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Obesity-Related Factors That Affect 6-Minute Walk Test Performance in Thai Obese Children

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ABSTRACT

Background: Obesity is a significant health issue that negatively impacts the cardiovascular system and quality of life. Six-minute walk test (6MWT) is one of the most used non-invasive tests for evaluating cardiovascular function in determining the impact of obesity on an individual's physical fitness.

Objective: To identify any obesity-related factors that affect 6MWT in Thai overweight and obese children.

Method: This is a prospective, cross-sectional study that enrolled 70 children with % weight for height (W/H) above 120 were assessed using 6MWT at Naresuan University Hospital. The participants were divided according to their W/H as overweight (15 children, 21.4%), obese (41 children, 60%), and morbidly obese (14 children, 20%). Data were collected from medical records and categorized as follows:

1. Anthropometric data, including weight, height, body mass index (BMI) and body fat percentage (%Fat)
2. Metabolic profile, including fasting blood sugar (FBS), triglyceride levels (TG), total cholesterol levels (TC) and HDL
3. Cardiac function using echocardiography.

Global Physical Activity Questionnaires (GPAQ) was used to assess physical activity and sedentary time. The Six-minute Walk Distance (6MWD) was compared to the reference value based on age and gender.

Results: The majority of the overweight and obese children had a lower 6MWD compared to the reference value (65 children, 92.9%). The mean 6MWD was considerably lower among children with morbid obesity (365.07 ± 37.06 m) compared to those with overweight (392.73 ± 41.02 m) and obesity (408.12 ± 55.16 m) (P=0.022). Higher %Fat (r=-0.396, P=0.001) and elevated TC (r=-0.386, P=0.001) were also related to a lower 6MWD. There was no correlation between cardiac function, physical activity, and sedentary time in the 6MWD.

Conclusion: The 6MWT performance of morbidly obese children was lower than that of healthy children. Higher %Fat and TC were also associated with reduced 6MWD. Lifestyle modification for children, who are overweight or obese, including fat restriction and nutrition control, will not only aid in weight loss but also enhance the child's physical fitness and quality of life over time.

Keywords: Obesity; Children; 6-Minute walk test; Obesity related factor; Metabolic syndrome

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INTRODUCTION

Obesity is a leading risk factor for many chronic non-communicable diseases in both children and adults, which has become a global health concern. From a report by the World Health Organization (WHO) in 2016, the prevalence among children and adolescents aged 5 to 19 increased dramatically from 4% in 1975 to 18% in 2016 [1]. In Thailand, the prevalence of obesity among children aged 6 to 14 years has increased to 13.9% over the past five years [2].

Obesity has detrimental impacts on numerous physiological systems, most notably the cardiovascular system, which includes hypertension (HT), heart failure, atherosclerosis, coronary artery disease, and arrhythmia. Obesity is also associated with obstructive sleep apnea, obesity hypoventilation syndrome, asthma, non-alcoholic fatty liver disease, insulin resistance, type 2 diabetes (DM), among others [3,4].

Adult research on the cardiovascular effects of obesity indicated that weight gain may increase intravascular volume, ventricular hypertrophy, and hypertension. This ultimately induces systolic and diastolic ventricular dysfunction because of the increased ventricular afterload. All these effects would impair cardiac function [3,4]. Moreover, a recent study concluded that obesity increases the incidence of arrhythmias and sudden cardiac arrest [5,6].

A study on heart function in children revealed enlarge cardiac chambers and mass. There was a trend of decreased systolic and diastolic performance, but there was no clinically significant reduction in myocardial function or cardiac capacity [7].

Physical fitness one of the determinants of a healthy lifestyle. The 6-Minute Walk Test (6MWT) is an easily accessible test used to gauge a person's physical fitness and ability to complete daily tasks [8]. This test consists of a six-minute brisk walk during which the distance is recorded [9]. This method reflects function of numerous systems, including the circulatory, respiratory, and musculoskeletal systems [10].

Numerous studies in the past have used the 6MWT to evaluate risk factors of physical fitness in obesity. Overweight and obese children walked significantly shorter distances than normal-weight children, according to two studies [11,12]. The body mass index (BMI) was the most relevant factor affecting 6MWD. In a 3-month weight loss program for children with obesity, 6MWD increased considerably when BMI decreased [11,13,14].

Cardiovascular and metabolic risk factors are associated with a significantly shorter 6MWD in obese children. The clustering of cardio-metabolic risk factors more than 2 factors, including fasting blood sugar (FBS), triglyceride (TG), total cholesterol (TC), and high-density lipoprotein-cholesterol (HDL), were related with a higher BMI. Consequently, they exhibited a shorter 6MWD than obese children without cardio-metabolic risk clustering [15].

The high prevalence of physical inactivity and sedentary lifestyle in obese children and was found to be associated with decreased heart rate variability and adverse respiratory and cardiovascular effects. Which could be explained the shorter 6MWD than children of normal weight [16]. WHO had announced that a sedentary lifestyle and physical inactivity doubled the risk of numerous health issues, such as cardiovascular disease, high blood pressure, diabetes, obesity, colon cancer, osteoporosis, atherosclerosis, depression, stress, and anxiety, etc. [17].

This study aimed to identify any obesity-related factors, such as metabolic parameters, physical activity, sedentary lifestyle, and cardiac function that influence 6MWT performance in overweight and obese Thai children. We should promote and control all relevant risk factors to improve the quality of life of obese children.

MATERIALS AND METHODS

Participants

This is a cross-sectional prospective study. We enrolled obese Thai children aged 5 to 15 years with a percentage of weight for height ratio (W/H) of more than 120 at the Obesity clinic, Department of Pediatrics, Naresuan University Hospital from March 3, 2021 to December 31, 2021. Ethics approval for this study was obtained from Naresuan University Institutional Review Board P3-0167/2563, which followed by Declaration of Helsinki. We started study protocol after participants and/or their parents or legal guardians signed the consent form. The exclusion criteria were as follows: disorders not listed in metabolic syndrome (diabetes, high blood pressure, and dyslipidemia), and uncompleted cardiometabolic data within 6 months of study.

Anthropometric measurements

Weight and height were measured according to standard procedure, while wearing just light clothing and without shoes. OMRON HBF-375 is a body composition monitor, which uses bioelectrical impedance analysis (BIA) method to measure weight and percentage of fat (%Fat). BMI was computed by dividing weight (kg) by height (m2). The height was determined using a stadiometer.

Cardiometabolic risk factor data

FBS, TG, TC, HDL, and cardiac function (left ventricular ejection fraction; LVEF for reflection of left ventricular function) were collected from medical records.

Physical activity and sedentary time assessment

The authors conducted face-to-face interviews to collect data using the Global Physical Activity Questionnaire (GPAQ version 2). The Thai version of the questionnaire, with a reliability of 0.67-0.81, was validated and translated by the Department of Health, Ministry of Public Health [18,19].

Physical fitness assessment

The 6MWT was conducted indoors on a flat surface, straight walkway. The participants were seated in a chair near the beginning of the walkway for at least 5 minutes without warming up. Test contraindications include chest discomfort, dyspnea, cramps, headache, ataxia or pallor, resting HR greater than 120 bpm, and BP>99th by age. Participants were instructed to walk in a straight line for 15 meters before turning around the cone and returning to the starting point. During the test, participants may walk slowly or take a break. The staff may encourage the participants to walk as far as possible. At the end of the test, the total distance walked was measured [9].

Definitions

We classified the severity of obesity as follows: %W/H ≥ 120 is overweight, %W/H ≥ 140 is obese, and %W/H ≥ 200 is morbidly obese. %Fat was compared with normal reference range (P2-85) of age and sex-matched controls [20]. The metabolic risk factor consists of impaired fasting glucose with FBS ≥ 100 mg/dl, and DM with FBS ≥ 126 mg/dl. Dyslipidemia consists of hypertriglyceridemia ≥ 150 mg/dl, hypercholesterolemia ≥ 200 mg/dl, and low HDL <40 mg/dl, according to the Pediatric Obesity Prevention and Treatment Practice Guideline3. Normal cardiac function is defined as LVEF ≥ 55% [21]. Physical activity level scoring from GPAQ version 2 with a cut-off value of less than 600 MET-minutes per week indicates physical inactivity. The 6MWD was compared to normal children of the same age and gender; the "Pass test" was defined as a walking distance greater than the 3rd percentile [22].

Statistical analysis

Pathare et al. observed that the mean 6MWD in overweight young children is 535.2 with SD=63.623. The error (d) of the calculated sample size is 15 m.

The outcome of the sample size computation in n4 Studies to determine the mean of an infinite population is 70 children. SD. (σ)=63.60 with Error (d)=15.00 and Alpha (α)=0.05.

Categorical data were shown as frequency and percentage. The Shapiro-Wilk W test was used to determine if continuous variable had a normal distribution. Continuous variables are presented as mean ± standard deviations (SD). When comparing the two groups, Chi-square or Fisher's exact test, independent t-test, and One Way Analysis of Variance with Scheffe post hoc test was utilized. Pearson product moment correlation (r) was used to determine the correlations between 6MWT distance and anthropometric, metabolic syndrome, and physical activity variables. Multiple linear regressions by stepwise method were used to predict 6MWD. Statistical analyses were performed using the STATA version 12.0 software (StataCorp, College Station, TX, USA). P<0.05 were considered significant for all tests.

RESULTS

There were 75 children at the obesity clinic, but only 70 were included in the study, with 49 of them being male. The mean BW and height were 70.81 ± 27.56 kg, 149.86 ± 17.73 cm, respectively. Participants were grouped as follows: overweight 15 (21.4%), obese 41 (60.0%) and morbidly obese 14 (20.0%) (**Figure 1**). The mean BMI was 31.87 ± 1.74 (kg/m2). The mean %Fat was 30.11 ± 4.28% higher than the normal value of age and sex-matched controls. **Table 1** displays the metabolic parameters of the participants. The echocardiography evaluation of heart function revealed a mean LVEF of 63.05 ± 6.04%.

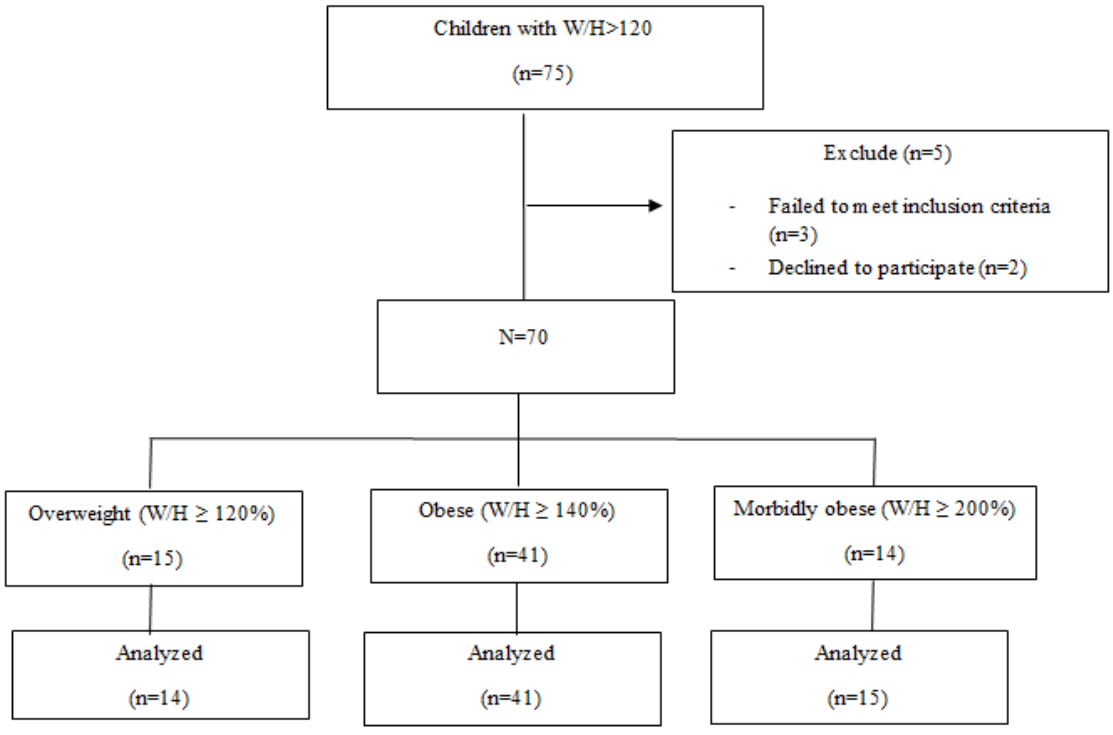

Figure 1: Consort diagram of participants in the study

Table 1: Anthropometric, metabolic parameters and cardiovascular function of the participants

Risk factors Age (years) n (%)	Total (n=70)	Overweight (n=15)	Obese (n=41)	Morbidly obese (n=14)
05-Sep	29 (41.4)	7 (46.7)	18 (43.9)	4 (28.6)
Oct-15	41 (58.6)	8 (53.3)	23 (56.1)	10 (71.4)
Male	49 (70.0)	10 (66.7)	31 (75.6)	8 (57.1)
Weight (kg)	70.81 ± 27.56	50.21 ± 17.20	69.13 ± 25.21	97.78 ± 21.82
Height (cm)	149.86 ± 17.73	144.27 ± 20.14	149.73 ± 17.99	156.21 ± 12.50

BMI (kg/m^2)	31.87 ± 1.74	23.78 ± 3.52	32.27 ± 2.75	39.36 ± 3.68
%Fat	30.11 ± 4.28	26.85 ± 4.88	30.03 ± 3.52	33.85 ± 2.50
Triglyceride level (mg/dL)	125.07 ± 7.74	108.20 ± 10.88	125.80 ± 12.30	141.00 ± 6.93
Cholesterol level (mg/dL)	168.87 ± 27.96	174.47 ± 30.95	165.22 ± 27.06	173.57 ± 27.60
HDL level (mg/dL)	46.46 ± 8.47	48.80 ± 7.79	46.22 ± 9.49	44.64 ± 5.39
FBS (mg/dL)	95.47 ± 18.55	99.47 ± 17.99	93.98 ± 20.82	95.57 ± 10.90
LVEF (%)	63.05 ± 6.04	63.10 ± 5.11	63.15 ± 6.08	62.71 ± 7.21

The physical activity assessment scores (GPAQ version 2) of all participants were a median of 640 (0-9360) min/week. The mean physical activity assessment scores for overweight, obese, and morbidly obese participants were 760(0-9360), 800(0-7320), and 180(0-7920) min/week, respectively. Forty children (57%) were reported to have sedentary time of >2 hours/day. Thirteen children had sedentary time of >2 hours/day on some days and 17 children had sedentary time of <2 hours /day.

The mean 6MWD in our study was 390 (297-576) m. All participants completed the test with no setbacks. The mean 6MWD for overweight, obese, and morbidly obese was 390(324-453), 400(318-576), and 376(297-417) m, respectively. Most of the participants had a lower 6MWD than the reference value (65 children, 92.9%). There were only 5 obese children (7.1%) who passed the 6MWD test. In the pass group, the mean BMI was 27.52 ± 4.01 and the mean %Fat was 30.78 ± 5.48. All participants in the pass group were obese, and one child exhibited dyslipidemia (hypertriglyceridemia, hypercholesterolemia, and low HDL). Subjects in this group had a normal fasting blood sugar level. No statistically significant difference was found between the two groups (**Table 2**).

Table 2: 6MWD of the study participants

Risk Factors Age (years) n (%)	Non-pass (n=65)	Pass (n=5)	p-value
5-9	26 (40.0)	3 (60.0)	0.382
10-15	39 (60.0)	2 (40.0)	
(Mean ± SD)	10.65 ± 0.36	8.20 ± 1.56	0.077
Sex n (%)			0.313
Male	44 (67.7)	5 (100.0)	
female	21 (32.3)	0 (0.0)	
BMI (Mean ± SD)	32.21 ± 15.00	27.52 ± 4.01	0.491
% W/H n (%)			0.208
Overweight	15 (23.1)	0 (0.0)	
Obese	36 (55.4)	5 (100.0)	
Morbidly obese	14 (21.5)	0 (0.0)	
% Fat (Mean ± SD)	30.06 ± 4.22	30.78 ± 5.48	0.72
Normal fat	7 (10.8)	0 (0.0)	0.581
Excessive fat	58 (89.2)	5 (100.0)	
HT n (%)	7 (10.8)	1 (20.0)	0.532
	Dyslipidemia		
Hypertriglyceridemia n (%)			0.875
High triglycerides	15 (23.1)	1 (20.0)	
Normal triglycerides	50 (76.9)	4 (80.0)	
Hypercholesterolemia n (%)			0.62
High cholesterol	8 (12.3)	1 (20.0)	
Normal cholesterol	57 (87.7)	4 (80.0)	
HDL n (%)			0.684
Low HDL	13 (20.0)	1 (20.0)	
Normal HDL	52 (80.0)	4 (80.0)	
DM n (%)			0.636
Impaired fasting glucose	12 (18.5)	0 (0.0)	

DM	2 (3.0)	0 (0.0)	
Normal	51 (78.5)	5 (100.0)	
Physical activity n (%)			0.643
Active (MET ≥ 600)	33 (50.8)	2 (40.0)	
Non active (MET<600)	32 (49.2)	3 (50.0)	
Sedentary time n (%)			0.283
>2 hours/day every day	37 (56.9)	3 (60.0)	
>2 hours/day some days	11 (16.9)	2 (40.0)	
<2 hours/day every day	17 (26.2)	0 (0.0)	
LVEF (%)	62.68 ± 5.96	67.84 ± 5.50	0.065

When 6MWD was compared with the risk factors of obesity between normal and abnormal levels based on the study's reference values, we discovered that morbidly obese children (365.07 ± 37.06 m) had a significantly shorter 6MWDs than overweight (392.73 ± 41.02 m) and obese children (408.12 ± 55.16 m) (p=0.022). Subjects with hypercholesterolemia (354.22 ± 34.97 m) had significantly shorter 6MWDs than those with normal cholesterol levels (404.02 ± 50.77 m) (p=0.008). Other risk factors, including age, gender, %Fat, HT, DM, hypertriglyceridemia, HDL, physical activity, and sedentary time, did not significantly impact 6MWD (Table 3).

Table 3: Comparison between 6MWD and risk factors of obesity

Factors	n	6 MWD (Mean ± SD)	p-value
Age (years)			0.05
5-9	29	381.93 ± 40.30	
10-15	41	406.32 ± 56.37	
Sex			0.067
Male	49	403.57 ± 52.98	
Female	21	379.05 ± 44.21	
% W/H n (%)			0.022*
Overweight	15	392.73 ± 41.02	
Obese	41	408.12 ± 55.16*	
Morbidly obese	14	365.07 ± 37.06*	
%Fat			0.129
Normal fat	7	424.29 ± 18.24	
Excessive fat	63	393.10 ± 53.06	
HT			0.878
Normotension	62	395.87 ± 6.05	
Hypertension	8	398.88 ± 28.13	
	Dyslipidemia		
Hypertriglyceridemia n (%)			0.981
High triglycerides	16	395.94 ± 54.02	
Normal triglycerides	54	396.30 ± 51.19	
Hypercholesterolemia n (%)			0.008*
High cholesterol	9	354.22 ± 34.97	
Normal cholesterol	61	404.02 ± 50.77	
HDL n (%)			0.251
Low HDL	14	410.43 ± 67.37	
Normal HDL	56	392.66 ± 46.74	

DM n (%)			0.172
Impaired fasting glucose	12	382.75 ± 33.88	
DM	2	456.00 ± 33.94	
Normal	56	396.96 ± 53.86	
Physical activity n (%)			0.488
Active (MET ≥ 600)	35	391.91 ± 45.93	
Non-active (MET<600)	35	400.51 ± 56.79	
Sedentary time n (%)			0.62
>2 hours/day everyday	40	397.80 ± 60.25	
>2 hours/day some days	13	404.23 ± 37.87	
<2 hours/day every day	17	386.13 ± 36.50	

Higher %fat (r=-0.396, P=0.001) and TC (r=-0.386, P=0.001) were found to be correlated with a lower 6MWD. Other risk factors, such as age, BMI, %W/H, TG level, HDL level, FBS, cardiac function, and physical activity, did not exhibit a significant correlation (**Table 4**, **Figure 2**).

Table 4: Correlation between 6MWD and risk factors of obesity

Factors	Relationship 6MWD (m)	p-value
Age (years)	r=0.216	0.072
BMI (kg/m^2)	r=-0.081	0.506
%W/H	r=-0.231	0.055
%Fat	r=-0.396	0.001*
Triglyceride level (mg/dL)	r=0.208	0.084
Cholesterol level (mg/dL)	r=-0.386	0.001*
HDL level (mg/dL)	r=-0.175	0.149
FBS (mg/dL)	r=0.166	0.169
MET	r=0.090	0.46
LVEF (%)	r=0.089	0.465

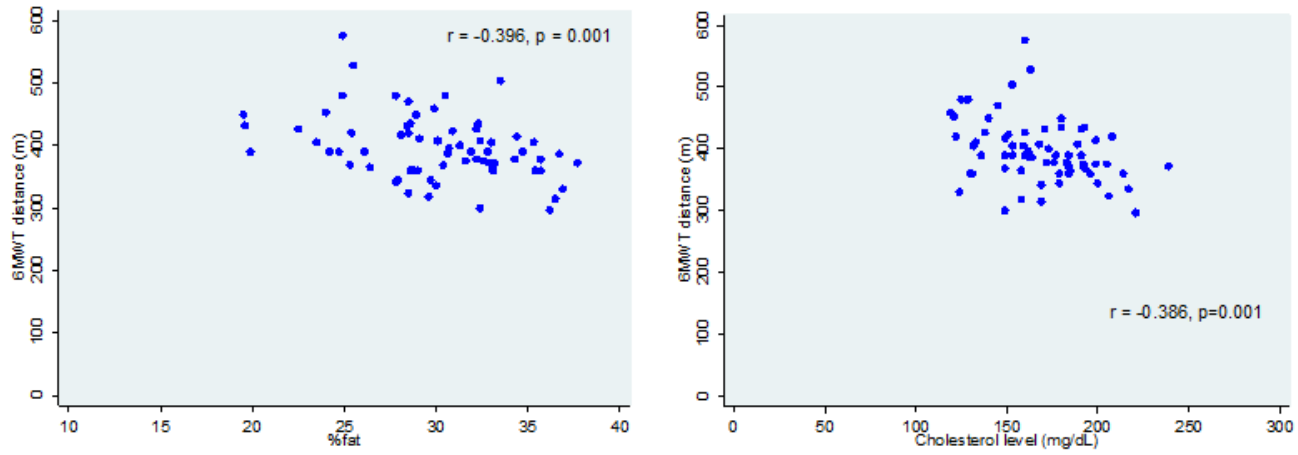

Figure 2: Graph illustrating the relationship between 6MWD and % Fat / Cholesterol level

Following multiple linear regression analysis (Stepwise Method) to predict 6MWD, we found that %Fat, TG and TC (R2 0.28, p<0.001) could predict 6MWD among obese children (**Table 5**).

Table 5: Predicted factors of 6MWD among obese children

Risk factors	b	t-value	p-value
%Fat	-3.26	-2.45	0.017
Triglyceride level (mg/dL)	0.18	2.09	0.041

Cholesterol level (mg/dL)	-0.51	-3	0.004
Constant	575.95	12.7	<0.001

The regression equations derived from our results were evaluated using gender-specific equations for the prediction of 6MWD especially in female equation. (R^2 0.76, p<0.001)

Regression equations	R^2	p-value
6MWD=575.95-3.26 (%Fat)+0.18 (TG)-0.51 (TC)	0.28	<0.001
6MWD(male)=689.50-4.59 (age)-4.80 (%Fat)+0.17 (TG)-0.70 (TC)	0.28	0.005
6MWD(female)=571.25+9.36 (age)-6.53 (%Fat)+0.36 (TG)-0.77 (TC)	0.76	<0.001

DISCUSSION

In this first study on pediatric obesity in Thailand, we found that obese children had a lower age and gender-matched 6MWD than the 3rd percentile of normal-weight children (92.9%) [22]. W/H, %Fat, and TC were the significant factors related to 6MWD performance in this study.

BMI is a well-established predictor of 6MWT performance in obese children and adolescents [11-14]. Increased BMI necessitates increased energy expenditure, which can limit physical fitness [23]. Since BMI varies with age, our study utilized %W/H to classify the severity of obesity. In Thailand, the severity of obesity was quantified using the W/H ratio derived from the growth curve of Thai children. Therefore, the 6MWD for morbidly obese children (365.07 ± 37.06 m) was shorter than that of the overweight (392.73 ± 41.02 m) and obese children (408.12 ± 55.16 m) (p=0.022), as shown this study.

In terms of body fat percentage (% Fat), we found a negative correlation between 6MWD and %Fat (r=-0.396, P=0.001), which is consistent with two previous studies that indicated adipose tissue in the legs and knees affect functional capacity, resulting in shorter walking distances [24,25]. In our study, the majority of participants had a higher %Fat which may have resulted in a reduction in muscle mass but no statistical difference in 6MWD.

Impaired cardiovascular function and hypertension are the primary risks associated with physical performance. Mahfouz et al. reported that walking distance and coronary flow reserve were reduced in obese adults with hypertension, which was attributed to micro-vascular dysfunction and arterial stiffness, which consequently limits exercise tolerance [26]. A study of pediatric patients with primary hypertension revealed that their exercise capacity was impaired [27]. However, due to the small sample size, we were unable to confirm this finding in our study.

All of the participants in our study had normal cardiac function reflection from normal LVEF (63.05 ± 6.04%), with observations of nearly lower normal values in morbid obesity (62.71 ± 7.21%), but without statistical significance. This observation finding is consistent with a prior study which demonstrated that obese adolescents had reduced systolic and diastolic cardiac function when compared to normal-weight adolescents who underwent interval aerobic training [28]. We found no correlation between LVEF and 6MWD, which may be due to a less sensitive cardiac function parameter. However, conventional echocardiography can be replaced by a more sensitive technique known as 3D wall motion tracking analysis, which is derived from magnetic resonance imaging scans. This technique can be used to evaluate cardiac remodeling and dysfunction in obese children [29]. Another method of evaluation by echocardiogram is the quantification of epicardial adipose tissue, which has been associated with visceral adipose tissue deposition. Children with obesity had more epicardial fat and impair cardiac function, including diastolic and systolic dysfunction, than children with normal weight [30].

Only TC exhibited a significant negative correlation with 6MWD (r=-0.386, P=0.001) among cardiometabolic risk variables. This is congruent with the findings of the study conducted by Tulika Kuman [31] and Valerio et al., which discovered that obese children with metabolic syndrome had a lower 6MWT performance. Adults with DM have a shorter walking distance than the healthy group [32]. This can be explained by poor glycemic management, which is related with an increase in atherosclerosis in numerous organs, including the lungs, and affects the coronary arteries, resulting in a decrease in blood flow to the heart muscle. A decrease in the heart's capacity to contract can impede physical activity. In this study, however, obese children with impaired fasting glucose and DM which well-controlled blood sugar had no correlation with 6MWD.

Previous studies on the effects of physical activity and sedentary lifestyle on 6MWT indicated that a sedentary lifestyle is associated with a shorter walking distance, but has no correlation with physical activity [15,33]. Our study did not find a significant correlation between physical activity and sedentary life style and 6MWT, which may be explained by the emerging epidemic of COVID-19 virus. The number of online home schools in Thailand has increased because of the COVID-19 pandemic. As a result, many children have exhibited sedentary behavior and engaged in less physical activities. To determine the level of physical activity, we utilized questionnaires that contained possible recall and desirability biases. In addition to questionnaires, other methods of assessing physical activity, such as muscular strength, were also employed.

Previous research utilized anthropometric data to predict the 6MWD among obese children; age, height, BMI, and hip circumference accounted for 69% of the 6MWD's variability [34]. In this study, we discovered an equation that utilized both anthropometric and metabolic variables; age, sex, %Fat, TG and TC, with R2 of 0.28 and p<0.001 for weight-control intervention follow-up.

LIMITATION

A key limitation of this research is the small sample size in the Pass group to compare obesity-related factors between the two groups.

CONCLUSION

W/H, %Fat, and TC were associated with 6MWT performance among obese children aged 5 to 15 years old. Therefore, weight control and a fat-restricted diet are mainly recommended to improve physical performance. For future research, it is suggested

that a pre and post diet fat-loss controlled trial be conducted to examine the improvement in physical performance.

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None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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