ORIGINAL ARTICLE

Effect of Body Mass Index on Postural Balance and Muscle Strength in Children Aged 8-10 years

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Abstract:

*Background:*Childhood overweight and obesity, which are considered as global epidemic, can be assessed using Body Mass Index (BMI). BMI difference can lead to anatomic changes due to an increased body load. This increase might also affect motor performance, including changes in postural balance and muscle strength. *Aims and Objectives:* to explain the influence of BMI on postural balance and lower limb muscle strength and to assess the correlation between those two variables in children aged 8-10 years. *Material and methods:*The sample consisted of 63 children aged 8-10 years, which were divided in 3 groups: BMI-normal, BMI-overweight, and BMI-obese. The postural balance was assessed using single leg balance test on *MatScan* and the Center Of Pressure (COP) area was recorded. Isometric muscle strength of hip extensor and knee extensor were measured using a hand-held dynamometer. *Results:* Obese children had significantly largerCOP area than overweight ($p = 0.004$) and normal weight children ($p = 0.000$).There were no significant differences in hip extensor muscle strength between obese children with overweight and normal weight children ($p=0.527$). The absolute knee extensor muscle strength in obese group was significantly higher than the overweight and normal group ($p = 0.003$). However the relative muscle strength of lower limb for obese children was significantly lower than for normal weight. There was no significant correlation between absolute hip extensor and knee extensor muscles strength with COP area. *Conclusion:* Obese children have decreased postural balance and increased absolute knee extensor muscle strength significantly when compared to overweight and normal children. There is no significant correlation between postural balance and muscle strength.

Keywords: Obesity, Overweight, Postural Control, Knee Extensor, Hip Extensor

Introduction:

Nutritional problem does not only concern with malnutrition but also other problems, including obesity and overweight. These two problems can lead to various health complications. World Health Organization (WHO) recommends nutritional assessment of children using Body Mass Index (BMI) [1]. BMI correlates significantly with fat mass [2, 3]. Overweight and obesity prevalence in children are starting to increase in developing countries [1, 4]. Obese children correlate with an increased prevalence of musculoskeletal abnormalities such as flatfoot, Blount disease, and slipped capital femoral epiphysis [5, 6]. Several studies have shown that obese children have a worse motor performance than normal weight children, including changes in balance, muscle strength, and locomotion [6-9].

Posture is the position of each part of the body that is interconnected overtime [10]. Postural control includes body position control for stability so that the balance of the body can be maintained [11].

Ability to control body weight on a base support will enable a person to perform activities effectively and efficiently. The development of posture control starts from birth to adulthood; however, there is a controversy about postural balance maturity. Different studies suggest different ages of postural balance maturity. Assaiante *et al*. (1998) suggested that children aged 7-8 years use adult postural control as well as balance control [12]. Ibrahim *et al.* stated that dynamic balance of children aged 8-10 years is better than 6-7 year olds [13].

Balance is important because it is used in everyday activities, such as walking, running, and playing games. Balance disorders that may occur in overweight and obese children can affect their physical activity. One of the balance control mechanism systems is the contraction of certain muscles.

Muscle strength in balance is associated with the muscle's ability to resist gravity and other external loads that are constantly affecting body position [14]. Muscle strength is generally required to perform daily activities. The most involved muscles are anti-gravity muscles, including trunk extensor, neck extensor, hip extensor, and knee extensor muscles [10]. Quadriceps muscles, as the prime drivers for knee extension are muscles that act to maintain an upright posture. Serving the same purpose, especially when restraining resistance, is the gluteus maximus muscle that acts as hip extensor [14].

Although postural balance [15, 16] and muscle strength [8, 17] are important in supporting daily physical activities, studies that investigate the association between postural balance and muscle strength [13, 18] especially in overweight and obese children aged 8-10 years are still limited. Therefore, this study aims to determine the influence of BMI on postural balance and muscle strength, as well as the relationship between postural balance and muscle strength in children aged 8-10 years.

Material and Methods:

This cross sectional study was performed on 63 children aged 8-10 years (29 boys, 34 girls). They were divided into 3 groups: BMI-normal (percentile 5-75), BMI- overweight (percentile 75-95) and BMI-obese (percentile> 95). Inclusion criteria: (1) have low level of physical activity and (2) agree to participate in the study. Exclusion criteria: (1) have postural and limb deformities, have history of neuromuscular disorders, trauma and/or surgery on the lower extremities, and have vestibular sensibility and propioception disorders, (2) using visual and movement aids, (3) feel pain on leg during examination (Visual Analog Scale-VAS> 4). This study had passed ethics protocol, stated in letter no. 705 / UN2.F1 / ETHICS / 2014.

Body Mass Index (BMI)

Body Weight (BW) was measured on the scales while wearing light weight clothing, on barefoot, with upright body position, and eyes straight ahead. Height was measured in an upright position, on barefoot, from the floor to the top of the head [19]. BMI value (kg/m^2) was calculated from weight in kilograms (kg) divided by squared height in meters (m^2). BMI data were classified into normal, overweight, and obesity according to the CDC 2000 chart for children of age group 2-20 years [4].

Single Leg Balance Test

Single leg balance test was performed on the MatScan platform (Fig.1). The MatScan was calibrated with the subject's BW. The child stood on one dominant leg while the other must not touch the standing leg or the platform. The child then had to hold this position for 10 seconds. During the test, both arms had to be kept on the sides of the body; eyes were opened and fixed ahead. The single leg balance test took place twice with an interval of 30 seconds between the two tests. Every subject made one trial and three attempts [20].

MatScan recorded the position and movement of the Center of Pressure (COP) during the standing test. The movement of COP for anterior-posterior (AP) and medial-lateral (ML) were measured. COP area (mm^2) is the quadraqular area formed by the movement of the AP and ML COP (Fig.2). Less COP area means better balance [21]. The value of single leg balance test was the mean of the COP area for three attemps measurement.

Isometric Muscle Strength Measurement

Isometric muscle strength was measured using Hand Held Dynamometer (HHD) which covered hip extensor strength and knee extensor strength. During hip extensor strength measurement: (a) subjects laid prone with hip joint in neutral position; (b) HHD was placed at the proximal popliteal fossa; and (c) subjects were asked to lift their thighs posteriorly as powerful as they can against the examiner's resistance [22]. During knee extensor strength measurement: (a) subjects sat with knee joint flexed to 90^o, (b) HHD was placed on anterior surface of leg, proximal to ankle (between two malleolus): and (c) subjects were asked to extend their knee against the examiner's resistance [23]. Each child performed one trial and three measurements with an interval 30 seconds during each measurement. Absolute isometric muscle strength values were calculated from the mean of these three measurements. Relative muscle strength was calculated by normalizing muscle strength per kg of BW.

Statistical Analysis

Data were analyzed using SPSS 20.0. Kruskal Wallis test was used to compare postural balance and muscle strength in each BMI group. Spearman correlation test was used to examine the relationship between the two variables. The statistical significance criteria was $p<0.05$.

Results:

The result of the studied variables are shown in table 1. Analysis was based on 3 BMI groups, i.e. normal, overweight, and obese. COP area in obese group (1415.57 ± 476.32) was significantly higher than normal ($p = 0.000$) and overweight ($p = 0.004$) groups. However, there was no significant difference between COP area in overweight and normal BMI groups ($p = 0.900$). These are illustrated in Fig. 3. Figure 4 shows the results of absolute hip extensor and knee extensor strength measurement, then relative muscle strength to body weight were presented in Fig. 5. Although absolute hip extensor strength of obese group was higher than overweight and normal groups, but it was not significantly different ($p = 0.527$). The absolute knee extensor strength of obese group was significantly higher than overweight and normal groups ($p = 0.003$). The relative hip extensor ($p = 0.000$) and knee extensor strength ($p = 0.000$) to body weight were lower significantly.Table 2 shows there was no correlation between hip extensor strength with COP area and between knee extensor strength with COP area for all groups.

Fig. 1: Single Leg Balance Test on MatScan

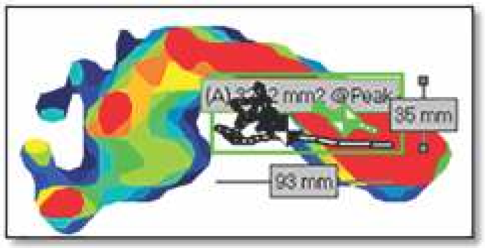


Fig. 2: Measurement of COP Area while Standing on MatScan

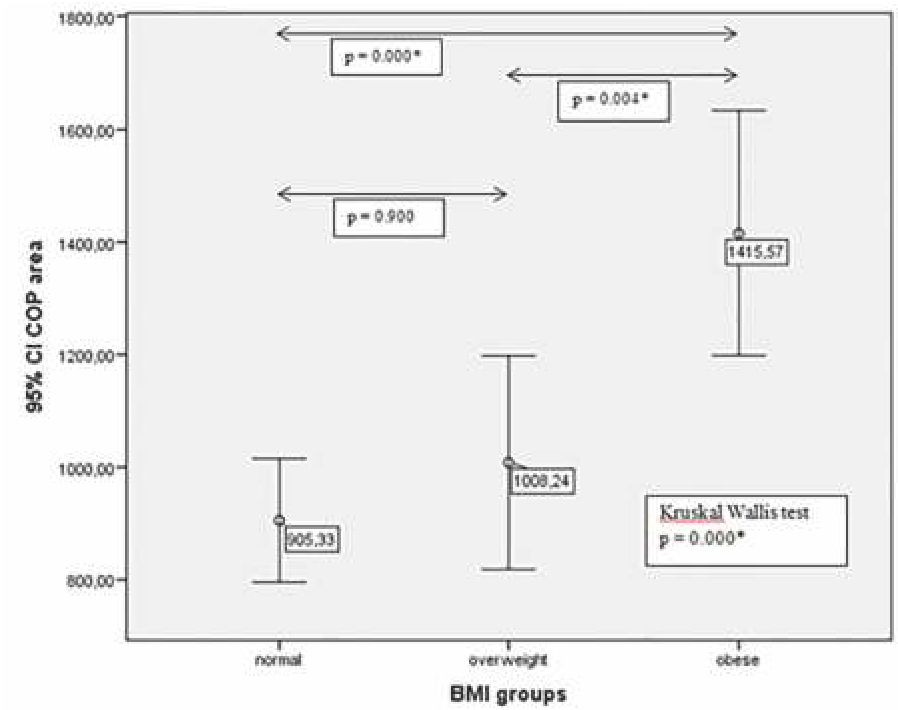
Table 1: Anthropometric and Clinical Data

Parameters	Normal	Overweight	Obese
N	21	21	21
Age (year)	9.05 ± 0.59	8.95 ± 0.67	9.38 ± 0.50
BW (kg)	28.0 ± 3.99	35.26 ± 4.54	51.96 ± 6.49
Height (cm)	131.33 ± 7.35	133.26 ± 6.20	138.49 ± 6.02
BMI (kg/m^2)	16.14 ± 1.05	19.81 ± 1.34	27.12 ± 3.31
COP area (mm^2)	905.53 ± 241.54	1008.24 ± 416.8	1415.57 ± 476.32
Hip extensor strength Absolute (N) Relative (N/kg)	 49.00 ± 8.25 1.79 ± 0.38	 52.99 ± 12.52 1.51 ± 0.34	 57.39 ± 17.95 1.09 ± 0.27
Knee extensor strength Absolute (N) Relative (N/kg)	 57.21 ± 7.76 2.07 ± 0.30	 61.22 ± 10.07 1.76 ± 0.36	 68.54 ± 12.25 1.32 ±0.25

Table 2: Relation between COP Area and Muscle Strength

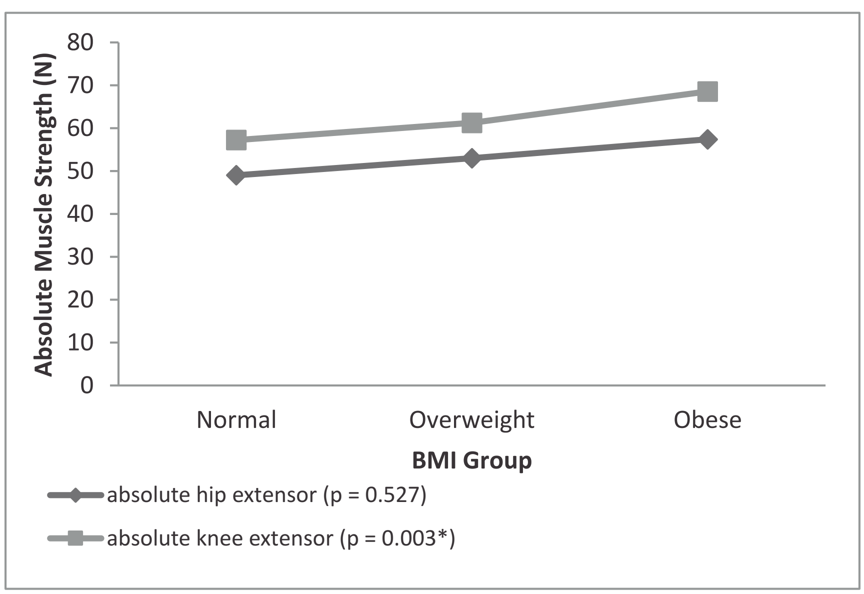
Variables	Normal		Overweight		Obese	
	r	P	r	P	r	p
Hip extensor	-0.09	0.699	0.061	0.792	0.122	0.599
Knee extensor	-0.103	0.658	0.119	0.608	0.239	0.297

**Indicates the level of significance ($p \leq 0.05$)*



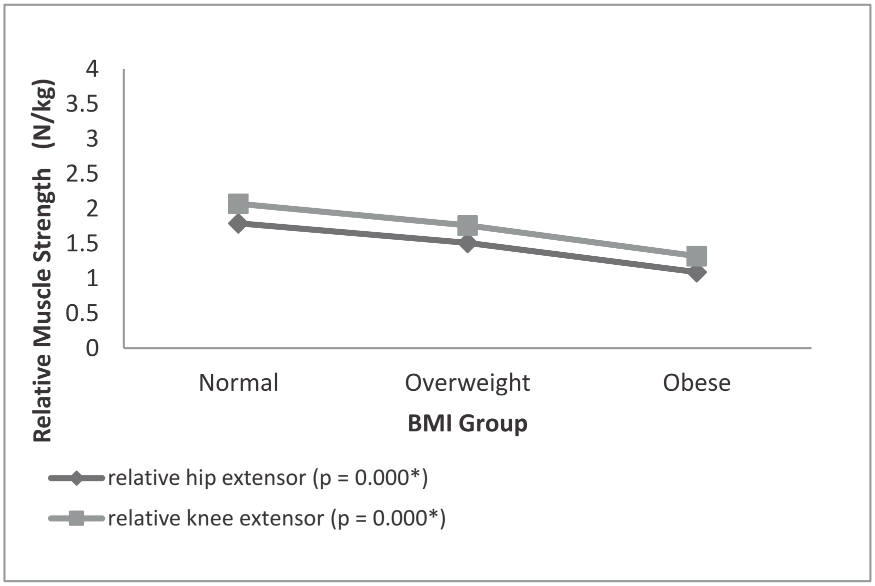
Indicates the level of significance (p≤0.05)

Fig. 3: The Comparison of COP Area Based on BMI Group



Indicates the level of significance (p≤0.05)

Fig. 4: The Comparison of Absolute Muscle Strength Based on BMI Group



*Indicates the level of significance ($p \leq 0.05$)

Fig. 5: The Comparison of Relative Muscle Strength Based per Kg of Body Weight Based on BMI Group

Discussion:

BMI on Postural Balance

The study shows that obese children have significantly larger COP area than overweight and normal children. It indicates that obese children have less ability to maintain posture while standing. This result is consistent with the study done by Wang and Chen which found that BW is an effective forecaster for estimating postural balance in children aged 9-12 years [18]. McGraw *et al*. (2000) showed a decreasing postural stability in obese prepubertal boys than non-obese while standing upright [24]. A study by Deforche *et al*. stated that overweight boys can not maintain balance longer than normal-weight boys [25].

Researchers assume that the decrease in postural balance in children with overweight and obesity is associated with the shifting Center of Gravity (COG). Corbeil *et al*. suggests that the loss of stability is detected when COP exceeds the limit of stability and when laying COG position moves more to anterior [26]. This occurs especially in obese individuals with body fat distribution in the abdominal region. These individuals are at higher risks of falling than normal-weight individuals as a result of the shifting of their COG to a more anterior position.

Balance differences in each group IMT are possible due to the differences in plantar contact area. Studies by Riddiford-Harland *et al*. and Nieto [20, 27] show increased plantar contact area in obese children. Increased plantar contact area is associated with flatfeet due to the excessive load received by the foot in long term. This relates to the contribution of mechanoreceptors in the foot that act as balance control [28]. Individuals with excess body weight are subjected to decreased sensitivity of mechanoreceptors in their foot, as indicated by a study on plantar contact area and plantar pressure on overweight and obese individuals [28].

BMI on Muscle Strength

The results show that the absolute strength of hip extensor in children with obese BMI is greater than those with overweight and normal BMI, but the difference is not significant. Results also show that absolute knee extensor strength of children with obesity is significantly greater than that of overweight and normal-weight children.

Increased BMI in children leads to increased muscle strength in the gluteal and thigh region. Changes in hip extensor strength are not significant when compared to changes in knee extensor strength. It is possibly due to the function of knee extension as a major force contributor on lower limbs for various activities such as walking, running, climbing stairs, and getting up from a seated position [14].

These results are in line with the studies by Tsiros *et al*. [29] and Maffiuleti [30] which state that obese children have greater absolute knee extensor muscle strength than normal children. Study by Rauch *et al*. (2012) of 8-18 year-old children investigated muscle strength while jumping and obtained results thatindicated increased absolute muscle strength in obese children and adolescents [31]. This result corresponds to Newton's law that the greater the body mass, the greater the inertia or resistance to a movement will be. Thus, larger external force is required. Rauch *et al*. Have suggested that obese and overweight children require greater force production according to the body mass to get the same body acceleration when performing an action (F = ma).

Nevertheless, this study shows that obese and overweight children achieved lower relative muscle strength per kg of BW significantly than normal-weight children. These results are in line with studies by Tsiros *et al*.[29] in 10-13 years old children and Abdelmoula *et al.* [32] in adolescent boys. Those studies stated that knee extensor tourque relative to body weight in obese is lower that non-obese. Isometric muscle stregth normalized for body weight consistenly reduced as BMI increased, could be support that obesity is associated with functional muscle strength deficits relative to body mass.

In other way, increasing BMI in children leads to an increase of absolute muscle strength but at the same time reduce the relative muscle strength of lower limb. The absolute strength is the force that a person can exert which importance for daily activities [32]. Whereas the decreasing functional lower limb strength relative to mass may also contributed to disability in common weight-bearing activities like walking, climbing stairs and sit-to-stand [29]. Hence, muscle strength is associated with body mass [31].

Postural Balance and Absolute Muscle Strength

This study finds no significant correlation between COP area with absolute hip extensor strength and knee extensor strength in all BMI groups. Though several studies have been conducted in children with normal weight, studies regarding the correlation between postural balance and muscle strength in obese children are still limited.

This study is in contrast to Ibrahim *et al*., which states that total stability index have strong positive correlation with muscle strength index in healthy children aged 6-10 years [13]. The study states that all trunk, upper limb, and lower limb muscles act as supports for upright stands against gravity. Study by Chou *et al.* resulted in strong correlation between leg muscles strength and balance control in healthy adult. The correlation becomes even more significant when overcoming difficult obstacles [33].

This study is also in line with Muehlbaur*et al*. [34] and Granacher and Golhofer [35] which promote no significant association between all variables of balance with static and dynamic muscle strength in normal prepubertal children. Children have greater body sway than adults, resulting in greater unstability and bigger risk of falling. While standing upright, in case of body sway to anterior or posterior, the body uses ankle strategy to maintain its position. This strategy is contributed by the gastrocnemius muscle contraction as a dominant plantarflexor [36].

Overweight and obese children have increased absolute knee extensor strength, which is the product of quadriceps femoris muscle, due to its dominant role in daily physical activities and the increased load inertia from the increasing BMI. However, knee extensor muscle shows less role in postural balance. To maintain upright standing, children tend to use ankle joint dominantly, utilizing plantar flexor contraction.

Conclusion:

The study concludes that increasing BMI signicantly decreases postural balance and increase absolute muscle strength but at the same time, it reduces the relative muscle strength in children aged 8-10 years. There is no significant correlation between the balance with hip extensor and knee extensor muscle strength. These results open up the opportunity to do further research on the relationship of muscle strength with plantar flexor posture balance in overweight and obese children. Despite the increases in both extensor muscle strength and knee extensor pelvis in obese children, these children are easily tired. Therefore, obese children need interventions such as balance training, aerobic exercise, and strength training.

Limitation of the study:

The sample size in the study is not adequate. It is required to increase sample size in further study.

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