Impact of Body Mass Index on Muscle Thickness and Physical Fitness in Adolescents: Cross-Sectional Study

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ABSTRACT

Background: Musculoskeletal fitness and body composition are usable markers of individual's total health. Adolescence represents a pivotal stage in development**. Aim:** To compare between different categories of body mass index (BMI) in muscle thickness and physical fitness in adolescents. **Subjects and Methods:** Cross sectional study included 100 adolescents aged from 12 to 18 years (42 girls and 58 boys) were categorised by BMI into 4 equal groups (overweight, obese, normal and underweight). Muscle thickness of biceps brachii, rectus abdominis and rectus femoris was measured by ultrasound imaging, and physical fitness was assessed by European physical fitness test battery. **Results:** There were significant differences between the 4 groups in tests of standing broad jump, sit-ups and bent arm hang tests (p=0.001) as normal adolescents were the best between groups in bent arm hang test and were better than obese and underweight in sit-ups test, while obese adolescents were the worst in sit-ups and standing broad jump tests compared to normal and overweight. Non-significant differences were found in tests of 10 x 5 shuttle run and plate tapping tests between the 4 groups (p=0.11, 0.09) respectively. There were significant differences (p=0.001) between the participating groups in muscle thickness. The underweight group had the lower muscle thickness for the three tested muscles compared to other groups, while the overweight and obese adolescents were higher in rectus abdominis and rectus femoris muscle thickness **Conclusion:** Obese adolescents are the worst in physical fitness tests performance; which emphasize the need for regular muscle strengthening and fitness activities for younger children and adolescents. It seems that individuals with a higher BMI have greater muscle thickness compared to their peers with normal or lower BMI.

Keywords: Adolescence, Body mass index, Muscle architecture, Physical fitness, Ultrasound imaging

INTRODUCTION

Body mass index (BMI) is a widely used anthropometric measure for screening of overweight and obesity as well as categorising people into different weight groups (underweight, normal, overweight, and obese)[1]. Girls and boys develop at different rates and have different amounts of body fat at different ages. For this reason, BMI measurements during childhood and adolescence take age and sex into consideration[2]. Being underweight, overweight, or obese during childhood and adolescence is associated with adverse health consequences throughout the life-course. Studies have reported that the high levels of obesity assessed by BMI could affect the motor performance and aerobic fitness of youths[3].

Muscle strength, power, and endurance are used to emphasise muscle function. The amount of force a muscle can produce with a single maximal effort is referred to as muscle strength. Muscle power, is the ability to exert maximum force in the shortest amount of time possible, as in accelerating, jumping, and throwing implements, and muscle endurance, is the ability of muscles to exert force against resistance over a sustained period of time[4]. Muscle strength is proportional to the physiological cross-sectional area of the muscle, and can be effectively estimated by muscle thickness[5].

Physical fitness is a powerful health marker during childhood and adolescents and predicts health later in life[6]**,** it includes both cardiorespiratory and musculoskeletal fitness. Musculoskeletal fitness includes the ability of a group of muscles to exert force maximally (muscular strength), quickly (muscular power), or repeatedly (muscular endurance), as well as the ability to move a joint through its full range of motion (flexibility)[7]. Muscular fitness is also related to cardiovascular risk, adiposity, skeletal health and even self-esteem in children[8].

Overweight and obesity has been linked to poor health outcomes and negatively impacts quality of life facing social, psychological and physical problems[9]. Evidence suggests that high levels of adiposity may impair muscle activation in the adolescents leading to functional limitation of low strength relative to body mass[10]. People who are underweight have too little body fat, or less than 12% body fat in female and 5% body fat in male. Worldwide, underweight due to inadequate diets is much more common than obesity and more life-threatening[11].

Muscle thickness (MT) was defined as the perpendicular distance between the deep and superficial aponeurosis, or the adipose tissue and bone. It was found to be age, height, and weight dependent in adults, but only weight dependent in children[12]**.** There is a positive significant relationship between the BMI and thickness of muscles, it seems that individuals with higher BMI had thicker muscles[13].Obesity influences muscle fiber size, as muscle hypertrophy develops in weight bearing muscles secondary to increased body weight[14]. Males had significantly thicker abdominal muscles than females[15].

It was reported that, in all muscles, the muscle thickness significantly depended on the child's weight up to the age of 16 years[16]. It was reported that, obese children have more strength and less endurance than overweight and normal-weight children. On the other hand underweight children exhibited smaller muscle mass which may affect their physical fitness[17].

Relatively few studies had examined the relationship between physical fitness and BMI spanning range from thin to obese in adolescents. The available literature did not confirm how muscle thickness could be varied according to different BMI. Therefore, this study aimed to determine the impact of different categories of BMI on physical fitness and muscle thickness in adolescents.

SUBJECTS AND METHODS

Subjects Selection

One hundred adolescents from both sexes were enrolled in this study according to sample size calculation using G-power test (effect size = 0.1, power = 95%, type 1 error = 0.95 and α = 0.05).

This study contained convenient sample of adolescents from both sexes recruited from Al-Minia governorate public preparatory and secondary schools (Al-shahed Mohamed Hamed school, Ramses school, Mallawi secondary school for girls and Mallawi secondary school for boys). Eligibility criteria were 1) ages ranged from 12 to 18 years, 2) body mass index ranged from more than +2SD to less than -2SD (obese, normal, overweight, underweight) according to BMI-for-age Z-scores[18], 3) able to follow instructions during the assessment procedures.

Adolescents with visual or auditory disorders, structural abnormalities in the spine or upper and lower limbs, neurological or musculoskeletal disorders or perceptual disorders were excluded.

Body weight was measured to the nearest 0.5 kg by using digital scale in light clothing. Height was measured to the nearest 0.5 cm without shoes, with hips and shoulders perpendicular to the central axis, feet and knees together and the head is perpendicular. BMI was calculated as body weight in (kilograms) divided by body height in (square meters). The adolescents were defined as obese, overweight, normal-weight and underweight according to the WHO child growth characteristics for age, sex, and BMI using BMI for age Z-score charts for boys and girls. Adolescent obesity is defined as a BMI-for-age greater than +2 Z-score. Underweight is defined as BMI-for-age of less than -2 Z-score. Overweight is defined as BMI-for-age from greater than +1 to +2 Z-score. Weight is considered Normal as BMI-for-age from +1 to -2 Zscore[18].

Study Design and Ethical Considerations

A cross sectional study conducted from December 2020 to April 2022. Before starting the study; the protocol of this study was approved by Research Ethical Committee of the Faculty of Physical Therapy, Cairo University (P.T.REC/012/003717); the purpose and the procedures were explained to all children and their parents; and an informed consent was obtained from all the participant's caregivers.

Procedures for assessment

Assessment of Muscle thickness

Ultrasound imaging was used for all children participated in this study to measure the muscle thickness of dominant upper and lower limbs including; Biceps brachii, Quadriceps (rectus femoris) and abdominal (rectus abdominis) using B-mode. Ultrasound imaging has been demonstrated as a valid and reliable method for measurement of thickness, echo-intensity and cross-sectional area of; muscle, nerve, tendon and fascia and muscle size[19,20].

According to **Heckmatt and Dubowitz**[21]**,** the following precautions were considered: 1) The site of measurement was determined precisely for each adolescent. 2) It was important to ensure that the child was completely relaxed, as the muscle thickness and echo intensity change with muscle contraction. According to **Scholten et al.**[16] and **Tahan et al.**[22] the following protocol was applied: For biceps brachii and rectus femoris muscles adolescents were examined from a supine lying position with their arms and legs extended and muscles completely relaxed. Biceps brachii muscle was measured at two-thirds of the distance from the acromion to the antecubital crease of the arm. Rectus femoris muscle was measured on the thigh halfway along the line from the anterior superior iliac spine to the superior aspect of the patella. For rectus abdominis, adolescents were examined from crook-lying position while pillows were placed under their head, the transducer was placed 2–3 cm above the umbilicus, 2–3 cm from the midline.

Assessment of Physical Fitness

European Physical Fitness Test Battery was used to assess physical fitness. The following tests were measured for the participated adolescents including; bent arm hang, plate tapping, standing broad jump, sit-ups and 10 x 5 shuttle run. This battery is designed for assessment of health-related fitness in children and adult, it provides reliable and valid health-related physical fitness measures [23,24].

Statistical Analysis

The data was statistically analyzed using Statistical Package for Social Sciences (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA). The mean and standard deviation were determined for demographic characteristics including age, weight, and height, BMI as well as for all measured variables in all groups. Analysis of variance was used to compare the mean values of all measured variables in all groups. The level of significance for all statistical tests was set at $p < 0.05$.

RESULTS

Subjects' characteristics:

One hundred adolescents participated in this study. Their mean values ±SD of age, weight, height and BMI were 14.76 ± 1.66 years, 55.68 ± 15.89 kg, 157.91 ± 8.63 cm and 22.22 ± 5.53 kg/m² respectively. The sex distribution of the study sample showed that there were 42 (42%) girls and 58 (58%) boys (Table 1).

Comparison between the mean values of standing broad jump test revealed that there were significant differences between the four groups ($p = 0.001$) (Table 2). Comparing the mean values of 10 x 5 m shuttle run and plate tapping tests test revealed that there was no significant difference in standing broad jump between the four groups ($p = 0.11, 0.09$) (Table 3).

Comparison between the mean values of sit-ups test and bent-arm hang test revealed that there were significant differences between the four groups ($p = 0.001$) (Table 4 and 5). Comparing the mean values of muscle thickness of biceps brachii, rectus abdominis and rectus femoris muscles revealed that there were significant differences between the four groups (p = 0.001) (Table 6, 7, 8).

Table (1): General characteristics of the study sample

Characteristic	$\overline{X}$ ±SD	
Age (years)	14.76 ± 1.66	
Weight (kg)	55.68 ± 15.89	
Height (cm)	157.91 ± 8.63	
BMI (kg/m²)	22.22 ± 5.53	
Sex distribution N. (%)	Girls	42 (42%)
	Boys	58 (58%)

BMI= body mass index $\overline{X}$: Mean   N=number   SD: Standard deviation

Table (2): Comparison of the mean values of standing broad jump test between the four groups

Standing broad jump (cm) $\overline{X}$ ±SD				p-value
Normal (n=25)	Overweight (n=25)	Obese (n=25)	Underweight (n=25)	
137.88 ± 30.56	130.56 ± 28.07	108.04 ± 20.79	119.16 ± 29.55	0.001
Multiple comparison (Bonferroni)				
		MD		p-value
Normal – Overweight		7.32		1
Normal – Obese		29.84		0.001
Normal – Underweight		18.72		0.11
Overweight – Obese		22.52		0.02
Overweight – Underweight		11.4		0.87
Obese – Underweight		-11.12		0.93

$\overline{X}$: Mean   SD: Standard deviation   P-value: Probability value
MD: Mean difference

Table (3): Comparison of the mean values of 10 x 5 m shuttle run and plate tapping tests between the four groups

10 x 5 m shuttle run Test (sec) $\overline{X}$ ±SD				p- value
Normal (n=25)	Overweight (n=25)	Obese (n=25)	Underweight (n=25)	
21.92 ± 2.84	22.76 ± 2.91	23.44 ± 2.21	21.88 ± 2.31	0.11
plate tapping test (sec)				**p- value**

$\bar{X}$ ±SD				
Normal (n=25)	**Overweight (n=25)**	**Obese (n=25)**	**Underweight (n=25)**	
11.88 ± 2.72	12.79 ± 3.56	12.92 ± 3.55	14.16 ± 2.62	0.09

$\bar{X}$: Mean SD: Standard deviation P-value: Probability value

Table (4): Comparison of the mean values of sit-ups test between the four groups

Sit-ups				**p-value**
$\bar{X}$ ±SD				
Normal (n=25)	**Overweight (n=25)**	**Obese (n=25)**	**Underweight (n=25)**	
11.84 ± 4.62	10.92 ± 5.82	6.12 ± 3.51	7.68 ± 5.32	0.001
Multiple comparison (Tukey)				
		MD	**p-value**	
Normal - Overweight		0.92	0.91	
Normal - Obese		5.72	0.001	
Normal - Underweight		4.16	0.01	
Overweight - Obese		4.8	0.004	
Overweight - Underweight		3.24	0.09	
Obese - Underweight		-1.56	0.67	

$\bar{X}$: Mean SD: Standard deviation P-value: Probability value
MD: Mean difference

Table (5): Comparison of the mean values of bent-arm hang test between the four groups

Bent-Arm Hang Test (sec)				**p-value**
$\bar{X}$ ±SD				
Normal (n=25)	**Overweight (n=25)**	**Obese (n=25)**	**Underweight (n=25)**	
4.72 ± 1.90	1.48 ± 0.77	1.56 ± 0.91	2.08 ± 1.80	0.001
Multiple comparison (Bonferroni)				
		MD	**p-value**	
Normal - Overweight		3.24	0.001	
Normal - Obese		3.16	0.001	
Normal - Underweight		2.64	0.001	
Overweight - Obese		-0.08	1	
Overweight - Underweight		-0.6	0.86	
Obese - Underweight		-0.52	1	

$\bar{X}$: Mean SD: Standard deviation P-value: Probability value
MD: Mean difference

Table (6): Comparison of mean values of biceps brachii muscle thickness between the four groups

Biceps brachii muscle thickness (cm)				p-value
$\bar{X}$ ±SD				
Normal (n=25)	**Overweight (n=25)**	**Obese (n=25)**	**Underweight (n=25)**	
1.39 ± 0.32	1.44 ± 0.25	1.55 ± 0.21	0.84 ± 0.20	0.001

Multiple comparison (Tukey)		
	MD	**p-value**
Normal - Overweight	-0.05	0.91
Normal – Obese	-0.16	0.13
Normal - Underweight	0.55	0.001
Overweight – Obese	-0.11	0.42
Overweight - Underweight	0.6	0.001
Obese - Underweight	0.71	0.001

$\bar{X}$: Mean SD: Standard deviation P-value: Probability value
MD: Mean difference

Table (7): Comparison of the mean values of rectus abdominis muscle thickness between the four groups

Rectus abdominis muscle thickness (cm)				p-value
$\bar{X}$ ±SD				
Normal (n=25)	**Overweight (n=25)**	**Obese (n=25)**	**Underweight (n=25)**	
0.95 ± 0.18	1.12 ± 0.17	1.11 ± 0.16	0.67 ± 0.11	0.001

Multiple comparison (Tukey)		
	MD	**p-value**
Normal - Overweight	-0.17	0.003
Normal – Obese	-0.16	0.01
Normal - Underweight	0.28	0.001
Overweight - Obese	0.01	0.98
Overweight - Underweight	0.45	0.001
Obese - Underweight	0.44	0.001

$\bar{X}$: Mean SD: Standard deviation P-value: Probability value
MD: Mean difference

Table (8): Comparison of the mean values of rectus femoris muscle thickness between the four groups

Rectus femoris muscle thickness (cm)				p- value
$\overline{X}$ ±SD				
Normal (n=25)	**Overweight (n=25)**	**Obese (n=25)**	**Underweight (n=25)**	
1.43 ± 0.33	1.70 ± 0.34	1.88 ± 0.28	0.81 ± 0.19	0.001
Multiple comparison (Tukey)				
		MD		**p-value**
Normal – Overweight		-0.27		0.009
Normal – Obese		-0.45		0.001
Normal – Underweight		0.62		0.001
Overweight – Obese		-0.18		0.14
Overweight - Underweight		0.89		0.001
Obese – Underweight		1.07		0.001

$\overline{X}$: Mean SD: Standard deviation P-value: Probability value
MD: Mean difference

DISCUSSION

As physical fitness plays key roles in health of children and adolescents; it would be helpful to understand the relation between body mass index (BMI) and physical fitness. This may be of value to understand the changes in the ability to have ideal function and health later in life. This study aims to compare between adolescents with different categories of BMI in muscle thickness and physical fitness.

This research highlights the importance of monitoring adolescents physical fitness which comes in agreement with the recommendations of Cvejić et al.[25] who suggested considering the assessment and monitoring of children physical fitness, a public health priority; as evidence showed that physical fitness is an excellent indicator of the health of children and adolescents and is a predictor of health in later life. The application of the EUROFIT test battery in various age groups can be helpful in the determination of general health status, providing information about the structural and functional characteristics of the children, and determining national policies related to children.

This cross sectional study included one-hundred adolescents aged from 12 to 18 years, the current study focused on the adolescence stage as it is a critical period for body image development because of the various social, cultural, physical, and psychological changes occurring between the ages of 12 years and 18 years of age. Similarly, Abarca-Gómez et al.[26] and Mendoza-Muñoz et al.[27] focused in their studies on adolescence stage as it represents a pivotal stage in the development.

Adolescence is characterized by changes in quantity and location of body fat, which is part of the reason that it is a critical period for abnormal weight gain[28]. Early adolescence is associated with a substantial increase in adipocyte (fat cell) size and number and the adolescent growth spurt is generally characterized by a rapid rate of growth in height[29]. Once peak height velocity is achieved, rates of growth generally slow down and plateau until adulthood. Certain indicators of maturation including menarche and peak height velocity (rate of change of height per unit of time) have been associated with increased adiposity [30,31].

The present study included a matched sample of one hundred adolescents from both sexes (42 females and 58 males). This comes in agreement with Malina et al.[29] who reported that body composition changes differ by sex throughout adolescence with adolescent males and females show increases in fat-free mass whereas the percentage of body fat decreases for males and increases for females during maturation.

The participated adolescents in this study were categorised by BMI into four equal groups (overweight, obese, normal-weight, underweight), their muscle thickness (biceps brachii, rectus abdominis and rectus femoris muscles) were measured by ultrasound imaging, and their physical fitness was assessed by European Physical Fitness (EUROFIT) Test battery.

The sample groups of this study were homogenous regarding the general characteristics as there were no significant differences between mean values of the four groups related to age ($p=0.7$), height ($p=0.47$) and sex ($p=0.61$). They were classified according to their BMI; so significant difference was found between their mean values of weight ($p=0.001$) and BMI ($p=0.001$).

The BMI was selected to be investigated in this study as it is an important indicator of good health, its correlation with physical fitness and muscle thickness. Janssen et al.[32] reviewed data from 34 countries and found that higher BMI was associated with lower levels of physical activity among adolescents. The BMI is considered the standard used to identify overweight and obesity. It was used to measure the levels of obesity of children and adolescents[33,34]. It is found to be the most significant anthropometric predictor of physical fitness status[35].

The adolescents participated in this study were classified into four different weight status groups according to the WHO child growth characteristics for age, sex, and BMI using BMI for age Z-score charts for boys and girls[18]. The four groups that were selected in this study included different categories; overweight, obese, normal-weight, underweight. Studies in the Eastern Mediterranean Region showed that the prevalence of overweight among school-aged children (6-18 years old) reached an alarming level[36].There are a number of underweight children and adolescents worldwide, especially in some developing countries in Latin America, Africa, and Asia[26].

Uunderweight and overweight are serious problems for Egyptian school children, particularly in the 9-11 years old age group. These abnormal weight categories are showed to be associated with a low level of physical fitness. Therefore, physical education teachers, parents, scientists, and coaches should be aware of the higher prevalence of underweight and overweight and its effects on physical fitness levels[37]. There are underweight children and adolescents worldwide, especially in some developing countries in Africa, Asia and Latin America. Underweight usually does not receive as much attention as overweight and obesity, this study tested large sample of both genders that allowed inclusion of different weight categories spanning the range from underweight to obese adolescents and on a wide range of adolescents' age[26].

Physical fitness is closely related to health, skills and sportive productivity, it is an important factor that affects activities of daily life, and also a predictor of suffering chronic diseases, such as cardiovascular diseases and obesity[38]. This study provides valuable insights into health-related physical fitness across weight categories and the impact of different weight categories on muscle thickness within the age range from 12 to 18 years for which data are scarce in the present literature.

The EUROFIT battery was developed by the Council of Europe; it includes different tests that are used to assess different physical fitness components, such as balance, speed, flexibility, power, muscle strength, muscle endurance, agility, and aerobic endurance. The reliability of the

EUROFIT test battery was recently reviewed and it was suggested to be used as a reliable battery of tests to assess physical fitness in research and practice[24].

Five tests (standing broad jump, bent arm hang, plate tapping, sit-ups and 10 x 5 shuttle run test) were selected from the EUROFIT test battery to assess the physical fitness for participated adolescents in this study. The standing broad jump test for lower body strength, bent arm hang test for upper-body muscle endurance, plate tapping test for upper-body speed, sit-ups for muscle endurance, and 10 x 5 shuttle run test for speed and agility. This comes in agreement with Karppanen et al.[39] who used the EUROFIT test battery to assess the physical fitness of 8 years old overweight and normal weight children. Also, Erikoğlu et al.[40] used the EUROFIT test battery to compare physical fitness parameters of male adolescent (13-14 years) soccer players and sedentary counterparts.

The findings of the current study indicated that Obese adolescents were the worst in physical fitness tests performance. There was non-significant difference between weight categories groups in the tests of speed and agility (plate tapping and 10 x 5 m shuttle run tests) and the difference was significantly regarding the tests of strength and endurance (standing broad jump, bent arm hang and sit-up tests).

The impact of BMI on physical fitness differs according to the performed test. In this study, there was a significant difference between the four groups in standing broad jump, sit-ups, bent-arm hang tests (p=0.001), while no significant difference was found in 10 x 5 m shuttle run test (p=0.11) and plate-tapping test (p=0.09).

Results of the current study showed that overweight adolescents were worse than their normal peers in bent arm hang test that require upper body strength and endurance, although they performed better than obese adolescents in other fitness tests as standing broad jump and sit-up test. Regarding the obese adolescents participated in this study, they were worse than normal peers in standing broad jump; sit-up and bent arm hang tests. Comparison between obese, normal and overweight adolescents for 10 x 5 m shuttle run and plate- tapping tests' scores revealed no significant difference.

Findings of the comparison of different weight categories performance in this study showed significant difference between normal and obese adolescents regarding the standing broad jump and sit-ups tests. This comes in agreement with the findings of Abdelkarim et al.[37] who reported that underweight and normal weight subjects showed higher performance in comparison to overweight peers.

The findings of the present study indicated that normal adolescents significantly performed better than obese peers in tests of bent arm hang and sit-ups tests. This comes in agreement with the findings of Dumith et al.[41] who conducted a cross-sectional study included 519 Brazilian students aged 7 to 15 years overweight, obese and normal weights. They reported that children and young adolescents with normal weight performed significantly better than their overweight/obese counterparts in abdominal and upper body strength and endurance**.**

The results of the present study regarding physical fitness come in agreement with the findings of Karppanen et al.[39] who compared the physical fitness between overweight and normal weight children. They found that normal children had significant increase than overweight children in four fitness tests; standing broad jump, sit-ups, bent arm hang, and 10 x 5 m shuttle run tests, while the overweight children were significantly increased in plate-tapping test than normal as this test don't rely on body lifting and moving. They reported that impaired performance of overweight children was found in tests that required explosive power of the lower extremities, muscle endurance, upper body strength and endurance and also speed and agility in both genders. These findings were explained by the fact that when performing tasks that require carrying or lifting their own body, overweight individuals are at a disadvantage because, fat tissue behaves as inert load.

Also, the results of the present study come in agreement with the finding of Xu et al.[33] who examined a sample aged 10-18 years adolescents spanning the range underweight to obese. They found that the obese participants showed poorer scores of standing broad jump than other three BMI category peers; it was justified by the barrier of high weight in fitness tests that required quick position changes; as body weight increased the forces exerted on knee extensors thus leading to difficulty for adolescents to conduct tests involving moving their weight or keeping it in the right position. Also, they found that obese adolescents performed worst in sit-ups test also compared to other weight groups in both genders. This was due to higher fat and lower muscle mass in the waist area.

Although the present study showed that the obese adolescents performed poorer than normal-weight peers in the test of broad jump, no significant difference was found between the overweight and normal-weight adolescents regarding this test. This comes in agreement with Mendoza-Muñoz et al.[27] who reported that overweight and obese adolescents showed poorer standing broad jump test scores compared to their normal-weight peers.

On the other hand, no significant difference was found in the current study between the performance of underweight adolescents and other categories in standing broad jump and sit-ups tests. This disagree with findings of García-Hermoso et al.[42] who suggested that underweight adolescents, have lower odds of having a healthy cardiorespiratory fitness profile when compared with their normal weight peers. Zenic et al.[35] also investigated the relation between health-related physical fitness and weight status in 13 to 15years old Latino adolescents and reported significant difference between underweight adolescents and other categories.

Awad and Aneis[34] revealed that children who were normal weight or underweight had higher motor skills than those who were overweight or obese, and that obese children had the worst motor ability. They concluded that excess body weight in early childhood has a deleterious effect on motor skill performance.

Muscle thickness was one of the main variables that were investigated in the present study; by comparing muscle thickness between adolescents with different weight categories. The morphological component of physical fitness refers to the muscle, fat, bone, and other vital components which are essential for optimal health and sportive performance[38]. It was reported by Ostojić et al.[43] that excess fatty tissue increases health risk of obesity, cardiovascular diseases and prevents optimal performance in sports dominated by running or jumping activities.

The ultrasound imaging was used in the current study to measure the muscle thickness of the participated adolescents; the dominant upper and lower limbs muscles were selected including: Biceps brachii, Quadriceps (rectus femoris) and abdominal (rectus abdominis) muscles. Ultrasound imaging was selected for measurement in this study because it is a reliable and valid tool for the assessment of muscle size[19]. This was based on the studies of Legerlotz et al.[12] and Chiaramonte et al.[44] who used ultrasound imaging to analyze the characteristics and age-related changes of muscle architecture; it was proven to be a good and accurate tool for muscle evaluation in children.

This comes in agreement with the work of Abe et al.[45] who used ultrasound for muscle thickness assessment of the extremity and trunk. Also, Lori et al.[46] used it to provide comprehensive pediatric muscle ultrasound normative data for muscle width on a sample of 120 healthy volunteers (59 males) aged 2–16 years. Rectus femoris muscle and biceps brachii muscle were included in their examination.

The findings of the current study indicated that underweight have the lowest muscle thickness. There was a significant difference between groups in muscle thickness of biceps brachii, rectus abdominis and rectus femoris. Overweight and obese categories have thicker muscle thickness than normal weight regarding rectus abdominis and rectus femoris muscle thickness. there was no significant difference between overweight and obese muscle thickness in the tested muscles.

This comes in agreement with Tahan et al.[22] who reported that individuals with higher BMI had thicker superficial layers of abdominal muscles compared to deep layers and body mass index was also positively correlated with muscle thickness of rectus abdominis and external oblique. Also, Springer et al.[47] reported a positive significant relationship between the BMI and thickness in all muscles of external abdominal layer.

Also, the results of the present study regarding muscle thickness come in agreement with the finding of Huang and Malina[17] who examined a sample of Taiwanese youth 9-18 years of age and were classified into five BMI categories, they found that obese children have more strength and less endurance time of quadriceps and abdominal muscles than overweight and normal weight children. On the other hand underweight children exhibited smaller muscle mass which may affect their physical fitness

The findings of the current study disagree with the results of Al-Qahtani et al.[48] who examined 21 healthy males with different BMI (overweight, obese, normal and underweight). They aimed to investigate the association of the effects of weight lifting on the biceps brachii muscle and distal bicep tendon concerning BMI. They found that biceps brachii muscle thickness did not increase with increase in BMI and was not significantly different between groups. They concluded that the biceps brachii muscle thickness is independent of BMI.

As children become obese because they are inactive and obese children tend not to participate in physical activity; this is a vicious cycle. Based on the findings of this study; early intervention programs should be considered and directed on decreasing fat mass for overweight and obese adolescents and increasing muscle mass for underweight adolescents. Early interaction with the environment is essential to enhance child motor development. Participation in fitness activities and doing regular muscle strengthening for younger children and adolescents are recommended for better health.

Further research is recommended to explore more factors that may affect the physical fitness of young people as nutrition and regularity of activities and sports participation. Future studies may use other methods for assessment of physical fitness in adolescents that may confirm the results. Muscle thickness measurements should be taken into consideration during the evaluation of adolescents' physical fitness. Keeping an adolescent weight within the normal range should be encouraged to achieve good physical fitness levels. Regular muscle strengthening and fitness activities should be considered as routine activities for younger children and adolescents.

CONCLUSION

According to the findings of the current study, overweight adolescents were worse than their normal peers in bent arm hang test that require upper body strength and endurance, while they performed better than obese adolescents in other fitness tests as standing broad jump and sit-up test. Obese adolescents were worse than normal peers in standing broad jump; sit-up and bent arm hang tests. Underweight adolescents have the lowest muscle thickness between groups in the tested muscles, while the overweight and obese adolescents have the higher thickness of rectus abdominis and rectus femoris muscles.

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Disclosure statement

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Conflict of interest

Authors report no conflict of interest.

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