学 位 論 文

Obesity in elementary school children in Northeast China: affecting factors, the effect of intervention, and the impact of body image on weight reduction

（中国東北部における小学生の肥満について―影響因子・介入効果・ボディイメージの体重減少に対する影響―）

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Abstract

Background:

Childhood obesity has become a major health issue. Obesity is a risk factor for lifestyle-related diseases such as high blood pressure, coronary heart disease, and stroke. While symptoms usually manifest in midlife, these conditions develop progressively over time with signs appearing as early as childhood and adolescence.

There are various kinds of methods for exercise and nutrition interventions among school children. Currently, there is no conclusion on whether the sole use of exercise or nutrition as an intervention is more effective than the combination of the two. In addition, there are a limited number of studies that have focused on changes soon after the intervention in addition to conducting a long-term follow-up survey assessing the effect of the intervention.

Body image is recognized as part of the spectrum of conditions related to disordered eating, and given its increasing trend, its relationship with body image and dissatisfaction has become a focus of research. Moreover, there are not many longitudinal studies on body dissatisfaction and its effects on weight reduction; thus, the causal relationship between body dissatisfaction and weight reduction needs to be clarified.

Objective:

The purposes of this study are to explore factors associated with nutritional status and designing obesity intervention program (Chapter I); to verify the long-term and short-term effects of this obesity intervention program (Chapter II); to investigate the impact of body image on weight reduction (Chapter III).

Materials and methods

In chapter I, anthropometric measurements, a dietary survey, and a physical fitness test were performed to assess 971 primary school children. Education levels of both father and mother, and monthly income were collected using a self-attested questionnaire at the parents' meeting.

In chapter II, 221 primary school children aged 9 to 12 years determined as overweight/obese were randomly assigned to 1 of 4 groups: exercise intervention, nutrition education, combination of both, and control. Nutrition education and rope-skipping sessions were performed for 2 months. Anthropometric measurements and nutrition knowledge test were administered at baseline, after 2 months (post intervention), and 1 year later (follow-up).

2 years later, 218 students aged 11-14 years and their parents were examined in the chapter III. Measured height and weight were used for calculating BMI. Ideal weight for children was reported by children themselves and their parents. Body dissatisfaction of children was calculated considering children's actual BMI and the ideal BMI values by children themselves, their fathers, and their mothers.

Results and Discussion

Proportions of overweight and obesity children were generally higher than the reference of China. Besides, skipping ropes for one minute was correlated with upper arm muscle in both urban and rural children ($P < 0.05$). Skipping rope ($\beta = - 0.34$, $P < 0.01$); daily exercise time ($\beta = - 0.30$, $P < 0.01$); daily screen time ($\beta = 0.24$, $P < 0.01$); edible oils ($\beta = 0.15$, $P < 0.01$), grain ($\beta = 0.13$, $P < 0.01$); family income ($\beta = 0.11$, $P < 0.01$); and sex ($\beta = 0.10$, $P < 0.01$) were significant predictive factors of overweight and obese

for both urban and rural children. Improvement in diet, such as reducing grain and edible oils intake, are essential, and increasing exercise to promote muscle mass are recommended. Finally, by increasing muscle mass, skipping ropes can help reduce obesity and improve physical fitness (Chapter I).

The effect of the intervention by the amount of change in body mass index standard deviation scores (BMI-SDS) was confirmed. Combined intervention was found to be most effective for the score of BMI-SDS followed by exercise intervention and nutrition education. Combined intervention was also most effective for the gap in the score of BMI-SDS between following-up and baseline followed by nutrition education and exercise intervention. Overall, the combined intervention had both strongest short-term and long-term effects compared to the other interventions. The exercise intervention had a better short-term effect than nutrition education, while nutrition education had a better long-term effect than the exercise intervention (Chapter II). This refers to the connotation that nutritional education has a larger impact in the long run, highlighting the importance of enlightening the children in nutritional aspects persistently.

The impact of body image on weight reduction was also investigated. Mothers' dissatisfaction with their children's body was found to significantly predict weight reduction in children. However, children's body dissatisfaction negatively predicted weight reduction. Higher BMI of father and mother negatively affected weight reduction of their same-sex children. Our findings indicate the importance of examining gender roles in body image perceptions of parents and children in order to address obesity issues in rural China (Chapter III).

Conclusions

Cross-sectional study (chapter I) implicated that skipping ropes may enhance muscle mass while intake of edible oil and grain may exacerbate obesity of children. The findings of the intervention study (chapter II) revealed that the combined intervention had the best short-term and long-term effects for overweight children of all interventions. Furthermore, the exercise intervention had a better short-term effect than nutrition education, while nutrition education had a better long-term effect than the exercise intervention. In psychological aspects, body image perceptions of parents and children had an important impact on weight reduction (chapter III).

General introduction

Childhood obesity

Childhood obesity has become a major health issue (Karnik et al., 2012). The overweight and obesity rate among children (age 2–19) exceeded that of adults (by 27.5%), increased by 47.1%, and reached about 25% (girls: 22.6% and boys: 23.8%) in developed countries in 2013; in developing countries, over 10% (girls: 13.4% and boys: 12.9%) of children are overweight or obese (Ng et al., 2013). Although developed countries have a higher rate of childhood obesity, the total number of obese children in developing countries is greater than in developed countries (Ng et al., 2013). Moreover, over the last decade, childhood obesity rates in developed countries stabilized while rates in developing countries continue to rise (Ng et al., 2013).

With its rapid economic development, China's childhood obesity has become a health issue that cannot be ignored. According to a report on the physical fitness of Chinese students, the rate of overweight and obesity of Chinese children aged 7–18 reached 27.3% in 2010 (Zheng et al., 2016). Additionally, the urban childhood obesity rate is higher than the rural rate, but the rural childhood obesity rate is growing faster than the urban rate (Zong et al., 2014). And it is especially important to intervene in, improve, or prevent obesity and keep fit during childhood (Pastor et al., 2012). Therefore, it is

necessary to develop proper interventions for rural children in order to control the development of obesity during childhood.

Poor physical fitness in children has also increased considerably. According to a review of 137 studies conducted in 19 countries, cardiorespiratory fitness in children aged 9-17 decreased significantly in most countries between 1981 and 2014, as measured by 20-m shuttle-run test performance (Tomkinson et al., 2017). A strong tendency toward obesity/overweight has also been observed in Asian children, and levels of physical activity and strength have been reported to be low (Yamauchi et al., 2007; Tomkinson et al., 2007; Chen et al., 2006). Issues surrounding childhood obesity and poor physical fitness are more serious in economically developing Asian countries, relative to those of Japan (Yamauchi et al., 2007; Tomkinson et al., 2012).

Obesity and poor physical fitness are risk factors for lifestyle-related diseases such as high blood pressure, coronary heart disease, and stroke (Akil & Ahmad, 2011; Venckunas et al., 2016). While symptoms usually manifest in midlife, these conditions develop progressively over time with signs appearing as early as childhood and adolescence (Venckunas et al., 2016). It is important to establish a high fitness potential and sustainable lifestyle habits during childhood and adolescence. A recent prospective study showed that moderate and vigorous physical activity levels can be predicted for up

to 6 years by physical fitness and fundamental movement skills developed in early adolescence (Jaakkola et al., 2016). Additionally, it is important to establish baseline measurements for body composition and physical fitness at a young age to monitor and prevent obesity and poor physical fitness.

The effect of exercise intervention and nutrition education

There are various kinds of methods for exercise and nutrition interventions. For exercise interventions, sports like swimming, jumping, skipping rope, cycling, tennis, and running are often used separately (Petit et al., 2002) or with a combination of 2 or more sports (Carrel et al., 2005; Nemet et al., 2005). Exercise interventions combining rope skipping with other sports are effective for improving obesity (Chang et al., 2008). The advantages of rope skipping were recognized in the national physical fitness survey for Chinese elementary school and secondary school students (MEPRC, 2007). This study chose skipping rope as a measure of physical fitness, which has relatively higher metabolic equivalents (METs = 10.0) (Ministry et al., 2007). For nutrition interventions, 2 methods dietary restriction (Nemet et al., 2005; Woo et al., 2004) and nutrition education (Viggiano et al., 2000) are implemented separately or simultaneously (Nemet et al., 2005).

Previous studies showed that nutrition education as an intervention has long-term effects that are maintained (Nemet et al., 2015; Reinehr et al., 2007). Currently, there is no conclusion on whether the sole use of exercise or nutrition as an intervention is more effective than the combination of the two (Thomas et al., 2006). There is only a limited number of studies that have focused on changes soon after the intervention in addition to conducting a long-term follow-up survey assessing the effect of the intervention. By clarifying short-term and long-term advantages of a single intervention involving exercise or nutrition education as well as the combination of the 2 types of interventions, the findings can be used as a reference for developing interventions to decrease childhood obesity and for conducting similar studies in the future.

Body image

Body image is a psychosocial dimension, defined by Schilder in the 1930s as 'the picture of our own body which we form in our own mind' (Schilder 1978). It is viewed as central to many aspects of human functioning, including emotions, thoughts, behaviors and relationships (85%) (Pallan et al, 2011). According to previous studies, methodology for infant feeding. Therefore, body image may affect eating habits and exercise habits. A previous study showed that body image has an important relationship with eating

disorders and active participation in sports (Neumark-Sztainer et al, 2006). Obesity is also recognized as part of the spectrum of conditions related to disordered eating, and with the escalation of the obesity problem, its relationship to body image and dissatisfaction has become a focus of research (Pallan et al., 2011).

In addition to media, parents are another factor that influences the body image (McCabe et al., 2016; Hutchinson et al., 2011). Most of the important information that children receive about their self-worth and body image was seen and heard at home (Hutchinson et al., 2011). Previous studies have shown that the diet of adults and the problem of body image are very likely to be transmitted to children (Phares et al, 2004). However, there are various theories about the relationship between parental influence and children's obesity. Previous studies showed that the parents' recognition of their children's obesity is a premise for their children's weight reduction (Jeffery et al, 2004; Maynard et al, 2003). However, another studies showed that as the parents' level of dissatisfaction to their children's body image increases, the children's dissatisfaction level of their body image also increases (Pierce et al, 1993; Faith, 2002). Increased body dissatisfaction will reduce children's self-esteem and make children less willing to participate in outdoor activities, which will adversely affect the improvement in obesity (Strauss, 2000). Therefore, it is important to reduce the adverse effects of body dissatisfaction from

parents to avoid obesity in children.

Purpose of Study

The purposes of this study are to explore factors associated with nutritional status and designing obesity intervention program (Chapter I); to verify the long-term and short-term effects of this obesity intervention program (Chapter II); to investigate the impact of body image on weight reduction (Chapter III).

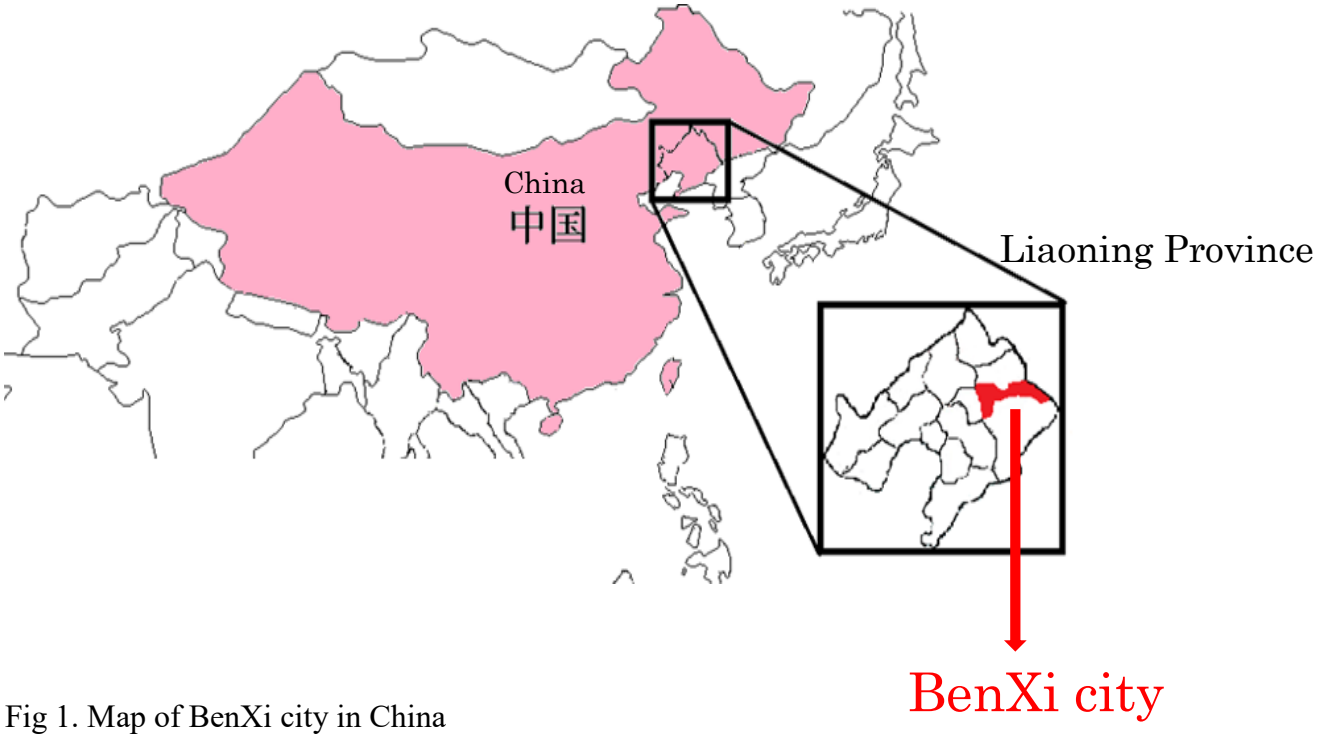


Fig 1. Map of BenXi city in China

Chapter I. Diet, fitness and nutritional status of school children

(*Modified the original article submitted to *School Health*.)

Aim of the study

The purpose of this study is to investigate nutritional status and physical fitness level in local elementary school children and explore factors associated with obesity.

Materials and methods

Participants

One urban elementary school and two rural elementary schools were selected from schools located in Benxi, Lianing province (Fig 1). Two classes from each grade were chosen at random. There was a minimal population of students aged 5 years and 12 years of age, therefore these students were excluded from the study. A total of 971 students (urban boys: 290; urban girls: 252; rural boys: 222; and rural girls: 207) ages 6–11 years were included in the study (Table 1).

Anthropometric measurements

Anthropometric measurements were performed at each elementary school between June and August 2014. Height was measured in units of 0.1 cm using a portable stadiometer (Seca 213, Seca Nihon). Weight was measured in units of 0.1 kg using digital

scales (BC754, Tanita). Upper arm circumference was measured in units of 0.1 cm using a fiberglass tape measure. Triceps skinfold thickness was measured in units of 2 mm using a plastic skinfold adipometer (Abbott, Japan). All anthropometric measurements were performed by the author (HM) and a local assistant. Body mass index (BMI; kg/m^2) was calculated using height and weight measurements. Arm muscle area (AMA) was calculated using upper-arm circumference and triceps skinfold thickness. BMI-for-age z-scores (BMIAZ) were calculated using WHO reference data for gender and age (WHO, 2007). Overweight and obese were defined using the WHO BMI classification. (Krebs et al., 2007)

Physical fitness

Subjects completed the Chinese Physical Fitness Test (MEPRC, 2007), which consists of the following activities: 50- and 400-m runs, sit-and-reach test, skipping rope for 1 min, and performing sit-ups for 1 min. Fitness testing took place at the rural and urban elementary schools in April 2014. The subjects' fitness scores were calculated based on the Chinese Physical Fitness Test (MEPRC, 2007).

Diet and nutrition

A parents' meeting, including children, was held at the schools so that children could complete a food frequency questionnaire with help from their parents. Daily, weekly, monthly, and yearly dietary intake was recorded using the Chinese Food Frequency Questionnaire (FFQ) (Chang & Wang, 2016). Images of food appearing in the Standard Tables of Food Composition in China were used to help calculate portion size (Zhang et al., 2009). Energy intake and the intakes of three major nutrients and nine food groups (grains, vegetables, fruit, meat products, egg, fish, bean products, milk, and edible oils) were calculated using standard Chinese food composition tables (Zhang et al., 2009).

Sociodemographic characteristics

Education level of both father and mother and family income (yuan/month) was collected using a self-attested questionnaire at the parents' meeting.

Lifestyle

Using a questionnaire, students were asked to record their average daily exercise time (min/day), screen time (min/day), and sleeping time (min/day) in the latest week. Exercise time was defined as the sum of the time spent in exercise or sports. Adolescent students were asked to separately report time spent in physical activities at

school (i.e., during physical education class), at sports clubs, and during their free time. To estimate screen time, adolescent students were asked to separately report time spent watching television, using a computer, and playing video games. Sleep time included sleep taking place overnight and during naps.

Statistical analysis

An independent t-test was performed to examine the differences in the subjects' mean body composition and physical fitness test results by area and sex. Pearson's correlation coefficients were calculated to assess the relationships between AMA and physical fitness test scores. Multiple regression analysis was performed to identify factors contributing to obesity/overweight in each area. BMIAZ was entered into the regression equations as a dependent variable with the following predictor variables: AMA (cm2), percent body fat (%), 50-m run time (sec), long-seat body anteflexion (cm), skipping rope (times/min), exercise time (min/day), screen time (min/day), sleeping time (min/day), intake values for nine food groups (g/day), three major nutrients (g/day), and energy (kcal/day), education level of the father and mother, family income (yuan/month), area, and sex. Stepwise variable selection using the increase-and-decrease method was used with a threshold P-value of 0.20, and calculated using a likelihood ratio test. JMP Pro

12.0.1 (SAS Institute Inc.) was used to perform statistical analyses, with significance of $P < 0.05$.

Ethics approval and consent to participate

Complete research objectives and procedures were explained to subjects and their parents in Chinese. Survey contents were explained to both parents and subjects with help from school principals and classroom teachers. Parents and subjects each provided written informed consent, agreeing to the required measurement and survey completion procedures. Ethical approval for the study was granted by the Graduate School of Health Sciences, Hokkaido University (13-37).

Results

Mean values for height, weight, BMI, and AMA were higher in urban children compared to rural children in most age groups for both boys and girls (data not shown). There was a high proportion of overweight and obese subjects: urban boys: 49%; rural boys: 35%; urban girls: 33%; and rural girls: 20% (Table 1).

Means and standard deviations for physical fitness test results (5 of 15 items: 50-m run time, 400-m run time, long-seat body anteflexion, skipping rope [1 min], and

raising the upper part of the body [1 min]) by area are shown in Table 1. Overall, rural children had better physical fitness test results than urban children (Table 1). Scores for the five items are shown in Fig 2. Except for the skipping rope score, mean scores exceeded cut-off values for passing marks in urban boys. Mean scores for long-seat body anteflexion and skipping rope were significantly different in rural and urban boys, and mean scores for skipping rope and 50-m run time were significantly different in rural and urban girls. Compared to the rural children, there was a higher proportion of failing scores in the urban children. In particular, the proportion of urban children with failing scores for skipping rope was 48%, which was much higher compared to other groups (Fig 2).

To clarify the relationship between muscle mass and physical fitness, we examined the correlations between AMA and individual physical fitness test scores. There was a significant positive correlation between skipping rope and AMA in all groups (r: 0.15-0.24, $P < 0.05$) (data not shown).

Energy intake, macronutrient intake (protein, fat, and carbohydrates), energy ratio (ratio for total energy intake), and intake of nine food groups was calculated for urban and rural children (Table 1, 2). Intakes of energy, protein, and fat were significantly higher in urban children than in rural children (Table 1).

Intake of nine food groups was determined by area and sex (Table 2). Intake of

grains, meat, eggs, and beans was higher compared to the Chinese recommended dietary allowance (Wang et al., 2018), while intake of fruit, fish, and milk was lower. In particular, milk intake was extremely low among rural children (boys: 15.5% and girls: 10.2%; Table 2) relative to the recommended dietary allowance of 300 g. Intake of vegetables and edible oils was within the recommended range. In urban children, mean intake values for all food groups were higher than in rural children, but significant differences were observed only for meat and milk ($P < 0.05$) (Table 2).

Reported means and standard deviations (min/day) for daily exercise time, screen time and sleeping time by area and sex are shown in Table 3. There was no significant difference in sleeping time between urban and rural school children, but exercise time and screen time of rural children were significantly longer than in urban children ($p < 0.05$) (Table 3). The mean daily exercise time was less than the Chinese recommended exercise time of 1 hour in both urban boys and girls (Wang & Jing, 2016). On the other hand, daily exercise time was longer than the Chinese recommended daily exercise time20 in both rural boys and girls. Screen time was two times longer in rural children than urban children for both boys and girls. ($p < 0.05$).

Multiple regression analysis was performed to identify factors that contributed to the tendency toward obesity (Table 4). BMIAZ was entered into the regression

equations as a dependent variable, while physical fitness (3 items), dietary habits (3 items), lifestyle (3 items), education level of the father and mother, family income (yuan/month), areas, and sex were included as predictor variables. Skipping rope ($\beta = -0.34$, $P < 0.01$); daily exercise time ($\beta = -0.30$, $P < 0.01$); daily screen time ($\beta = 0.24$, $P < 0.01$); edible oils ($\beta = 0.15$, $P < 0.01$), grain ($\beta = 0.13$, $P < 0.01$); family income (yuan / month) ($\beta = 0.11$, $P < 0.01$); and sex ($\beta = 0.10$, $P < 0.01$) were significant predictive factors (Table 4).

Table 1. BMI category, 5 items of physical fitness and food consumption for urban and rural children†

	Urban	Rural
BMI category (kg/m^2)		
Boys		
Underweight & Normal	148 (51%)	144 (65%)
Overweight & obese	142 (49%)	78 (35%)
Girls		
Underweight & Normal	169 (67%)	166 (80%)
Overweight & Obese	83 (33%)	41 (20%)
Results of 5 items of physical fitness test‡		
Boys		
50 meters run (s)	10.7 ± 1.5	10.5 ± 2.3
Body anteflexion in sitting (cm)	2.2 ± 5.9	4.4** ± 5.3
Skipping Rope (n)	48.8 ± 42.9	65.7** ± 41.1
Sit ups (n)	25.6 ± 10.4	28.8** ± 11.8
Run 400 meters (s)	110.4 ± 19.6	104.9* ± 17.0
Girls		
50 meters run (s)	11.0 ± 1.51	10.6* ± 2.1
Body anteflexion in sitting (cm)	6.8 ± 5.9	7.5 ± 5.0
Skipping rope (n)	71.0 ± 40.4	94.4**± 45.3
Sit ups (n)	25.1 ± 10.4	26.6 ± 11.9
Run 400 meters (s)	111.9 ± 19.6	105.3**± 14.9
Food consumption		
Boys		
Energy (kcal)	2311.7 ± 685.31	2050.4**± 514.8
Proteins (g)	76.9 ± 24.7	65.6** ± 17.5
Fat (g)	89.2 ± 34.8	59.6** ± 21.5
Carbohydrate (g)	302.5 ± 90.5	320.0 ± 83.8
Girls		
Energy (kcal)	2177.9 ± 582.51	1927.0** ± 451.31
Proteins (g)	74.1 ± 22.4	63.0** ± 16.1
Fat (g)	84.8 ± 31.6	55.7** ± 21.7
Carbohydrate (g)	286.8 ±73.3	296.9 ± 68.9

*p <0.05; **p < 0.01.

†Values are n (%) or mean ± SD.

‡ All the students conducted the 50 meters run, body anteflexion in sitting and rope skipping test. The number of participants: Urban boys: 290; Urban girls: 252; Rural boys: 222; Rural girls: 207. Students in the fifth and sixth grades conducted the sit ups test. The number of participants: Urban boys: 195; Urban girls: 180; Rural boys: 156; Rural girls: 137. Students in the sixth grade conducted the 50 meters run test. The number of participants: Urban boys: 112; Urban girls: 90; Rural boys: 86; Rural girls: 82.

Table 2. Intake of nine food groups (g)

Food groups	Recommendation †	Boy		Girls	
		Urban (n = 290)	Rural (n = 222)	Urban (n = 252)	Rural (n = 207)
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Grains	250 - 400	608.1 ± 168.9	583.2 ± 156.5	458.2 ± 122.3	423.1 ± 110.6
Vegetables	300 - 500	457.5 ± 135.6	447.8 ± 138.8	389.2 ± 121.2	348.9 ± 103.6
Fruit	200 - 400	183.4 ± 88.5	165.4 ± 80.6	231.6 ± 98.6	214.7 ± 79.6
Meat	50 - 75	168.4 * ± 80.6	101.1 ± 72.5	115.5 * ± 69.9	88.9 ± 56.8
Eggs	25 - 50	69.4 ± 33.6	68.5 ± 35.5	54.6 ± 30.1	50.1 ± 28.6
Fish	50 - 100	35.5 ± 20.1	20.7 ± 17.6	27.9 ± 19.9	20.5 ± 17.9
Beans	30 - 50	67.7 ± 30.5	60.5 ± 29.8	52.8 ± 28.6	51.0 ± 23.6
Milk	300	85.5 * ± 75.6	46.4 ± 39.8	86.5 * ± 52.9	32.1 ± 21.0
Edible oils	<30	31.5 ± 18.5	24.6 ± 16.6	31.6 ± 19.6	26.5 ± 15.5

*$p < 0.05$.

† (Zhang, et al., 2009).

Table 3. Daily exercise time, screen time and sleeping time for urban and rural children

	Urban	Rural
	n = 290	n = 222
	Mean ± SD	Mean ± SD
Boys		
Daily exercise time (min)	57.6 ± 31.6	95.9** ± 47.0
Daily screen time (min)	39.5 ± 19.8	83.5** ± 44.9
Daily sleeping time (min)	557.3 ± 42.9	564.9 ± 44.9
Girls	n = 252	n = 207
Daily exercise time (min)	55.5 ± 31.4	90.8** ± 45.3
Daily screen time (min)	39.8 ± 19.9	86.3** ± 43.9
Daily sleeping time (min)	555.3 ± 44.3	565.3 ± 46.7

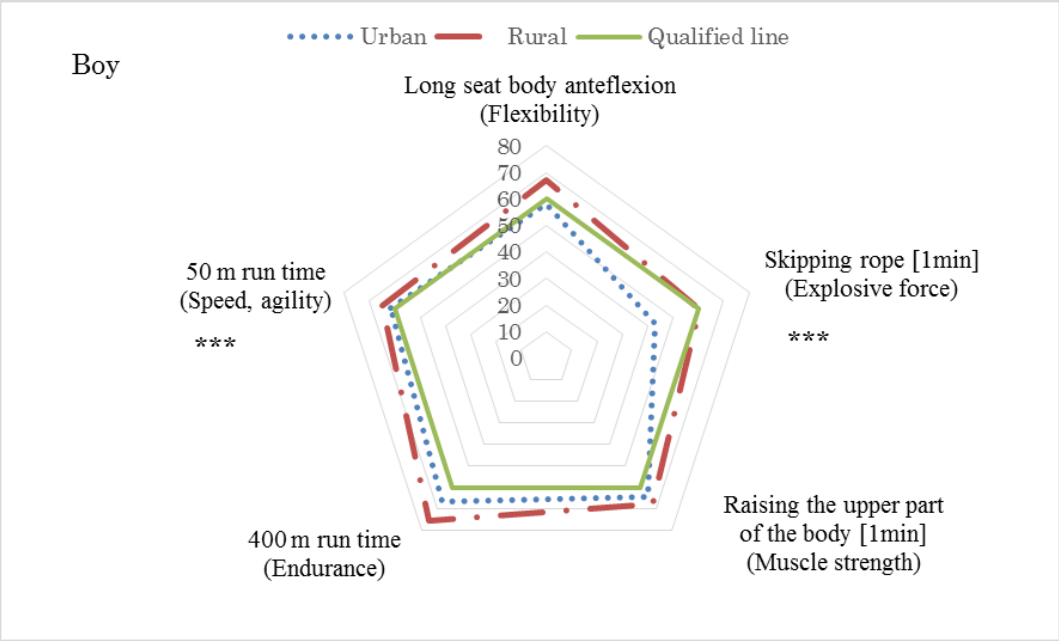
*p < 0.05; **p < 0.01.

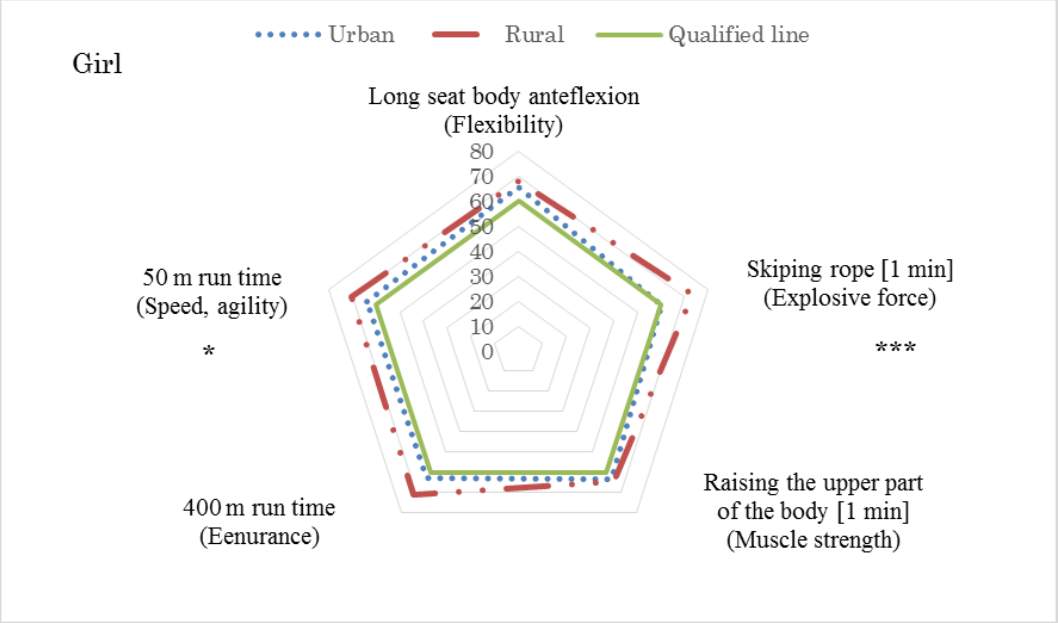
Table 4. Factors that contributed to the tendency toward BMI-SDS[†]

	β	*t*	VIF	*P*
Skipping rope (n/min)	- 0.34	- 11.51	1.23	< 0.01
Daily exercise time (min/d)	- 0.30	- 10.32	1.17	< 0.01
Daily screen time (min/d)	0.24	8.48	1.09	< 0.01
Oil (g/d)	0.15	5.09	1.19	< 0.01
Grain (g/d)	0.13	4.04	1.49	< 0.01
Family income (yuan / month)	0.11	3.90	0.07	< 0.01
Sex[‡]	0.10	- 2.84	1.69	< 0.01

[†] R^2: 0.30, P < 0.01; RMES: 1.09.

[‡]Girls = 0; Boy = 1.





*p <0.05; ***p < 0.001.

All the students conducted the 50 meters run, body anteflexion in sitting and rope skipping test. The number of participants: Urban boys: 290; Urban girls: 252; Rural boys: 222; Rural girls: 207. Students in the fifth and sixth grades conducted the sit ups test. The number of participants: Urban boys: 195; Urban girls: 180; Rural boys: 156; Rural girls: 137. Students in the sixth grade conducted the 50 meters run test. The number of participants: Urban boys: 112; Urban girls: 90; Rural boys: 86; Rural girls: 82.

Fig 2. The average score of physical fitness test

Discussion

In this study, we found that school children in Northeastern China have high rates of overweight and obesity. The proportions of overweight and obese subjects were lowest in rural girls relative to those of the other groups; however, 20% of rural girls were considered overweight or obesity. The prevalence of overweight or obesity in this study was higher than the China national survey results (21.1%), except for rural girls (CCDCP, 2010). Signs of poor physical fitness have also been found (table 1), compared to the results of previous studies including 89,949 children chosen from the 32 provinces of China in 2016 (Zhu et al., 2017). Results for 50-m run time, long-seat body anteflexion, and skipping rope (Zhu et al., 2017) were better than in this study. In addition, results for the 50-m run and long-seat body anteflexion in the Japanese physical fitness test (SPF, 2016) were better than in this study (Table 1). Similar to results found by the China national survey (Zhu et al., 2017) and in other developing countries (Yamauchi & Ohtsuka, 2000; Özdirenç et al., 2005), rural children performed better on their physical fitness tests than urban children.

Overweight and obesity were associated with excessive intake of grains and edible oils (Table 4). Intake of nine food groups was relatively higher in urban children than in rural children, consistent with the finding that intakes of energy, protein, and fat

were higher in urban children than in rural children (Table 1, 2). These results could be related to our findings that anthropometric measurement values in urban children exceeded those of rural children (Table 1). Based on the results of multiple regression analysis, BMIAZ increased as intake of grains and edible oils increased (Table 4). Traditional Chinese meals contain large amounts of grain and vegetables (DU et al., 2014). These meals tend to include fried dishes. A survey of Chinese adults revealed that intake of food edible oils rises with vegetable consumption, thereby promoting obesity (Shi et al., 2008). Therefore, traditional preparations of vegetables are considered to be a cause of childhood obesity.

The result of multiple regression analysis for all subjects demonstrated that grain and oil intake were influential factors contributing to BMI-SDS, which successfully shows that reducing cereals and oil intake is recommended to lower the risk for obesity. However, considering overweight and obese children, 81% of these participants had higher grain intake than recommended guidelines by Chinese government; furthermore, there was no significant relationship between grain intake and BMI-SDS in overweight and obese children (data not show). Based on the reason above, reduction of cereals and oil intake could be suggested to be recommended only for overweight and obese children particularly than non-obese ones who do not meet the expected amount intake.

Boys and children from high-income families were more likely to become obese (Table 4). The social economic status (SES) influenced food selection and physical activity and was reported as a factor in childhood obesity (Wang et al., 2001). In developed countries, low SES groups experience higher rates of overweight and obesity in children, while in developing countries higher SES groups experience higher rates of overweight and obesity in children (Wang et al., 2001). Individuals in China with higher SES consumed more high-calorie foods such as meat (which tends to be costlier than vegetables) compared to individuals with lower SES (Ge et al., 1999). Supporting previous studies, the results of multiple regression analysis showed a positive correlation between household income and overweight and obesity in children (Table 4) in our study.

The one-child policy has been considered one of the causes of the deepening childhood obesity problem in China (Heskeh et al., 2006). This study (Table 1) and a previous study have jointly found that the obesity rate in boys is higher than in girls in China (Sum et al., 2014). In addition, boys are more likely to become obese than girls (Table 4). The male/female birth ratio has increased since the one-child policy commenced in 1978, and many Chinese prefer boys (Heskeh et al., 2006). The culture of the paternal authority system in traditional Confucianism in China allocates more domestic resources to boys compared to girls (Zheng et al., 2013) and this could be one

reason there was a higher proportion of obese in boys' than in girls. It is highly possible that more food was provided to boys than girls, and at the same time less likely that boys participated in family work (Sun et al., 2014).

Short exercise time and long screen time were risks of obesity (Table 4). While physical activity has been demonstrated to help children control weight and reduce behaviors linked to health problems such as cardiovascular disease, diabetes, hypertension (CDC, 2014), the screened device is a dominant recreational activity for all ages, especially children (Swinburn & Shelly, 2009). Regardless of participation in physical activity, screen time has a negative influence on health and is associated with health-related risk factors including obesity, cardiovascular disease, and type 2 diabetes (Starkoff et al., 2014). Increasing exercise time and decreasing screen time are important in reducing obesity.

Exercise was effective in reducing fat and enhancing lean body mass in children, which has positive effects on obesity (Watts et al., 2005). From our results, there was a significant positive correlation between the skipping rope test and BMIAZ (Table 4). The metabolic equivalent (MET) of skipping rope was 11.7 to 12.5 from the different fluctuation frequency (Ainsworth et al., 2000), approximately three times as much as jogging (4.5) (Ainsworth et al., 2000). Therefore, skipping rope could produce the same

effect on metabolic rate as jogging in less time, making it an efficient exercise to reduce obesity. Exercise-based weight loss programs (including skipping rope) have proven effective in reducing childhood obesity (Chang et al., 2008; Braet et al., 1997; Sollerhed & Ejlertsson, 2008), accordingly skipping rope as exercise can be expected to lessen obesity. Furthermore, this study indicated that skipping rope can increase muscle mass, and it can be expected that muscle mass will increase with the amount of exercise performed. Skeletal muscle is the primary site of glucose uptake in the postprandial state, an important site of lipid oxidation, and the most significant contributor to basal metabolism (Wolfe, 2006). Skipping rope exercise can increase muscle mass and therefore basal metabolism, which can contribute to preventing obesity.

Moreover, skipping rope has been shown to build upper and lower body strength (Colakoglu et al., 2017). Skipping rope requires the coordination of several muscle groups to sustain the precisely timed and rhythmic movements that are integral to the exercise (Colakoglu et al., 2017). Coordination of these muscle groups increases the athlete's capacity for dynamic balance (Colakoglu et al., 2017). A previous study in Germany demonstrated that five months of skipping rope training increased whole-body adjustment and complicated eye-hand-leg adjustment ability, endurance, and shoulder mobility in elementary school children (Postler et al., 2017). Therefore, skipping rope

could be expected to prevent obesity, increase muscle mass, improve strength, and increase athletic performance.

Limitations

We selected only one city of Benxi as the research area. It is therefore difficult to generalize to other cities in Liaoning Province and the northeastern part of China. However, compared with the results of previous studies, this study indicates that rising levels of childhood obesity and reduced physical strength in China are not only limited to urban school children, but also appear in rural school children.

Because this was a cross-sectional study, it is not possible to determine the causal relationships between nutritional status, diet, lifestyle, exercise performance and the factors affecting them in elementary school children. However, this study revealed various potential factors, including appropriate lifestyle changes (increased exercise time and decreased screen time) and reduced intake of grains and edible oils, that can protect against childhood obesity.

The nutrition survey was conducted using the Chinese Food Intake Frequency Questionnaire (FFQ). There was a possibility that results were confounded by recall bias in the participants. It was particularly difficult for school children in the lower grades to

answer these questions correctly. However, holding the parents' meeting with children allowed the students to answer the FFQ with the help of their parents. Confirmation from parents could reduce the possibility of omissions.

The Food Quality Questionnaire did not measure the amount of meal. However, we provided food images to help students calculate portion size when completing the questionnaire. Photos have been effectively and widely used to estimate portion size (Nelson et al., 1996).

While we did not measure physical activity and could not consider the energy balance, we did investigate daily exercise time. This study demonstrated that increasing exercise time is especially important in preventing obesity in elementary school children.

Conclusions

In this study, rural children had better nutritional status and physical fitness than urban children. However, both urban and rural children showed high rates of obesity and poor physical fitness. For overweight and obesity children, improvements to diet, such as reducing grain and edible oils intake, are essential, and increasing exercise to promote muscle mass is recommended. Finally, by increasing muscle mass, skipping ropes can help reduce obesity and improve physical fitness.

Chapter II. Effects of a combined intervention of rope skipping and nutrition education for overweight children

(*Modified the original article published on *Asia Pacific Journal of Public Health*.)

Aim of this study

This study aimed to compare the effects of 3 methods for improving body measurements—exercise or nutrition education as sole interventions and the combination of exercise and nutrition education—and to verify the maintenance of the effects of the 3 types of interventions 1 year later for overweight and obese elementary school children in a rural area of China.

Materials and methods

Participants

We selected 2 of 3 rural elementary schools with the largest number of students in one district of Benxi City, Liaoning Province, in Northeast China. We measured height and weight for all students in Grades 4 through 6, and 235 students (33% of total children) aged 9 to 12 years were determined to be overweight or obese based on China's body mass index (BMI) classification criterion (Ji et al., 2005). We sent an invitation letter to their parents or guardians, and 229 students (104 girls and 125 boys) agreed to participate.

Design of the Intervention

We divided the participants randomly into 4 groups: an exercise intervention group (E; girls: n = 25; boys: n = 32), a nutrition education intervention group (N; girls: n = 27; boys: n = 33), an exercise and nutrition education intervention group (EN; girls: n = 25; boys: n = 31), and a control group (C; girls: n = 27; boys: n = 29). Weight, height, nutrition knowledge, and daily energy intake were measured at baseline, after the 2-month intervention, and in a follow-up survey 1 year later, and the results of the measurements for each group were compared.

Exercise Intervention

Skipping rope has often been used with other sports as an exercise intervention for obesity, and it was adopted in the national physical fitness survey for Chinese elementary and secondary school students (MEPRC, 2007). This study chose skipping rope, which has relatively high METs (METs = 10.0) (Ainsworth et al., 2000) and the effects can be achieved in a short amount of time. The exercise intervention involved 30 minutes of rope skipping on the school sports grounds every morning before class. The 30-minute exercise was divided into the following phases. The first phase lasted 10 minutes, and the students were asked to skip rope as fast as they could. In the next 10 minutes, boys and girls were grouped by 2 and skipped rope at the same time, playing the

game of “who skips for the longest time and who skips the most.” Because of cumulative fatigue, in the last 10 minutes, in one group, one skipped rope and the other watched and counted to play a game of rope skipping competition. In addition to the intervention, the students had two 45-minute physical education classes each week.

Nutrition Education

Nutrition education has not yet been conducted in China (CSN&HPA, 2014). A textbook widely used in China (Ma & Hu, 2008) was adopted by a local nutritionist to give a 45-minute lecture about nutrition education once a week for 2 months (8 lectures, 6 hours in total). The textbook covers the following content areas: characteristics of growth and development of children and juveniles (chapter 1); nutritional requirements of children and juveniles (chapter 2); daily diet plan (chapter 3); how to use Western fast food and beverages (chapter 4); nutrition for special periods (chapter 5); developing good dietary habits (chapter 6); common dietary mistakes (chapter 7); nutrition, exercise, and disease (chapter 8); common problems and countermeasures (Chapter 9); and recommendations (chapter 10). Specific to the intervention, the lecture included content on nutritional status and growth (chapter 1) and mentioned the importance of exercise (chapter 8). We combined the content from chapters 5 and 6. We also combined the

content from chapters 9 and 10 in one lesson since one of the chapters had less content. Thus, the 10 chapters were covered in 8 lectures.

Anthropometry

Height was measured with a portable stadiometer (Seca 213 and Seca Nihon) with 0.1 cm precision. Body weight (0.1 kg precision) was measured with a weighing scale (BC 754, Tanita). All anthropometric measurements were performed by the author (HM) and with the help of a local nurse. BMI (kg/m^2) was calculated using height and weight. Students aged between 9 and 12 years are experiencing rapid growth during this time, and the BMI of students can vary substantially even in the same age group. In order to reduce the effect of children's normal growth and the differences in age on the intervention effects, BMI standard deviation scores (BMI-SDS) (Reinehr et al., 2009) were used. The standardized China growth curve was used as the reference for the standard deviation value (Li et al., 2009). BMI-SDS were quantified using Cole's Box-Cox transformation, which normalizes the BMI-skewed distribution in childhood and expresses BMI as a standard deviation score (BMI-SDS), calculated as follows:

$$BMI - SDS = [(BMI / M)L - 1] / S*L$$

The parameters are the median (M), the generalized coefficient of variation (S),

and the power in the Box-Cox transformation (L).

Dietary Survey

The parents of the participants were invited to the schools to conduct a dietary survey with their children. The parents sat with the children while the student answered the questions after consulting with their father or mother. China's Food Frequency Questionnaire (Chang & Wang, 2016) for children was used to investigate food frequency for 1 day, 1 week, 1 month, and 1 year, and intake of each food was completed by rationing according to an appendix (size and quantity) of the China Food Composition Table (Yang et al., 2009). Daily energy intake was calculated for each participant.

Nutrition Knowledge

To verify the outcome of nutrition education, the nutritionist who provided the lectures developed a nutrition knowledge test based on the textbook (Ma et al., 2008) used in the class. The measure comprised 10 items according to the content of each chapter, or 1 test question per chapter. Five of the questions were from the 5-item questionnaire that was used in Nanjing city of China (Hu et al., 2005), and the others were designed by the nutritionist according to the textbook. We administered the test before the nutrition

education intervention (baseline), after completing the nutrition education (post intervention), and 1 year later (follow-up). Three patterns of the test with the same content but with different response options were administered on each occasion, that is, baseline, post intervention, and follow-up.

Exercise Habit

The measure of exercise frequency was designed based on the questionnaire that was used in Jiangsu province of China to investigate the physical activity level of children (Shi et al, 2006). We asked the participants, “How many times per week do you work, play, or exercise hard enough to make you sweat and breathe heavily (Shi et al, 2006)?” Those who answered “more than 3 times a week” were defined as having an “exercise habit.”

Statistical Analyses

Differences in BMI, nutrition knowledge, and daily energy intake at post intervention and follow-up compared with baseline were examined by paired t tests. One-way ANOVA (analysis of variance) was used to compare the changes in BMI-SDS between post intervention and baseline and BMI-SDS between follow-up and baseline of

each group. When compared with baseline, a decrease in BMI-SDS of 0.5 or above was defined as “success.” (Reinehr et al., 2009) This value was used because in a previous study, a reduction in the incidence of obesity-related diseases was only observed in an overweight reduction of > 0.5 BMI-SDS (Reinehr et al., 2009). Statistical significance was set at $P < 0.05$. JMP ver.12.01J (SAS Institute, Inc, Cary, NC) was used for all statistical analyses.

Ethical Approval and Consent

Only those participants who agreed and submitted written consent were included in the study. The study was approved by the Ethics Committee of the Faculty of Health Science of Hokkaido University (15-44).

Results

The results of the effect of the intervention on BMI, nutrition knowledge, and energy intake are provided in Table 5. Both in boys and girls, BMI significantly decreased in all the 3 groups at post intervention compared with baseline ($P < 0.05$). Although BMI values rebounded except for girls in the nutrition education (N) group, the values were still significantly lower than at baseline ($P < 0.05$).

Scores on the nutrition knowledge test significantly increased after the intervention (40% to 82%) in both girls and boys in the 2 groups (N and EN) who took the nutrition education class ($P < 0.05$). The test scores significantly decreased at follow-up 1 year later, but were still significantly higher than at baseline ($P < 0.05$). On the contrary, in the C group and E group, except for girls in the E group at follow-up and boys in the E group at post intervention, there was no significant change among girls and boys at post intervention and follow-up (Table 5).

Among the 2 groups who received nutrition education, girls' energy intake significantly decreased at post intervention ($P < 0.05$). Energy intake rebounded at follow-up, but remained significantly lower than at baseline ($P < 0.05$). On the other hand, a downward trend of energy intake was found in boys in the 2 groups at post intervention and follow-up ($P < 0.05$). Thus, there was a significant decrease in energy intake that lasted 1 year after the intervention in both boys and girls who received nutrition education (Table 5).

As for the percentage of children who had an exercise habit, the percentage did not change markedly in the C group at post intervention and follow-up compared with baseline (Fig 3). When the E group completed the intervention, the percentage of children with an exercise habit increased considerably. On the other hand, the percentage of

children who had an exercise habit in the N group did not increase at post intervention, but increased considerably at follow-up compared with baseline. The EN group experienced both short- and long-term effects. In terms of the short-term effect, the percentage of girls with an exercise habit was 8 times higher than at baseline and the percentage of boys was 3.8 times higher. One year later at follow-up, the percentage was 7.8 times higher than baseline among girls and 3.5 times higher among boys.

Changes in BMI-SDS between post intervention and baseline and between follow-up and baseline for each group are shown in Fig 4. The order of change in BMI-SDS between post intervention and baseline from highest to lowest for the 4 groups was EN, E, N, and then C. However, the order of change in BMI-SDS between follow-up and baseline from the highest to lowest for the 4 groups was EN, N, E, and then C.

Table 5. Impact of intervention on body mass index (BMI), score of nutrition knowledge and energy intake

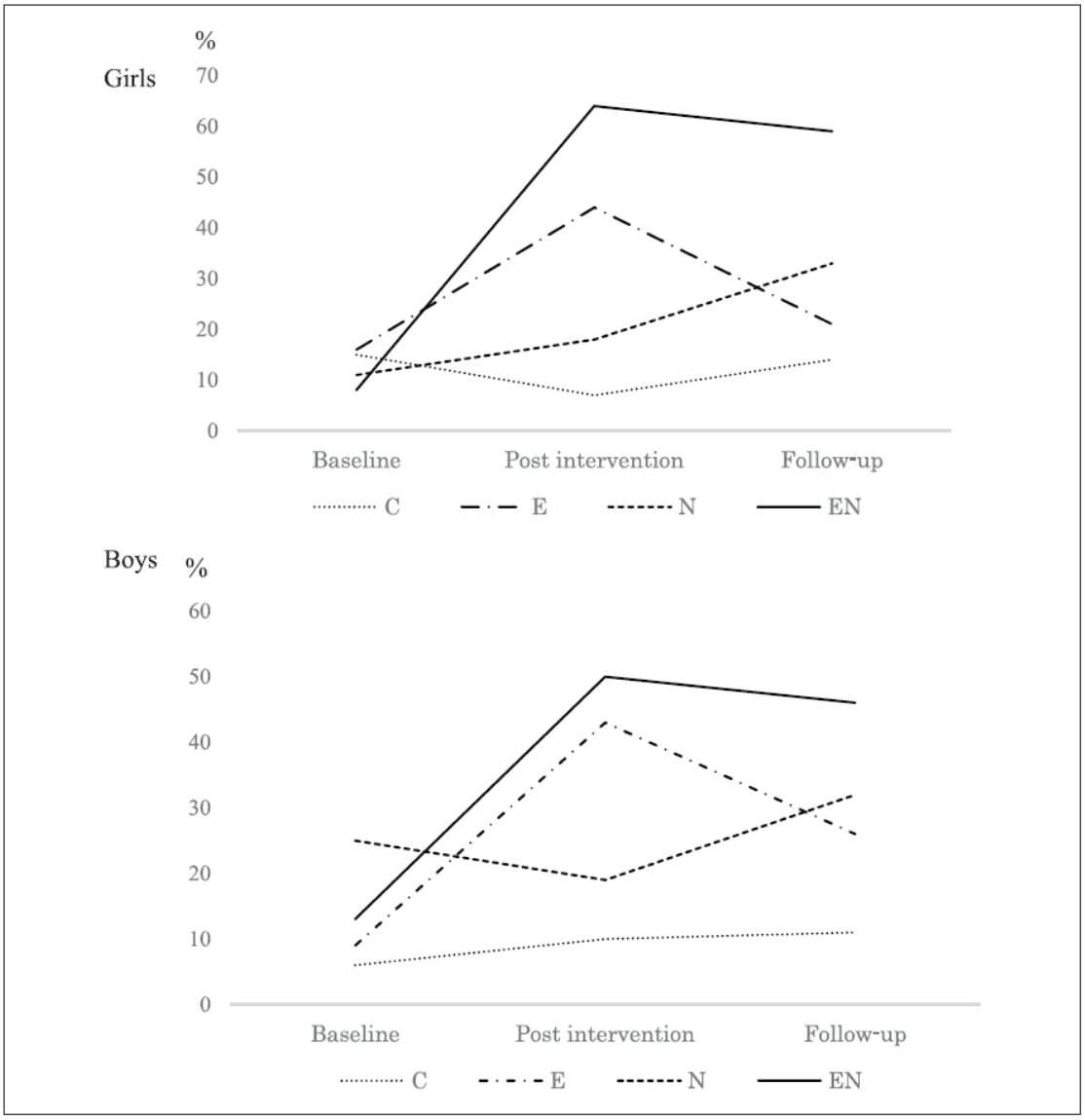
		Group (n)	Baseline (B) Mean ± SD	Post Intervention Mean ± SD	Follow-up† (F) Mean ± SD
BMI (kg/m^2)	Girls	C (27)	22.7 ± 2.0	22.9 ± 1.9	22.9 ± 1.8
		E (25)	22.6 ± 2.1	20.9* ± 2.6	21.9* ± 2.2
		N (27)	23.0 ± 2.4	22.3* ± 1.9	22.7 ± 2.1
		EN (25)	22.8 ± 2.2	21.0* ± 2.0	21.9* ± 2.3
	Boys	C (29)	23.2 ± 2.5	23.3 ± 2.3	23.0 ± 2.0
		E (32)	23.2 ± 2.7	21.5* ± 2.6	22.5* ± 2.8
		N (33)	23.0 ± 2.6	21.9* ± 2.1	22.5* ± 2.6
		EN (31)	23.2 ± 2.8	21.5* ± 2.7	21.9* ± 2.7
Nutrition knowledge (score‡).	Girls	C (27)	5.1 ± 0.9	5.3 ± 0.9	5.3 ± 1.2
		E (25)	4.6 ± 1.0	5.1 ± 1.3	5.4* ± 1.1
		N (27)	5.1 ± 0.8	8.2* ± 0.8	7.3* ± 1.6
		EN (25)	5.3 ± 0.8	8.8* ± 0.7	7.2* ± 1.8
	Boys	C (29)	5.2 ± 1.0	5.7 ± 1.2	5.5 ± 1.3
		E (32)	5.7 ± 1.0	5.2* ± 0.7	5.5 ± 1.2
		N (33)	5.3 ± 0.8	8.3* ± 1.1	7.3* ± 2.0
		EN (31)	5.1 ± 0.9	9.1* ± 0.8	7.0* ± 1.7
Energy intake	Girls	C (27)	2359 ± 241	2327 ± 423	2377 ± 412
		E (25)	2320 ± 426	2311 ± 390	2362 ± 407
		N (27)	2467 ± 445	2194* ± 334	2277* ± 360
		EN (25)	2467 ± 486	2156* ± 296	2239* ± 315
	Boys	C (29)	2540 ± 486	2551 ± 511	2594 ± 509
		E (32)	2400 ± 558	2311 ± 401	2406 ± 514
		N (33)	2714 ± 682	2364* ± 446	2316* ± 456
		EN (31)	2541 ± 568	2556* ± 585	2386* ± 528

*Significant difference compared with baseline ($P < 0.05$).

Abbreviations: BMI, body mass index; C, control group; E, exercise intervention group; N, nutrition education intervention group; EN, exercise and nutrition education intervention group.

†1 year after intervention, the number of students decreased; Girls: C (22); E (23); N (24); EN (22). Boys: C (27); E (31); N (28);

‡A total of 10 questions, a correct answer to get one point.



Baseline and post intervention, the number of students decreased; girls: C (27), E (25), N (27), and EN (25); and boys: C (31), E (32), N (32), and EN (30).
One year after intervention, the number of students decreased; girls: C (22), E (23), N (24), and EN (22); and boys: C (27), E (31), N (28), and EN (26).

Fig 3. Change of percentage in physical activity that make themselves sweat and breathe heavily more than 3 times per-week.

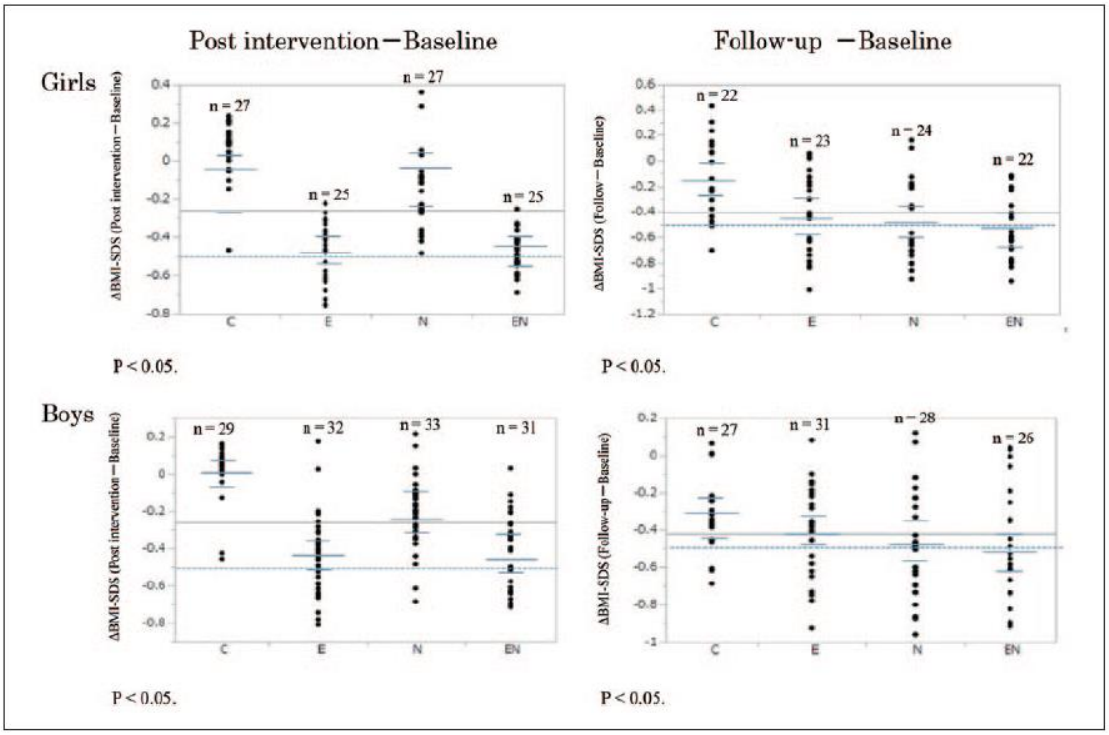


Fig 4. Changes in BMI-SDS between post intervention and baseline and BMI-SDS between follow-up and baseline (mean, 95% confidence interval).

Discussion

Since the 1980s, studies on interventions for preventing childhood obesity have rapidly increased in number (Lobstein et al., 2015). Major intervention methods involve exercise (Petit et al., 2002), nutrition (dietary restriction (Woo et al., 2004) and nutrition education (Viffiano, et al., 2015), and the combination of exercise and nutrition interventions (Chang et al., 2008; Woo et al., 2004; Roberts et al., 2007; Fitzgibbon et al., 2006). Compared with the sole implementation of exercise or nutrition-focused interventions, combining the 2 methods tends to produce a better outcome in reduction of anthropometric measurements (waist-hip ratio (Woo et al., 2004), BMI (Chang et al., 2008; Roberts et al., 2007; 27), and BMI-SDS (Reinehr et al., 2006)). In particular, the results of previous studies from 1975 to 2010 that examined exercise, nutrition, and exercise and nutrition combined as interventions for children under 18 years of age showed that the combined intervention of exercise and nutrition education had a better effect on obesity (Ho et al, 2013). The results of the present study are consistent with these previous studies. Exercise can increase lean body mass (Ho et al, 2013) and can help increase the basal metabolic rate while increasing energy consumption. Nutrition education can have the effect of decreasing energy intake. As such, energy consumption increases at the same time as energy intake decreases, leading to the combination of

exercise and nutrition education having the greatest effect on obesity.

In previous studies, sports that were used for the exercise intervention included swimming (METs: 7.0) (Ainsworth, et al., 2000), rope skipping (METs: 10.0) (Ainsworth, et al., 2000), cycling (METs: 8.0) (Ainsworth, et al., 2000), tennis (METs: 7.0) (Ainsworth, et al., 2000), and running (METs: 7.0) (Ainsworth et al., 2000). Some studies chose one exercise as the intervention method (Carrel et al., 2005), while others had an exercise intervention consisting of 2 or more of types of exercises (Chang et al., 2008; Woo et al., 2004; Roberts et al., 2007; Fitzgibbon et al., 2006). Additionally, among these studies, the duration of the intervention ranged from 2 weeks (Fitzgibbon et al., 2006) to 1 year, (Chang et al., 2008) the frequency ranged from once a week (Reinehr et al., 2006) to once a day, (Roberts et al., 2007) and the intervention period each time ranged from 20 minutes (Fitzgibbon et al., 2006) to 2.5 hours (Roberts et al., 2007).

This study chose skipping rope as the exercise intervention, which has relatively high METs (METs: 10.0) (Ainsworth et al., 2000). The participants performed 30 minutes of rope-skipping in the morning of every school day for 2 months. It is physically challenging for overweight and obese elementary school students to skip rope for 30 minutes as it is a high-intensity exercise. Furthermore, rope skipping only would disinterest and bore students. Therefore, after consulting with the elementary school

physical education teacher, we designed and implemented three 10-minute phases: (1) maximum speed, (2) competition for 2 (rope-skipping together), and (3) competition for 2 (2 skip rope one after another). None of the participants dropped out during the 2-month intervention period.

A study showed that an exercise intervention combining rope skipping with other sports is effective for reducing obesity (Chang et al., 2008). An advantage of rope skipping is that it was adopted in the national physical fitness survey for Chinese elementary and secondary school students (MEPRC, 2007), and participants were already familiar with skipping rope. Additionally, a jump rope is light and easy to carry, requires little space, and can be used both indoors and outdoors, making exercise weatherproof.

As for the nutrition intervention, there are generally 2 methods: one is to provide meals with already-determined energy intakes (dietary restriction (Nemet et al., 2005; Woo et al., 2004; Roberts et al., 2007)) and the other is instruction on food and nutrition knowledge (nutrition education (Pastor et al., 2012; Nemet et al., 2005; Chang et al., 2008; Reinehr et al., 2017; Fitzgibbon et al., 2006; Fahlman et al., 2008)). The 2 methods are used separately (Pastor et al., 2012; Nemet et al., 2005; Chang et al., 2008; Reinehr et al., 2017; Fitzgibbon et al., 2006) or simultaneously (Woo et al., 2004; Fahlman et al., 2008). The intervention duration ranges from 2 weeks (Fahlman et al., 2008) to 1

year (Pastor et al., 2012). The frequency of dietary restriction is per meal, and the frequency of nutrition education ranges from once a month for 3 months (Nemet et al., 2005) to 4 times/week (Fahlman et al., 2008), and for 20 minutes (Fitzgibbon et al., 2006) to 90 minutes (Reinehr et al., 2006) each session.

In the present study, a nutritionist who lived near the schools and was familiar with local conditions gave a 45-minute nutrition lecture each week over 2 months (6 hours in total). After receiving nutrition education, the average score of the participants on the nutrition knowledge questionnaire increased by 65%, and the knowledge gained lasted for 1 year after the intervention. Nutrition education has not yet been conducted in both urban and rural areas in China (CSN&HPA, 2008). Thus, we assume that learning about food and nutrition was something new and fresh for the elementary school students, which was an important reason as to why they retained what they had learned about nutrition. As for energy intake, it decreased significantly after the intervention and the decrease lasted for 1 year after the intervention, suggesting that nutrition education can be an effective intervention for overweight and obese children in rural areas of China.

On the other hand, several previous studies that focused on the effects of nutrition education found an increase in nutrition knowledge and in the intake of vegetables and fruits (Shah et al., 2010; Katz et al., 2011; Horne et al., 2004), while daily

energy intake did not significantly decrease (Katz et al., 2011). Furthermore, only one study showed an improvement in anthropometric measurements (Thomas et al., 2006). In previous studies, nutrition education was provided by general teachers who had received short-term training, whereas in the present study a nutritionist who lived near the schools and was familiar with local conditions taught the class. Additionally, while in a previous study nutrition education after school reduced students' free time and lowered their interest in the class (Kelder et al., 2005), in the present study nutrition education was during regular school hours, which may have contributed to the positive outcomes.

There are numerous studies on interventions for childhood obesity, but only a few have conducted a follow-up survey after the intervention (Nemet et al., 2005; Woo et al., 2004; Reinehr et al., 2007; Horne et al., 2004; Kelishadi et al., 2008). Although the amount of time after the intervention in which the follow-up survey took place has ranged from 4 months (Horne et al., 2004) to 3 years (Reinehr et al., 2007), most studies have conducted the follow-up 1 year after the intervention (Nemet et al., 2005; Reinehr et al., 2007; Kelishadi et al., 2008). Previous studies showed that the sole implementation of dietary restriction or exercise intervention has weaker long-term effects and that the combination is better, especially those that include nutrition education maintain long-term effect (Nemet et al., 2005; Reinehr et al., 2007).

Contrary to the results of the present study, previous research has shown that increasing knowledge about nutrition is not enough to affect a change in eating habits (Kigaru et al., 2015). Insufficient knowledge about nutrition is an important cause of poor eating habits (Kostanjevec et al., 2013), but it is difficult to improve eating habits by increasing nutrition knowledge alone (Kigaru et al., 2015). Recognizing that you are obese is a prerequisite for consciously improving obesity (Edwards et al., 2010). However, actual weight and perception of weight status often do not coincide; for example, in one study many children did not recognize that they were obese (Edwards et al., 2010; Maximova et al., 2008). In the present study, students learned how to judge their nutritional status by using BMI cutoff values, which was covered in the first chapter of nutrition education. Allowing them to correctly recognize their obesity may be an important motivator for them to reduce their energy intake. Similarly, the importance of exercise was covered in the text. Understanding the importance of exercise for health and weight control is very important for adhering to exercise (De et al., 2011). Consequently, the percentage of school children who had exercise habits increased considerably at follow-up compared with baseline. In addition, school children who received nutrition education did not forget the contents even 1 year later.

The development of exercise habits is the key to long-term effects of the

exercise intervention. In this study, there are no students who dropped out of the two-month exercise intervention. In addition, it can be suggested that PE- teacher supervision and active participation of students in exercise intervention are the most effective elements that contribute to short-term effect on obesity reduction. However, exercise behaviors are difficult to sustain long term (Maximova et al., 2008). Very few people exercise without positive intentions (De et al., 2011), and persuasive messages emphasizing health and weight management benefits are good for motivating exercisers to continue exercising (De et al., 2011). The lack of such messages for the participants in the exercise group may be a reason for why the exercise intervention did not have long-term effects.

Limitations

Participants in this study were 229 elementary school students (aged 9-12 years) and the results of this study are difficult to generalize since the sample size was small, but it is important to understand that a 2-month rope-skipping exercise intervention and nutrition education intervention in Chinese elementary school students was effective for improving obesity, and this effect could last up to 1 year after the intervention.

Conclusions

The present study found that rope skipping and nutrition education are effective interventions that can be used to address the problem of childhood obesity in rural China. The effects of exercise, nutrition education, and the combination of exercise and nutrition education as an intervention were compared, and the combined intervention had the best short- and long-term effects. Additionally, exercise had a better short-term effect than nutrition education, while nutrition education had a better long-term effect then exercise.

Chapter III. The association of parents' perceptions of body image on children's obesity

(*Modified the original article submitted to *Nursing & Health Sciences*.)

Aim of this study

The aim of this study was to examine gender differences in parents' dissatisfaction with their children's body and body dissatisfaction among children themselves, and lastly to investigate the factors affecting weight reduction.

Materials and methods

Participants

We selected two elementary schools in the rural areas of Benxi City, Liaoning Province, Northeast China. In these schools, there were 229 children identified as overweight and obese based on their age, gender, and China's BMI classification criterion (Li H et al., 2009). These children participated in a rope skipping exercise intervention and nutrition education conducted from August to September 2015 (Hao et al., 2019). We surveyed 218 students aged 11-14 years and their parents, who agreed to cooperate in this study conducted from August to September 2017.

Measures

For height and weight, we used physical examination data collected in June

2017 and the data authors measured in June 2015. BMI (kg/m^2) was calculated using height and weight. Moreover, BMI standard deviation scores (BMI-SDS) were calculated according to Chinese reference data by gender and age (Li H et al., 2009). The change in BMI-SDS (ΔBMI-SDS) was calculated as the subtraction BMI-SDS (2015) - BMI-SDS (2017), and was used as a measure of weight reduction.

Regarding body image, children's ideal weight according to children and their parents in units of 0.1 kg was recorded using a questionnaire. Subsequently, the ideal BMI was calculated using children's height and ideal weights. Three types of body dissatisfaction were calculated considering children's actual BMI (2015) and the three ideal BMI values (2017) (i.e., according to children themselves, their fathers, and their mothers).

Household attribute

Regarding household attributes, education level and household monthly income were collected from the parents by questionnaire.

Statistical analyses

Tukey's test was performed to examine the differences between the mean

values of the three types of children's body dissatisfaction (according to themselves, fathers, and mothers) according to gender. An independent t test was performed to examine the differences according to gender in body dissatisfaction for each of the three types (according to children, fathers, and mothers). Differences in body dissatisfaction between the children of non-obese and obese fathers and mothers were also examined using an independent t test. The change in BMI-SDS from before the intervention to follow-up was entered into a multiple regression analysis as the dependent variable, while the three types of body dissatisfaction, BMI of father, BMI of mother, education of father, education of mother, and household monthly income were included as predictor variables. The variables were chosen according to the stepwise increase-and-decrease method and a threshold P-value of 0.20, which was calculated using the likelihood ratio test. Dunnett's test was used to compare the difference in body dissatisfaction from children themselves between control and each intervention groups. Statistical significance was set at $P < 0.05$. JMP version 14.0J (SAS Institute Inc., Cary, NC) was used for all statistical analyses.

Ethical considerations

The purpose and procedures of the study were fully explained in Chinese to the participants. Children and their parents signed an informed consent form. This study was

conducted with the approval (17-31) of the Ethics Review Board of the Hokkaido University Graduate School of Health Sciences and complied with the Declaration of Helsinki.

Results

The socio-demographic characteristics of participants are shown in Table 6. Nearly half of the parents (47%) were overweight or obese. The majority of the families had low- or middle-level incomes. BMI and the change in BMI-SDS from before the intervention to follow-up did not differ significantly between boys and girls.

The three types of children's body dissatisfaction (according to children, fathers, and mothers) are shown in Fig 5 and Fig 6. For girls, their own and their mothers' body dissatisfaction were significantly higher than their fathers' ($P < 0.05$) (Fig 5). For boys, the body dissatisfaction of their fathers and mothers was significantly higher than their own body dissatisfaction ($P < 0.05$) (Fig 5). The level of body dissatisfaction of girls was significantly higher than that of boys ($P < 0.05$) (Fig 6). There was no difference in the level of body dissatisfaction of the fathers according to their children's gender; however, mothers' dissatisfaction with their daughters' bodies was significantly higher than with their sons' bodies ($P < 0.05$).

Among girls, non-obese mothers had a significantly higher level of dissatisfaction with their daughters' body than did obese mothers, but obese and non-obese fathers had similar levels of dissatisfaction with their daughters' body. Among boys, there were no significant differences between obese and non-obese fathers or mothers in the dissatisfaction with their sons' body (Table 7).

Multiple regression analysis was performed to identify the factors that contributed to weight reduction for each gender (Table 8). For girls, mother's dissatisfaction with daughters' body ($\beta = 0.43$, $P < 0.01$), BMI of mothers ($\beta = -0.37$, $P < 0.01$), girls' own body dissatisfaction ($\beta = -0.24$, $P < 0.01$), and age ($\beta = 0.17$, $P < 0.01$) were significant predictive factors of weight loss. For boys, mother's dissatisfaction with sons' body ($\beta = 0.28$, $P < 0.01$), boys' own body dissatisfaction ($\beta = -0.28$, $P < 0.01$), education level of fathers ($\beta = 0.22$, $P < 0.01$), household monthly income ($\beta = 0.20$, $P < 0.01$), and BMI of fathers ($\beta = -0.20$, $P < 0.01$) were significant predictive factors of weight loss.

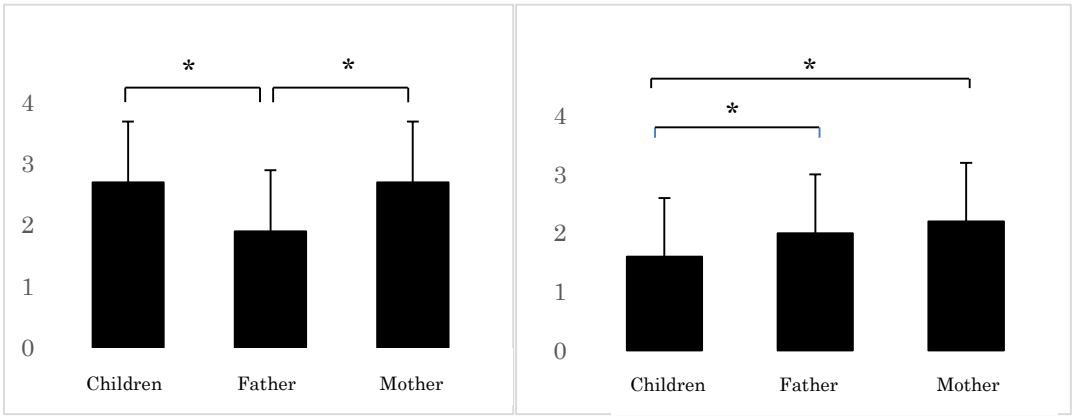
Differences in body dissatisfaction from children themselves in every group shown in Fig 7. Each intervention group were not significantly different from the control group.

Table 6. Characteristics of the study subjects

	mean	SD	n (%)
Girls (n = 86)			
Age	10.5	1.1	
BMI (kg/m^2)	22.4	2.1	
△BMI-SDS†	0.40	0.32	
Boys (n = 102)			
Age	10.5	1.1	
BMI (kg/m^2)	22.3	2.6	
△BMI-SDS	0.42	0.28	
Mothers (n = 188)			
Age	36.1	1.7	
BMI category (kg/m^2)			
Overweight (≥ 24)			103 (55)
Other (< 24)			85 (45)
Education			
Secondary school or below			30 (16)
High school			114 (61)
College or above			44 (23)
Fathers (n = 188)			
Age	36.4	2.6	
BMI category (kg/m^2)			
Overweight (≥ 24)			75 (40)
Other (< 24)			117 (60)
Education			
Secondary school or below			37 (20)
High school			84 (45)
College or above			67 (35)
Family monthly income (yuan)			
≤ 3000			40 (21)
3001–5000			107 (57)
> 5000			41 (22)

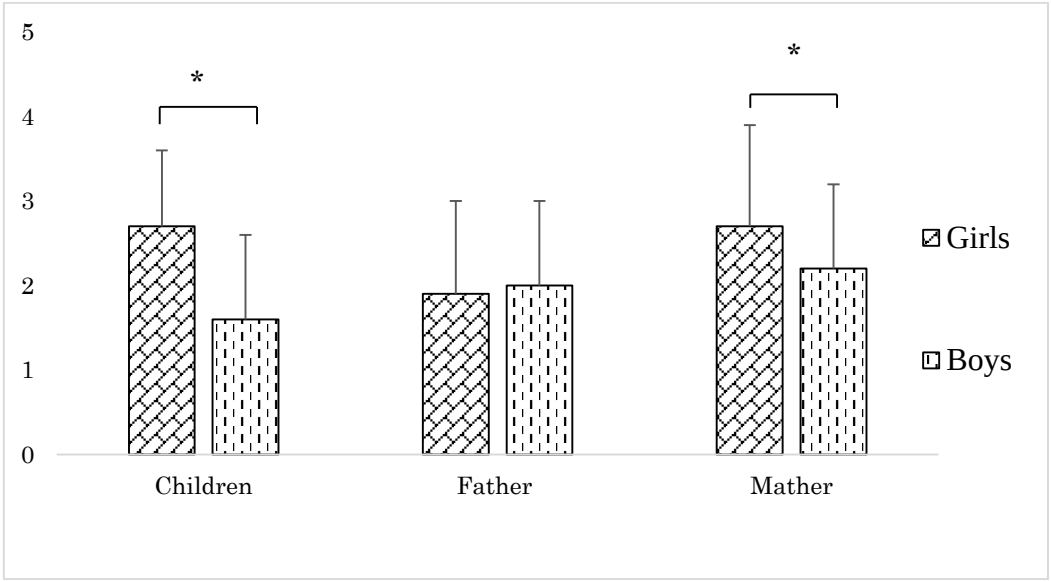
Abbreviations: BMI, body mass index; BMI-SDS, BMI-standard deviation score; △BMI-SDS, the change in BMI-SDS was calculated as the subtraction BMI-SDS (2015) - BMI-SDS (2017), and was used as a measure of weight reduction.

Girls Boys



* P < 0.05.

Fig 5. Body dissatisfaction for children of children themselves and parents



* P < 0.05.

Fig 6. Gender differences in body dissatisfaction from children themselves and parents

Table 7. The dissatisfaction of parents with their children's body indifferent body types

Mother	n	Normal	n	Overweight
Girls	40	3.3* ± 1.0	46	2.3 ± 1.1
Boys	45	2.2 ± 1.1	57	2.3 ± 1.1
Fathers				
Girls	51	1.8 ± 1.0	35	1.9 ± 1.2
Boys	62	1.9 ± 0.9	40	2.1 ± 0.9

$P < 0.05$.

Table 8. Factors that contributed to weight reduction[†]

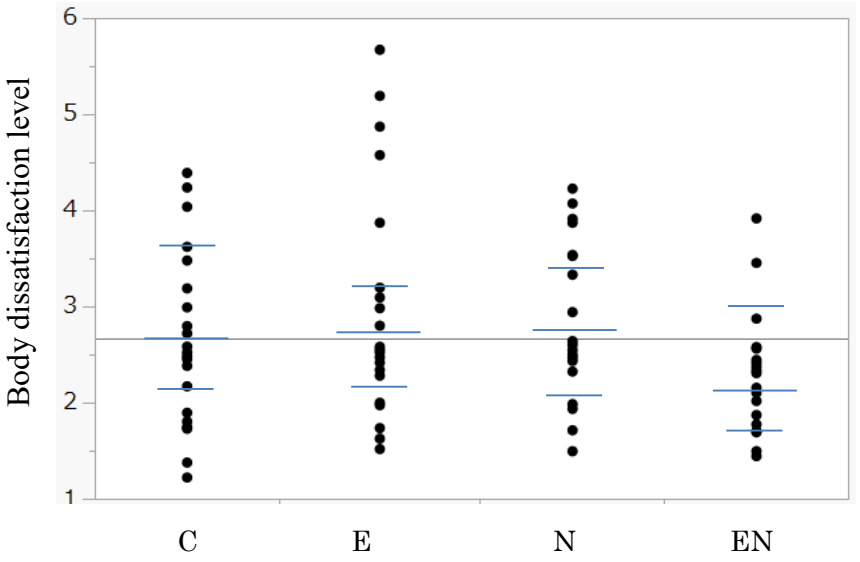
	β	*t*	VIF	*P*
Girls[†]				
Body dissatisfaction (Mother)	0.43	5.66	1.18	**
BMI (Mother)	- 0.37	- 4.97	1.17	**
Body dissatisfaction (Children)	- 0.24	- 3.01	1.20	**
age	0.17	2.33	1.14	**
Education level (Father)	0.10	1.38	1.01	NS
Boys[‡]				
Body dissatisfaction (Mother)	0.28	3.33	1.35	**
Body dissatisfaction (Children)	- 0.28	- 3.57	1.14	**
Education level (Father)	0.22	2.88	1.09	**
Income	0.20	2.67	1.07	**
BMI (Father)	- 0.20	- 2.41	1.27	*

*P<0.05; **P<0.01.

[†] R^2: 0.50, P < 0.01; RMES: 0.21.

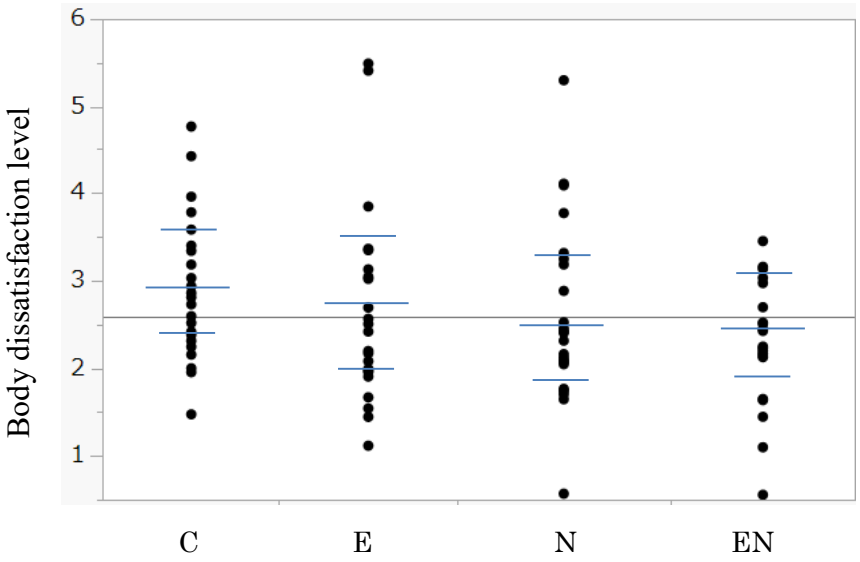
[‡] R^2: 0.61, P < 0.01; RMES: 0.20.

Girls



P > 0.05.

Boys



P > 0.05.

Fig 7. Differences in body dissatisfaction from children themselves between control and each intervention groups (mean, 95% confidence interval).

Discussion

According to the results of this study, boys and girls did not differ in BMI (Table 6); however, mothers' level of dissatisfaction with their daughters' body was higher than that with their sons' body (Fig 6). These findings replicate previous research (Chen & Jackson, 2005; Mellor et al., 2008). With the increased presence of the media not only in the West but also in China, the concept that women's slim figure is beautiful has been deeply rooted in the public's mind (Xu et al., 2010). In modern society, women tend to consider a slim figure as one of the conditions to gain more benefits (Teng et al., 2017). Parent's dissatisfaction with their children's body type has been known to affect the body image of children, particularly in girls (McCabe et al., 2006). Therefore, girls are more likely to change their lifestyle habits when parents criticize their body type (McCabe et al., 2006). Actually, slimness has become one of the factors that men consider when identifying attractive women. Slim girls are more likely to find a potential partner in China (Meizi et al., 2007). It has also been shown that the mother's focus on her daughter's figure is needed not only for health but also for aesthetic reasons (Meizi et al., 2007). In this study, it is considered that the higher level of dissatisfaction with girls' bodies reflects the socio-cultural background described above.

Gender differences in body dissatisfaction also existed in children. The level of

body dissatisfaction in girls was higher than in boys (Fig 6). The higher the BMI of a child, the higher the level of body dissatisfaction (Duchin et al., 2015). According to a pioneering study that examined the body image of men and women, women have higher requirements for a slim body than do men; thus, more women try to lose weight compared to men (Arroyo et al., 2010). Gender differences in body image are important reasons for this result (Xu et al., 2010). While men want to have a strong body, women recognize that their slim figure is considered beautiful (Xu et al., 2010). Furthermore, from a cultural point of view, there is a traditional notion in rural China that obesity is a symbol of wealth for boys, which is reflected in our results, with boys having a lower level of body dissatisfaction level compared with girls (Fig 6) (Hesketh & Xing, 2006). In addition, it is known that behaviors in relation with body monitoring and body change among women in Chinese society are steeper (Sai et al., 2018). Therefore, in this study, the level of body dissatisfaction of girls was higher than that of boys. The differences in body image between boys and girls as well as Chinese cultural values in rural areas may be the cause of gender differences in children's body dissatisfaction in this area.

The dissatisfaction of parents with their children's body was a predictor of weight reduction in children (Table 7, 8). A premise in reducing obesity in children is that parents recognize their children as obese (Jeffery et al., 2004; He et al., 2007). However,

many studies have shown that many parents fail to recognize their children's obesity (He et al., 2007; Jeffery et al., 2004; Maynard et al., 2003). For example, according to a study of 777 children and about 277 pairs of parents in the United Kingdom, 33% of mothers and 57% of fathers thought that their children had a normal weight even if they were overweight (Jeffery et al., 2004). In addition, obese parents are less likely to correctly recognize their children's body type than are non-obese parents (Jeffery et al., 2004; Baughcum et al., 2000). It is known that parents' perceptions and lifestyle have a significant effect on children's physical activity and diet (Scaglioni et al., 2011, Adamo et al., 2010). Therefore, parents' obesity may have a negative impact on their children's health. Parents with higher BMI are less likely to recognize their children's obesity and have a lower rate of improving because of their lifestyle, values, and lack of desire to improve.

In this study, it was shown that the higher the degree of obesity in same-sex parents, the lower the reduction in obesity among children (Table 8). To our knowledge, there are few studies on the effect of the relationship between same-sex parents and children on weight reduction. The physical self-worth of the same-sex parent was found to have a stronger influence on children than that of the other-sex parent (Michael et al., 2014). Similar to physical self-worth, the BMI of parents has a strong influence on weight

reduction in children, particularly the BMI of same-sex parents (Sabine W, 2014). Therefore, this study supports these previous findings.

In this study, it was shown that having a high level of body dissatisfaction may not imply weight loss in obese children (Table 8). Previous studies showed body dissatisfaction levels in obese and non-obese girls ranging between 0 and 2: Chinese female students aged 12-25 (1.26), living in China (1.1) (Tao 2010); female Chinese, living in the United States (0.65) (Davis & Katzman, 1998); and general female university students aged 19-25 years in Japan and Korea (1.6) (Sakamaki et al., 2005). In contrast, the mean level of body dissatisfaction of girls in this study was 2.7 (Fig 5). Notably, all children in this study categorized as obese were found to be dissatisfied with their bodies, with their level of body dissatisfaction being over 1.1 (a boy, data not shown). Taken together, this suggests that obese children in rural areas of China may be at risk of maintaining their current weight status because of the gap between their current and ideal weight, which could end up discouraging them to reduce weight.

Unlike children's dissatisfaction, the higher the level of mothers' dissatisfaction with their children's body, the higher the reduction in childhood obesity (Table 8). Mothers are more likely to feel anxious about their adolescent children (McCabe & Ricciardelli, 2005). Compared with fathers, mothers are more likely to pass on their own

ideals and values to their children through their words and deeds (Field et al., 2005). In addition, mothers spend more time taking care of their children than do fathers (Field et al., 2005). Therefore, mothers have a higher influence on preventing childhood obesity. On the other hand, compared with mothers, fathers' involvement with children's education and growth is almost unspoken (Lamb et al., 2004). In summary, the higher the level of dissatisfaction of mothers with their children's bodies, the higher the reduction in children's obesity.

A higher level of fathers' education was associated with a higher reduction in obesity among boys (Table 8). In adolescence, fathers tend to encourage achievement, mastery, and skill development in their sons more strongly than do mothers (Lipscomb, 2011). Chinese society tends to emphasize that intellectual ability is a means to social success and status acquisition for men (Chou et al., 2000). Therefore, it is thought that fathers require their sons' self-management ability in the process of intellectual development (Zhang, 2005). This tendency is more pronounced in men than woman (Hannum et al., 2009). In addition, the birth male-to-female ratio has increased since the one-child policy started in 1978, and it is said that many Chinese parents wish to have a boy in order to have a successor and to help them with labor and farming work (Murphy 2003). Therefore, parents seek higher ideals for boys, and children try to meet these

expectations (Wang, 2005). As a result, the cultural values of masculinity and the expectations for boys in Chinese society may affect weight reduction among boys.

Limitations

There are some limitations in this study, which should be contemplated.

One of the limitations of the present study is the sample size, which represents limited age groups comprising 188 pairs of children at the age of 11-14 years and their parents compared to numerous studies on obesity issues (Mellissa et al., 2011). However, we believe that the current study showed an important scientific direction in the relevant field given the special focus on overweight and obese children.

Another limitation is generalization to the other age groups in the other areas in broad China given that our study was conducted particularly in the rural area of Northeast China with a limited focus on students participating in the intervention study. However, the present study with a special focus on the specific age groups could demonstrate the current situation of overweight and obese children in the rural area of China, which should be carefully considered for policy making.

In addition, this study is limited by the fact that we investigated body dissatisfaction based on ideal body weight after intervention, compared to the extensive

literature using ideal body weight before intervention. In this context, we measured body dissatisfaction based on reality body weight before intervention and ideal body weight after 2 years including two-month intervention. Two years later, the degree of body dissatisfaction was not found to be different between each intervention group and control group. This result can be supported by some previous study (McCabe et al., 2005) showing that body dissatisfaction may not change by age in elementary school students. Moreover, based on the reason that there was not significant difference found between each intervention group and control group two years later including short-term intervention, it could be suggested that the potential results would be similar in the same groups even before intervention.

Conclusions

Our findings indicate that parents' perception of their children's body, particularly mothers' dissatisfaction with their children's body, plays a significantly important role in reducing obesity in children. Besides, it is notable that mothers hold a harsher level of bodily evaluation towards their daughters compared with their sons. Therefore, future research should address gender differences when investigating body image in Chinese children, also highlighting the need for international attention to the potential role of mothers in tackling growing obesity issues in China.

General discussion

Chapter 1 shows that BMIAZ increased as intake of grains and edible oils increased (Table 4). Traditional Chinese meals contain large amounts of grain and vegetables (Du et al., 2014). These meals tend to include fried dishes. A survey of Chinese adults revealed that intake of food edible oils rises with vegetable consumption, thereby promoting obesity (Shi et al., 2008). Therefore, traditional preparations of vegetables are considered to be a cause of childhood obesity and the thickness of porridge.

Chapter 1 also shows that exercise was effective in reducing fat and enhancing lean body mass in children, which has positive effects on obesity (Table 4). By the results of chapter 2, there was a significant positive correlation between the skipping rope test and BMIAZ (Table 4). The metabolic equivalent (MET) of skipping rope was 10.0 (Ainsworth et al., 2000), over two times as much as jogging (4.5) (Ainsworth et al., 2000). Therefore, skipping rope could produce the same effect on metabolic rate as jogging in less time, making it an efficient exercise to reduce obesity.

In chapter 2, the short-term and long-term effects of a combined intervention of rope skipping and nutrition education for overweight children were verified. The exercise intervention had a better short-term effect than nutrition education, while nutrition education had a better long-term effect than the exercise intervention.

Skipping rope has been chosen as the exercise intervention, which has relatively high METs (METs: 10.0) (Ainsworth et al., 2000). And after consulting with the elementary school physical education teacher, the authors designed and implemented three 10-minute phases. None of the participants dropped out during the 2-month intervention period. Therefore, exercise intervention has short-term effects on the improvement of obesity among school children.

The development of exercise habits is the key to long-term effects of the exercise intervention. However, exercise behaviors are difficult to sustain in the long term (Maximova et al., 2008). Positive intentions of exercise have a positive impact on the sustainability of exercise (De et al., 2011). In Chapter 2, the lack of such messages for the participants in the exercise group may be a reason for why the exercise intervention did not have long-term effects.

Nutrition education was found to have a long-term effect on the improvement of obesity among school children (Fig 4). Recognizing that he/she is obese is a prerequisite for consciously improving obesity (Edwards et al., 2010). However, actual weight and perception of weight status often do not coincide, many obese children did not recognize that they were obese (Edwards et al., 2010; Maximova et al., 2008). In the present study, students learned how to judge their nutritional status by using BMI cutoff

values in the first class of nutrition education. Similarly, the importance of exercise was covered in the text of nutrition education. Understanding the importance of exercise for health and weight control is very important for adhering to exercise (De et al., 2011). The reason that nutrition education has a better long-term effect is because the participants of this study recognized their being obesity and understood the importance of exercise for health.

In chapter 3, it was shown that having a high level of body dissatisfaction may not imply weight loss in obese children (Table 8). Previous studies showed body dissatisfaction levels in obese and non-obese girls ranging between 0 and 2 (Tao 2010; Davis & Katzman, 1998; Sakamaki et al., 2005). In contrast, the mean level of body dissatisfaction of girls in this study was 2.7 (Fig 5). Notably, all children in this study categorized as obese were found to be dissatisfied with their bodies, with their level of body dissatisfaction being over 1.1 (a boy, data not shown). Taken together, this suggests that obese children in rural areas of China may be at risk of maintaining their current weight status because of the gap between their current and ideal weight, which could end up discouraging them to reduce weight.

Unlike children's dissatisfaction, the higher the level of mothers' dissatisfaction with their children's body, the higher the reduction in childhood obesity (Table 8).

Mothers are more likely to feel anxious about their adolescent children (McCabe & Ricciardelli, 2005). Compared with fathers, mothers are more likely to pass on their own ideals and values to their children through their words and deeds (Field et al., 2005). In addition, mothers spend more time taking care of their children than do fathers (Field et al., 2005). Therefore, mothers have a higher influence on preventing childhood obesity. In summary, the higher the level of dissatisfaction of mothers with their children's bodies, the higher the reduction in children's obesity.

VI. Conclusion

Cross-sectional study (chapter 1) implicated that skipping ropes may enhance muscle mass while intake of edible oil and grain may exacerbate obesity of children. By increasing muscle mass, skipping ropes can help reduce obesity and improve physical fitness.

Rope skipping and nutrition education are effective interventions that can be used to address the problem of childhood obesity in rural China. The effects of exercise, nutrition education, and the combination of exercise and nutrition education as an intervention were compared, and the combined intervention had the strongest short- and long-term effects. Additionally, exercise had a better short-term effect than nutrition

education, while nutrition education had a better long-term effect than exercise.

The parents' perception of body image, particularly mothers' body dissatisfaction towards their children, plays a significantly important role in improving obesity in the children. It highlights the need for international attention to the potential roles of motherhood in tackling with growing obesity issues in China.

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