childhood obesity: an update to the obesity guidance produced by the National Institute for Health and Clinical Excellence. Obesity Rev 2009;10:110–41.
[29] Knöpfli B, Radtke T, Lehmann M, et al. Effects of a multidisciplinary inpatient intervention on body composition, aerobic fitness, and quality of life inseverely obese girls and boys. J Adoles Health 2008;42:119–27.
[30] Erfle SE, Gamble A. Effects of daily physical education on physical fitness and weight status in middle school adolescents. J Sch Health 2015;85:27–35.
[31] Kropski JA, Keckley PH, Jensen GL. School-based obesity prevention programs: an evidence-based review. Obesity 2008;16:1009–18.
[32] Koca C, Asci FH, Demirhan G. Attitudes toward physical education and class preferences of Turkish adolescents in terms of school gender composition. Adolescence 2005;40:365–75.
[33] Hilland TA, Ridgers ND, Stratton G, et al. Associations between selected demographic, biological,school environmental and physical education based correlates, and adolescent physical activity. Pediatric Exercise Sci 2011;23:61–71.
[34] Magnusson KT, Sigurgeirsson I, Sveinsson T, et al. Assessment of a two-year school-based physical activity intervention among 7-9-year-old children. Int J Behav Nutr Phys Act 2011;8:138.
[35] Govindan M, Gurm R, Mohan S, et al. Gender differences in physiologic markers and health behaviors associated with childhood obesity. Pediatrics 2013;132:468–74.