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ORIGINAL ARTICLE

Relation between body mass index percentile and muscle strength and endurance

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KEYWORDS

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Abstract *Background:* Muscle strength and endurance in children are very important to develop physical activities and cardiorespiratory functions, so factors that might affect their development must be studied; thus the aim of this study is to identify if there is a relation between body mass index percentile and muscle strength and endurance time in healthy normal and obese children.

Subjects and methods: A group of 75 healthy children without orthopedic, perceptual or cognitive problems were selected from Awlady Association in Maadi, Cairo, their ages ranged from 10 to 13 years old from both sexes. They were divided into three groups according to their body mass index percentile where group (a) is equal to or more than 5% percentile yet less than 85% percentile, group (b) is equal to or more than 85% percentile however under 95% percentile, while group (c) is equal to or more than the 95%th percentile. Two assessments had been carried out with respect to the peak torque for triceps muscle and quadriceps muscle, they were surveyed by Biodex isokinetic dynamometer at an angular velocity of 60°/s in concentric contraction mode while abdominal muscles were evaluated by manual muscle testing. A stop watch was utilized to calculate the length of time to fatigue to evaluate endurance time.

The results: A significant distinction in muscle strength and endurance time among the obese, overweight groups comparing to the normal weight groups was identified. Additionally there was a positive correlation between muscle strength and body mass index percentile while muscle endurance time had a negative correlation with it.

Conclusion: The study shows that the BMI of children had a positive correlation with the muscle strength of quadriceps, triceps, and abdominal muscles while a negative correlation with the endurance time of these muscles.

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1. Introduction

Childhood obesity has come to epidemic extents and its prevalence is expanding over the world [1] particularly in the Middle East and Eastern Europe [2]. Body mass index (BMI)) is considered a reasonable measure that aids in the evaluation process of fatness in children and adolescents. Additionally it is a standard used to identify overweight and obesity [3]. Moreover, BMI is related to the body size however it cannot differentiate between fat and muscle tissue [4]. Factors like age and sex greatly affect levels of BMI among children and teens where they differ due to pattern of growth and presence of sex hormones. So it is essential to express the BMI of children relative to other children of the same sex and age [5,6]. The percentile refers to the position of a child on a given reference distribution which is often age-sex-specific. Percentiles are recommended to assess children's growth and nutritional status that in view of considering anthropometric measures as well as other health conditions [7].

Muscles make up more than 40% of body mass so they represent a substantial site of energy reactions (metabolism). Individual's daily activities are performed without much difficulty by Muscles help, muscles also protect the body from injury, and enhance salubrity [8]. Muscle strength refers to the maximal amount of individual's ability to exert a maximum muscular force in a specific movement pattern at definite velocity against any type of resistance [9].It is affected by angle of pull, size and muscle cell length, number of fibers (motor unit) recruited, speed and type of contraction, age and gender [10]. Isokinetic dynamometry, hand-held dynamometry, field tests, and standard weights equipment are multitude ways of measurement of muscle strength in children [11]. Isokinetic dynamometry has reliable protocols for measuring strength and fatigue of a single muscle or group of muscles under controlled conditions, that protocols have been set up for children [12,11].

Muscle endurance reflects the ability to sustain repeated muscle contraction furthermore the ability to perform work over an elongated period of time [13,21]. Children need endurance to perform perpetual daily activities, playing actively for quite a long time, or walking up stairs. Endurance can be affected by strength of an individual muscle, group of muscle, or the total body. The strength of total body reflects the capacity of the heart to deliver a steady supply of oxygen to working muscles so it usually refers to cardiopulmonary endurance [14]. Developmentally at childhood stage, muscle endurance has been shown to increase linearly in boys somewhere around 5 and 13 years old, after which a spurt is observed while there is a steady linear increase in girls [13]. Muscle endurance tests are often employed to assess the process of muscle fatigue. This process is gradual and attributable to physiological transmutes which occur before and during the mechanical failure [15].

Obesity and overweight continue to pose a serious health concern on the development of the child's musculoskeletal system which is still poorly understood [16]. However, the relations between muscle strength, especially leg strength and anthropometric measurements, body composition parameters still require more investigations [17].

So the aim of the study is to compare strength and endurance time of quadriceps, triceps, and abdominal muscles among healthy normal, overweight and obese children to identify if there is a relationship between BMI percentiles and muscle strength and endurance in these groups.

1.1. Subjects

A group of 75 children included in the study from both sexes (45 males and 30 females), their ages ranged from 10 to 13 years old. They were selected from Awlady Association in Maadi, Giza governorate, Egypt. They were classified into three groups according to their body mass index percentile, group (a): is equal to or more than 5%th percentile yet less than 85% percentile, group (b): is equal to or more than 85% percentile but less than 95% percentile, group (c): is equal to or more than 95% percentile [5,6]. All children were healthy without orthopedic problems, without heart problems, and without neurological manifestations.

1.2. II- Instruments

The biodex isokinetic dynamometer, in isokinetic laboratory in the Faculty of Physical Therapy, Cairo university, was used to measure average peak torque and to determine the point at which endurance time was calculated for quadriceps and triceps muscles (isokinetic testing provides accurate data of an individual muscle groups) [11]. Isokinetic Dynamometer consists of the head assembly that includes force acceptance unit which is the interface between the child and the system. The head is a metallic attachment which can be shifted and rotated in order to fit the position of the trained joint. It is connected to lever arm by the load cell which converts force signals to electrical signals. The seat of Isokinetic Dynamometer is motorized for 360° rotation, so it can be adjusted vertically or horizontally and it has superior stabilization. The control unit which consists of a computer is used to monitor and record torque of muscle, which express muscle performance (actual force of muscle).

1.3. III-Procedures

Isokinetic dynamometer was calibrated and the test was set up by determining the basic input parameters including: 1- speed: which was 60°/s, 2- range of motion: for quadriceps muscle was from 90° flexion knee to 0° extension and for triceps muscle was from 130° flexion elbow to 0° extension, 3- mode of muscle contraction was the concentric mode. Data about name, age, sex, height and weight of each child were gathered and entered to the control unit of Isokinetic Dynamometer. The test was carried out in the seated position using the three principles of positioning described by

Goslinand Charteris [18]: (1) Parallel alignment of the limb with the lever arm of the dynamometer, (2) Alignment of the anatomical axis of rotation of the knee joint and elbow joint with the rotational axis of the dynamometer, and (3) Proper stabilization to proximal joints as thigh, ankle, and chest by straps and encouraged the children to use the handles on either side of the chair to provide further stabilization. Before the test, the children and parents were informed about the purpose and procedures of the test and the instructions regarding the apparatus.

For quadriceps muscle strength and endurance time: The isokinetic dynamometer was oriented according to the manual of the device to knee extension, the knee attachment to the right side was selected and attached to leg cuff. The child sat on a seat with his/her hip and knee flexed at 110° and 90° respectively [19].The seat was adjusted to keep his/her knee at the level of the center of load cell then the chest, pelvis, and thigh were stabilized. The test started at 90° knee flexion, then the child was asked to push to full knee extension as much as he/she could with motivated manner with maximum five repetitions that recorded the maximum peak torque. Then the child had to repeat the movement until the curve of torque was below 50% of maximum peak torque according to Noelle [9] who stated that endurance can also be studied as an objective process with reduction in peak torque or work. The length of time starting from maximum peak torque at first 30 s to the time of decreased peak torque below 50% represents the endurance time of quadriceps muscle that is measured by a stop watch.

For triceps muscle strength and endurance time: The isokinetic dynamometer was oriented according to the manual of the device to elbow extension. The elbow attachment to the dominant side of each child was selected and attached. The child sat on a seat that was adjusted to keep his/her elbow at the level of the center of load cell then the shoulder, chest, and pelvis were stabilized. The test started at 130°elbow flexion, then the child was asked to push to full elbow extension as much as he/she could with motivated manner for maximum five repetitions that recorded the maximum peak torque. The child had to repeat the test until the curve was below 50% of maximum peak torque. Assistance might be given during this test when the child pull toward elbow flexion (since the elbow flexors were not measured and to exclude their fatigue). The length of time starting from maximum peak torque at first 30 s to the time of decreased peak torque below 50% representing triceps endurance time (muscle fatigability) that was measured by stop watch.

For abdominal muscles strength and endurance time: Manual muscle testing is an ordinarily utilized examination tool used to survey the strength of a specific group of muscles. The strength of a group of muscles is graded with respect to various factors namely: gravity, the range of movement, and the amount of force resisted by the muscle(s). The strength of abdominal muscles was evaluated by utilizing the modified Medical Research Council (mMRC) grading scale (Table 1) that is used to evaluate muscle strength by numbers ranging from 0 to 5, where 0 represents stability and 5 represents the normal strength. The modification of the MRC scale incorporates the use of "+" and "–" to the numerical score to include extra reviewing subdivisions [20]. The manual muscle test procedure ought to be briefly disclosed to the child who lied on crook lying position, then the child was asked to raise his/her head and trunk to get sitting. Assistance or resistance were applied to abdominal muscles by changing arm positions (sideways, forward, elevated or crossed). Endurance time of abdominal muscles was recorded from the time at which the child was able to raise his/her trunk reaching knees, then he/she had to repeat movement till he/she became unable to raise his/her trunk.

Table 1 The mMRC grading criteria for each numerical value (Florence et al.) [20].

0	No movement
1	Flicker of movement is seen or palpated in the muscle
2–	Muscle moves the joint through partial range of motion when gravity is eliminated
2	Muscle moves the joint through full range of motion when gravity is eliminated
2+	Muscle holds the joint against minimal resistance
3–	Muscle moves the joint against gravity, but not through full mechanical range of motion
3	Muscle cannot hold the joint against resistance, but moves the joint through the full range of motion against gravity
3+	Muscle moves the joint fully against gravity and is capable of transient resistance, but collapses abruptly
4–	Muscle holds the joint only against minimal resistance
4	Muscle holds the joint against a combination of gravity and moderate resistance
4+	Muscle holds the joint against moderate to maximal resistance
5	Muscle holds the joint against gravity and maximal resistance

1.4. Data analysis

Data were collected, automated and then analyzed using SPSS software through descriptive statistics (the mean and standard deviation). Interferential statistics by using ANOVA test were used to compare the correlation among three groups for peak torque and endurance time of quadriceps and triceps muscles. Kruskal–Wallis test was used to compare abdominal muscles strength while ANOVA test was used to detect the endurance time of abdominal muscles.

1.5. Results

The study compromised 75 children from both genders (30 girls&45 boys). They were classified by BMI percentiles to normal, overweight and obese (a, b, c respectively) (Table 2).

1.5.1. I- Comparison of quadriceps mean values of peak torque and endurance time

There was a significant difference in quadriceps peak torque and endurance time among the three groups ($p = 0.001$) (Table 3). The mean difference in quadriceps peak torque between group (a) and (b) was −6.05 Nm with critical increment in group (b) ($p = 0.03$). The mean difference between group (a) and (c) was −8.89 Nm with huge increment in group (c) ($p = 0.001$). The mean difference of quadriceps peak torque between group (b) and (c) was −2.84 Nm with no significant difference ($p = 0.45$). It has appeared to be a significant increase in endurance time of quadriceps in group (a) when it was compared with group (b) with mean difference of

Table 2 Descriptive statistics for the mean age of the three groups a, b, and c.

	Group a		Group b		Group c	
Sex	Girls 10	Boys 15	Girls 11	Boys 14	Girls 9	Boys 16
Weight (kg) (mean ± SD)	35.9 ± 6.8		46.5 ± 4.8		52.25 ± 10.57	
Height (cm)	150.7 ± 8.9		155.7 ± 5.9		152.4 ± 10	
BMI percentile	⩾5th percentile		⩾85th percentile		⩾95th percentile	

Table 3 Comparison of muscle peak torque and endurance time among the three groups.

	Quadriceps		Triceps		Abdominal	
	Peak torque (Nm)	Endurance time (s)	Peak torque (Nm)	Endurance time (s)	Strength grade	Endurance time (s)
Group a $\overline{X} \pm SD$	45.59 ± 5.34	83.88 ± 13.35	23.19 ± 5.66	72.2 ± 12.41	5	70.92 ± 14.68
Group b $\overline{X} \pm SD$	51.64 ± 9.68	66.28 ± 6.24	25.94 ± 5.77	67.08 ± 14.26	5	63.2 ± 13.1
Group c $\overline{X} \pm SD$	54.48 ± 9.29	55.36 ± 17.08	27.74 ± 5.37	65.92 ± 15.73	4	49.4 ± 9.16
p-Value	0.001	0.0001	0.01	0.25	0.0001	0.0001
Sig	S	S	S	NS	S	S

$\overline{X}$: Mean SD: Standard deviation S: Significant *p* value: Probability value NS: no Significance.

17.6 s and $p = 0.0001$, a noteworthy increment in endurance time in group (a) demonstrated when it was compared with group (c) of a mean difference of 28.52 s and $p = 0.0001$. There was a significant increase in endurance time of quadriceps of group (b) when it was compared with group (c) with a mean difference of 10.92 s and $p = 0.04$.

1.5.2. II- Comparison of peak torque and endurance time of triceps muscle

There was a significant difference in triceps peak torque among the three groups ($p = 0.01$) (Table 3). While there was no noteworthy distinction in triceps peak torque between group (a) and (b) with *a* mean difference of −2.75 Nm ($p = 0.19$).There was a critical increment in triceps peak torque between group (c) and group (b) with a mean difference of −4.55 Nm ($p = 0.01$), and there was no huge contrast between group (b) and (c) with mean difference of −1.8 Nm ($p = 0.49$). The mean ± SD of endurance time (time to fatigue) of triceps among the groups a, b, and c was 72.2 ± 12.41, 67.08 ± 14.26, and 65.92 ± 15.73 s respectively. There was no significant difference in endurance time of triceps among the groups ($p = 0.25$).

1.5.3. III- Comparison of abdominal muscle strength grade and endurance time

The median values of abdominal muscle strength grade of groups a, b, and c were graded to 5, 5, and 4 respectively. There was a significant difference in abdominal muscle strength grade among the three groups ($p = 0.0001$) (Table3). However, there was no huge increment in median value of abdominal muscle strength grade between group (a) and (b) ($p = 0.12$), while there was a significant increase in median value of abdominal muscles strength grade between group (a) and (c) ($p = 0.0001$). Results demonstrated additionally that there was likewise a significant increase in median value of abdominal muscles strength grade of group (b) compared with group (c) ($p = 0.007$). No huge distinction in endurance time of abdominal muscles recorded between group (a) and (b) with a mean difference of 7.72 s ($p = 0.08$).There was a significant increase between group (a) and (c) with mean difference of 21.52 s ($p = 0.0001$), and there was a significant increase between group (b) and (c) with a mean difference of 13.8 s ($p = 0.001$).

1.5.4. IV- Correlation between BMI and muscle strength and endurance time

There was a positive significant correlation between BMI percentiles and quadriceps and triceps peak torque ($r = 0.44$, $p = 0.0001$), ($r = 0.3$, $p = 0.009$) respectively, while there was a negative noteworthy correlation between BMI percentiles and the strength of abdominal muscles ($r = -0.54$, $p = 0.0001$). A negative significant correlation between BMI and endurance time of quadriceps and abdominal muscles ($r = -0.55$, $p = 0.0001$), ($r = -0.53$, $p = 0.0001$) was recorded respectively, while there was no significant correlation between BMI and endurance time of triceps muscle ($r = -0.21$, $p = 0.06$) (Fig. 1).

2. Discussion

The purpose of this study is to determine the relation between body mass index (BMI) and muscle strength and endurance time of quadriceps, triceps, and abdominal muscles in healthy children, as the physical capacities such as muscle strength, endurance and power are reliant on body or muscle mass [21]. Different distinctive physical factors such as variations in height and weight have been associated with changes in muscle strength [22].

This study shows that the strength of quadriceps and abdominal muscles of obese children was greater than those of overweight and normal weight, obese children were expected to represent a higher strength and power of abdominal, back, and quadriceps muscles on the grounds that their more noteworthy body mass require more muscle forces to move against gravity and to maintain stability [23,24]. These outcomes contradicted with a study conducted by Lafortuna et al. [25] who reported that quadriceps muscle strength and power, when compared to body mass, have in reality been observed to be altogether lower in obese than in non-obese subjects.

The result of the study revealed decrease in endurance time of abdominal and quadriceps muscles of obese children than that in overweight and normal weight children. These results conformed to the studies carried on obese school children who engaged in less moderate-to-vigorous physical activity as they concluded that obese children are physically less fit than their non-obese peers. Higher proportion of fast-fatigable fibers in the skeletal muscles of obese human was observed when compared with those in lean subjects [26]. Higher levels of muscle power are normally expected for obese subjects to move their heavy bodies during exercises that might decrease their ability to sustain activities for a long time [27]. While the results revealed non-significant difference among the groups in endurance time of triceps muscle which previous studies had mentioned and showed that the upper extremity

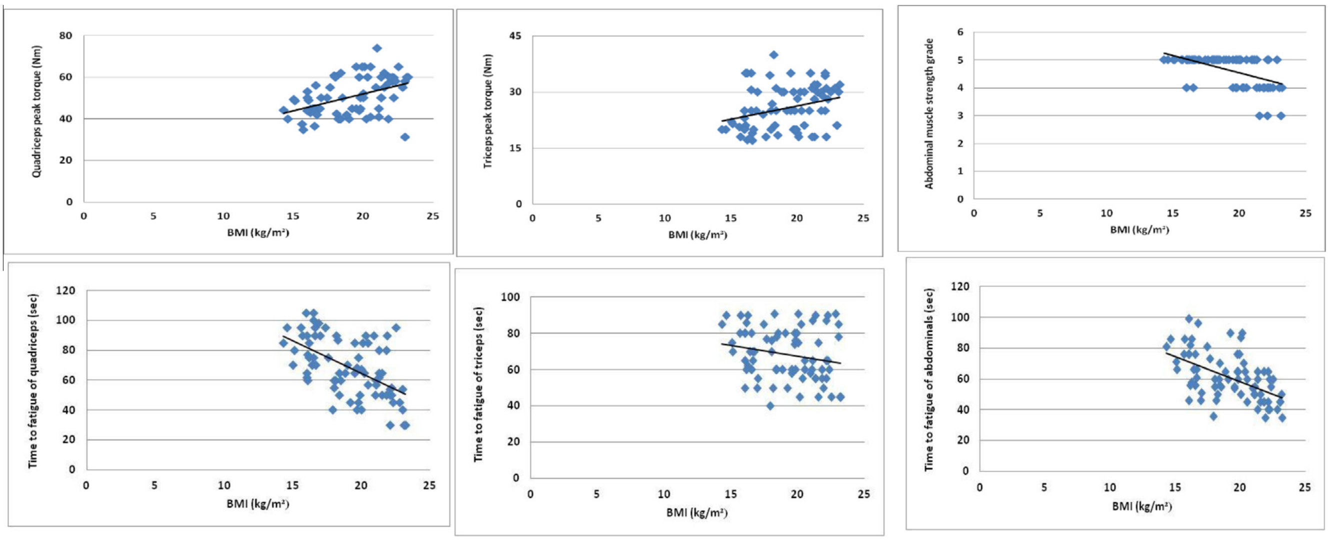

Figure 1 Correlation between BMI and muscle strength and endurance time (time to fatigue) of quadriceps, triceps, and abdominal muscles.

strength appeared to be fair in both obese children and their non-obese peers [16].

Correlation coefficients uncovered positive correlation between BMI percentile and muscle strength of quadriceps, triceps, and abdominal muscles. Body size is one of the major determinants of muscle strength while poor muscle strength has been observed to be associated with lower body weight and vice versa [28,29]. In conformity it was specified, there was a significance increase in triceps strength in obese children compared with non-obese ones, which concurred with Riddiford-Harland et al. [30] who compared obese children with their non-obese peers in upper limb push and pull strength indicating noteworthy greater results in obese children, while that was contradicted with Đokić and Međedović [31] who concluded that overweight was negatively associated with the muscle strength of arms and shoulders.

Correlation coefficients of the study revealed negative correlation between BMI percentile and endurance time of quadriceps and triceps muscles with no correlation between BMI percentile and endurance time of abdominal muscles. These results came in conformity with what previous studies concluded from Portuguese [32], Greek [33], Taiwanese [4], and Flemish [23] as they concluded that obese children showed poorer performance in abdominal endurance compared with normal weight. Additionally Centers for Disease Control and Prevention (CDC) [5] reported that the increase in fat mass in children and adolescents has occurred concomitantly with a decrease in time of activity in aerobic exercises. While these outcomes contradicted with other studies completed by Motka and Shah [34] who mentioned that obese children had poorer abdominal muscles strength as they displayed a protruding abdomen which results in anterior displacement of the center of gravity, that is associated with an increase in lumbar lordosis and anteversion of pelvis, continual exaggeration of curves leads to impairment in posture and muscle strength of abdomen and hip.

Limitation of the study: The sample size is low as some children of the selected age had signs of puberty so they were excluded.

3. Conclusion

In conclusion, this study suggests that BMI of children has a positive correlation with the muscle strength of quadriceps, triceps, and abdominal muscles, and a negative correlation with the endurance time of these muscles. It implies that obese children have more strength and less endurance time of triceps, quadriceps, and abdominal muscles than overweight and normal weight children.

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None.

Conflict of interest

The authors have declared the absence of any financial support with any commercial or personnel identities, so there is no conflict of interest that might inappropriately influence the study.

Ethical approval

Parents of children with selected criteria were asked to sign an informed consent form approved by the Committee on the Protection of the Rights of Human Subjects at the faculty of physical therapy, Cairo University.

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