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RESEARCH ARTICLE

EFFECT OF BODY MASS INDEX ON KNEE JOINT ALIGNMENT IN OVERWEIGHT AND OBESE CHILDREN

[1]Samah Attia El Shemy, [2]Asmaa Osama El Sayed, [3,*]Hanaa Shaker Hamdy and [4]Hassan Magdy El Barbary

[1]Professor at Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt

[2]Assistant professor at Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt

[3]Physical Therapist at El Menshawy General Hospital, Egypt

[4]Professor at Department of Orthopedics, Faculty of Medicine, Cairo University, Egypt

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ABSTRACT

Objectives: A cross sectional study was conducted to assess the knee joint alignment in overweight and obese children, compare their findings with normal weight children and to determine the relationship between body mass index and deformities of the knee joint in the 3 groups. **Methods:** 220 children from both sexes with age ranged from 8 to 12 years were participated in this study. They were classified according to body mass index into normal, overweight and obese children. The tibiofemoral and knee hyperextension angles were measured by using a computer aided design (Auto CAD) program and the intermalleolar and intercondylar distances were assessed for all children. **Results:** Statistically significant differences in tibiofemoral angle, intermalleolar distance and knee hyperextension angle were found among the 3 groups with greater values in obese children. There were significant correlations between body mass index and intermalleolar distance as well as knee hyperextension angle in overweight and obese children. Significant differences were also observed between boys and girls in tibiofemoral angle in the 3 groups. **Conclusion:** It was concluded that increased body mass index in children may lead to adverse effects on the knee joint in the form of genu valgus and recurvatum which may progress to sever deformities later in life if body mass indexis not controlled.

INTRODUCTION

Obesity is a physical condition characterized by excessive deposition or storage of fats in adipose tissue that usually results from consumption of foods in excess of physiological needs (Cole et al., 2000). Knee joint malalignment is more prevalent in overweight children and adolescents (Taylor et al., 2006)**.** Malalignment results in excessive compression of the patella in the trochlea groove. It occurs with varus or valgus knees, recurvatum, persistant femoral anteversion and compensatory external tibial torsion (Michael et al., 2010)**.** Even mild malalignment in overweight or obese children can lead to skeletal discomfort and pain (Taylor et al., 2006). Genu valgus and varus may cause shifting of the mechanical axis and joint load. Genu valgus can affect knee function, leading to patellar maltracking, overload of the lateral compartment of the knee and medial collateral ligament stress. These may further lead to pathological gait with patellar instability and activity-related pain. Similarly, genu varus can cause medial compartment overload with lateral collateral ligament laxity with a lateral thrust, subsequent knee instability and eventually pain (Schoenecker and Rich, 2006).

***Corresponding author:* Hanaa Shaker Hamdy,**

Physical therapist at El Menshawy General Hospital, Egypt.

Knee-joint mechanical loading is much worse in genu valgum as it is a predominant malalignment of the distal extremities in youth with morbid obesity (O'Malley et al., 2012)**.** Genu varum is not commonly expected among children who are obese (Guven et al., 2014)**.** Also, knee hyperextension may influence proprioception and the peak joint moments associated with joint loading (Shultz et al., 2009)**.** Longstanding deformities during childhood either knee varus or valgus can lead to growth plate damage that may progress to degenerative changes (Tanamas et al., 2009). Tibiofemoral angle (TFA) is used to describe angular deformities of the tibia or femur in the frontal plane (Kaspiris et al., 2013). Pathological angular deformities are associated with gait disturbance, joint instability and limitation of activities. These deformities may predispose to early arthritic changes in the knee joint and secondary changes in the hip and ankle joints (Wiemann et al., 2009). Development of TFA in normal children has been reported in previous studies (Mathew and Madhuri, 2013; Yoo et al., 2008) but without addressing the effect of increased body mass index (BMI) on the knee joint alignment. So, this study aimed to assess the knee joint alignment in overweight and obese children, compare their findings with normal weight children and determine the relationships between BMI and knee joint deformities.

MATERIALS AND METHODS

Subjects: Two hundred and twenty children from both sexes (119 girls and 101 boys) were participated in this study. Their ages ranged from 8 to 12 years and they were randomly selected from governmental Egyptian primary schools in Tanta city. Children were included in this study if they had BMI above 5th percentile according to BMI for age percentile (Centers for Disease Control and Prevention, 2000). They participated in noncompetitive sports and they were able to understand and follow instructions. Children were excluded if they had one or more of the following disorders; neurological disorders, congenital knee or foot deformities, developmental dislocation of the hip, or previous orthopedic surgeries. Also, children who had leg length discrepancy or BMI below 5th percentile for age were excluded. They were classified into 3 groups according to BMI percentile for age; normal group which included 60 normal weight children with BMI from 5th to less than 85th percentile, overweight group which included 80 overweight children with BMI from 85th to less than 95th percentile and obese group which included 80 obese children with BMI at 95thpercentile or greater.

Materials

A digital camera, circular markers and Auto CAD program were used to assess TFA and knee hyperextension angles. A Weighing scale and children´s BMI-percentile-for-age were used to calculate BMI and a tape measurement was used for measuring intermalleolar (IMD) and intercondylar distances (ICD). The study was conducted according to the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. It was approved by the Ethical Review Committee of Faculty of Physical Therapy, Cairo University, Egypt. (No: P.T.REC/012/001082). Approvals from the authorities of educations and school managers in Tanta city were obtained. A consent form was signed by the parents of participated children after detailed explanation of the procedures.

Procedures

The following procedures were applied systematically with each child

- Height was measured to the nearest centimeter with all participants standing without shoes against the wall.Weight was recorded to the nearest kilogram and BMI was calculated using the formula weight/height^2 where weight is in kilograms and height is in meters.
- Children were asked to be in standing position with hips and knees in full extension to determine the location of bony landmarks by palpation after asking the children to expose the lower limbs and the pelvic area.
- Circular skin markers were placed over: a) Anterior-superior iliac spines (ASIS), the center of the patella and the talus head for measuring TFA. b) Greater trochanter, lateral malleolus and the mid-lateral border of the knee joint for measuring knee hyperextension angle from the lateral view.
- A computer program (AUTO CAD) was used to measure the TFA from frontal view by drawning two straight lines; one joining the ASIS to the center of the patella and the other joining the center of the patella to the talus head. From the lateral view, knee hyperextension angle was measured by drawing two straight lines one joining the center of greater trochanter of the femur to the mid-lateral border of the knee joint and the other from mid-lateral border of the knee joint to center of the lateral malleolus.
- The intermalleolar distance was recorded as the distance between the left and right medial malleoli, measured with both knees in full extension, patellae facing exactly forward, and the medial condyles of the femur brought together with moderate firm pressure to compress excessive subcutaneous fat. The intercondylar distance was obtained from standing position by asking the child to get his or her malleoli brought together firmly. Measurement was performed using tape measurement and values were recorded in centimeters.

Statistical analysis

Data were statistically described in terms of mean standard deviation. Comparison of the mean values of measured variables between the study groups was done using one way analysis of variance (ANOVA) test with posthoc pair wise comparisons. Correlations between the measured variables were conducted using Pearson correlation coefficient. P values less than 0.05 was considered statistically significant. Statistical analysis was conducted using computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, USA) (version 22 for Microsoft Windows).

RESULTS

The descriptive characteristics of participated children were shown in table (1) with significant differences among the 3 groups regarding weight and BMI (p-value<0.05) while non-significant differences were observed regarding age and height (p-value>0.05). As shown in table (2), there were significant differences among the 3 groups in TFA, IMD and knee hyperextension angle with p value<0.05 while no significant differences were observed in ICD (p-value >0.05). Multiple pair wise comparisons revealed significant differences between obese and normal children and between overweight and obese children in TFA, IMD and knee hyperextension angle as demonstrated in table (3) with greater values in obese children.

Table (4) summarized the relationships between the measured variables. Weak positive significant correlation was observed between BMI and IMD in overweight and obese children with non significant correlation in normal children. Weak negative significant correlation was found between BMI and ICD in normal children while there was non-significant correlation in overweight children. There were weak negative significant correlations between BMI and the angle of knee hyperextension in normal children while there was weak positive correlation in overweight and obese children. Also, there were no significant correlations between BMI and TFA in the 3 groups. Moreover, weak positive significant correlation was found between IMD and TFA in normal and overweight children while moderate positive significant correlation was observed in obese children. Finally there was a moderate negative significant correlation between TFA with ICD in normal and overweight children. Comparisons between boys and girls in the 3 groups revealed significant differences in TFA and non-significant differences

Table 1. Demographic characteristics of normal, overweight and obese children

Groups	Normal (n=6o)	Overweight (n=80)	Obese (n=80)	p-value
Age(year)	9.94±1.183	9.96±1.115	9.99±1.19	0.966
Weight (kg)	30.73±6.648	39.91±6.6	51.7±10.74	0.000*
Height(cm)	136.42±8.45	136.79±8.428	138.86±7.42	0.140
BMI(Kg/m2)	16.31±1.86	21.169±1.314	26.52±3.37	0.000*

Data are presented as mean ± standard deviation, N: number, BMI: body mass index, p-value: probability value, *p value < 0.05.

Table 2. Comparison of tibiofemoral and knee hyperextension angles, inter malleolar, and inter condylar distances among the 3 groups

Variable	Normal (n=60)	Overweight (n=80)	Obese (n=80)	p-value
IMD	0.20 ± 0.58	0.59 ±0.84	2.078 ± 1.405	0.000*a
ICD	0.17 ±0.38	0.05±0.30	—	0.099b
TFA	5.97 ±2.083	6.46±1.350	7.43 ±1.621	0.000*a
Kneehyperextension angle	5.48 ± 2.95	5.7± 2.6	6.59±3	0.043*a

IMD: inter malleolar distance, ICD: inter condylar distance, TFA: tibio femoral angle, p-value: probability value, a: probability value by ANOVA, b: probability value by independent t-test, *p- value<0.05

Table 3. Pair wise comparisons between normal, overweight and obese children

Variable	Groups	Mean Difference	p-value	95% CI	
				Upper Bound	Lower Bound
TFA	Obese versus normal	1.458	0.000*	0.77	2.15
	Overweight versus normal	0.496	0.252	0.19	1.19
	Overweight versus obese	-0.962	0.001*	-1.60	-0.32
IMD	Obese versus normal	1.825	0.000*	1.395	2.254
	Overweight versus normal	0.387	0.086	0.042	0.817
	Overweight versus obese	-1.438	0.000*	-1.835	-1.040
Knee hyperextension angle	Obese versus normal	1.117	0.023*	0.157	2.077
	Overweight versus normal	0.217	0.657	-0.743	1.117
	Overweight versus obese	-0.900	0.047*	-1.789	-0.011

TFA: tibiofemoral angle, IMD: intermalleolar distance, CI: confidence interval, p-value: probability value by post hoc test, * p< 0.05 level.

Table 4. Correlations between the measured variables in normal, overweight and obese children

Variables		Normal	Overweight	Obese
BMI and IMD	r- value	0.23	0.233	0.39
	p- value	0.06	0.038*	0.000*
BMI and ICD	r- value	-0.35	0.164	—
	p- value	0.00*	0.147	—
BMI and knee hyperextension angle	r- value	-0.268	0.286	0.31
	p- value	0.03*	0.010*	0.005*
BMI and TFA	r- value	0.214	-0.150	0.048
	p- value	0.101	0.185	0.670
TFA and IMD	r- value	0.315	0.378	0.522
	p- value	0.014*	0.001*	0.000*
TFA and ICD	r- value	-0.522	-0.542	—
	p- value	0.000*	0.000*	—

BMI: body mass index, IMD: intermalleolar distance, ICD: Intercondylar distance, TFA: tibiofemoral angle, P-value: probability value, r-value: Person correlation co-efficient, * p< 0.05.

Table 5. Gender differences between boys and girls in the measured variables in the 3 groups

Variables		Normal		Overweight		Obese	
		Boys	Girls	Boys	Girls	Boys	Girls
TFA	$\overline{X}$ ±SD	4.9±1.83	7.03±1.85	5.72±1.34	7.07±1.02	6.87±1.81	7.76±1.41
	p-value	0.000		0.000*		0.016*	
IMD	$\overline{X}$ ±SD	0.18±0.5	0.22±0.59	0.39±0.77	0.75±0.87	2.05±1.78	2.01±1.26
	p-value	0.809		0.062		0.919	
Knee hyperextension angle	$\overline{X}$ ±SD	6.03±2.67	4.93±3.15	6.25±2.7	5.25±2.49	6.49±2.67	6.69±3.26
	p-value	0.15		0.092		0.67	
ICD	$\overline{X}$ ±SD	0.27±0.46	0.07±0.26	—		_	
	p-value	0.041*					

TFA: tibiofemoral angle, IMD: intermalleolar distance, ICD: intercondylar distance, $\overline{X}$: mean, SD: standard deviation, p-value: probability value by independent t- test, * p< 0 .05.

in IMD and knee hyperextension angle. Also, a significant difference in ICD was observed in normal children as demonstrated in table (5).

DISCUSSION

Malalignment of the knee joint can result in excessive loading on its structures including; menisci, ligaments, or cartilage. Associated changes to these structures, as a result of abnormal stress, can be detrimental to the integrity of knee joint (Hunter et al., 2009). This study aimed to assess the knee joint alignment in overweight and obese children, compare their findings with normal weight children and determine the relationships between BMI and deformities of the knee joint. The results of this study revealed that there were significant differences among the 3 groups in TFA, IMD and angle of knee hyperextension with non-significant differences in ICD. Positive significant correlations were found between TFA and IMD in the 3 groups, between BMI and IMD and knee hyperextension angle in overweight and obese children. Negative significant correlations were observed between BMI and ICD and knee hyperextension angle in normal children, between TFA and ICD in normal and overweight children and a non significant correlation between BMI and TFA in the 3 groups. Significant differences were found between boys and girls in TFA and ICD with non-significant differences in IMD and knee hyperextension angle.

The primary finding of this study revealed a significant difference in TFA among normal, overweight and obese children with greater values in obese children. This comes in agreement with the results of Shultez et al. (2014) who study the effect of acute loads on gait kinetics in forty obese children aged 8 to 12 years old. They found that these children had more adducted and internally rotated hip combined with an externally rotated knee and abducted foot. Furthermore, they added that the combination of these malalignments indicate that obese children move with their knees spaced closer together and their feet spaced farther apart, thus maintaining a genu valgum position throughout functional movement. Additionally, Bonet Serra et al. (2003) and Taylor et al. (2006) found that the incidence of genu valgum was greater in overweight children than in non-overweight group. Similarly**,** De Sa pinto et al. (2006) found a higher frequency of genu valgum, commonly called 'knock-knee' (55.1%) in obese children compared with normal-weight children (2%). Martinelli et al. (2011) also found that the prevalence of genu valgum was 87% among overweight children of both sexes aged 5 to 9 years.

According to the results of this study, there were significant differences in IMD among the 3 groups. Weak positive significant correlation was observed between BMI and IMD in overweight and obese children, as the BMI increase, the IMD increase, but in normal children, there was no significant correlation. These findings come in agreement with Bonet Serra et al. (2003) who stated that the incidence of increased IMD was greater in overweight children than in non-overweight group. They confirmed that there was a positive correlation between the IMD and the BMI in overweight group, also Cahujaz et al. (1995) and Arazi et al. (2001) observed the largest IMDs in overweight children suggesting that this could possibly be due to differences in soft-tissue thickness at the knees. There were positive significant correlations between TFA and IMD in the 3 groups, as the IMD increase, the TFA also increase. This finding agrees with the results of Mathew and Madhuri (2013) and Baruah et al. (2017) who found a significant positive correlation between the IMD and the TFA. The results of the present study revealed that there is no significant correlation between TFA and BMI. This come in consistent with Kaspiris et al. (2013) who found non-significant negative correlation between TFA and BMI in Greek children and disagree with Bafor et al. (2012) who found a negative correlation between TFA and BMI in a study of 471 Nigerian elementary school children aged 3 to 10 years. They explained that axial loading, as represented by BMI, does not contribute to the increasing magnitude of knee angles in normal, healthy-weight children, but it may not necessarily be the case with overweight children. Also Baruah et al. (2017) found weak negative significant correlation between TFA and BMI**.** Felson et al. (2004) stated that elevated BMI increases the risk of knee deformities progression. According to the results of this study, a significant difference was observed among the 3 groups in the knee hyperextesion angle with greater values in obese children. Also, there was a positive significant correlation in overweight and obese children. These finding agrees with the results of De Sa pinto et al. (2006) who found a higher frequency of knee hyperextension (24.2%) in obese children compared with the control group of normal-weight children (2%). They highlight a serious risk to the skeletal system of a child who is either overweight or obese and the pain associated with musculoskeletal dysfunction and deformity.

The results of the present study revealed that there was a non significant difference in ICD between normal and overweight children with greater values in normal children. Moreover, there was a moderate negative significant correlation between TFA and ICD in normal and overweight children, as the TFA decrease, the ICD increase. This finding agrees with Maduka et al. (2017) who found a negative significant correlation between TFA and ICD in a study of 1775 children aged 3 to 17 years. There was a weak negative significant correlation between BMI and ICD in normal children and a non significant correlation in overweight children, as the BMI decrease, the ICD increase. These findings come in agreement with Fakoor et al. (2009) who found that the intercondylar distance was greater in normal children and no relation was found in overweight children and obese children.

A significant difference was found between boys and girls in TFA as girls had greater TFA than boys in the 3 groups. This finding comes in agreement with Oginni et al. (2004) who reported that the TFA of normal girls was more than boys by about 1° at ages from 8 to 12 years. Similarly**,** Yoo et al. (2008) found significant differences between normal boys and girls at the age of 12 years. Sainni et al. (2010) also reported that the normal Indian girls had statistically significant more knee valgus than boys. Mathew and Madhuri (2013) stated that normal girls had a greater valgus angle than boys. Sex differences in lower extremity alignment could occur because females had greater anterior pelvic tilt, thigh internal rotation and wide pelvis than boys (Nguyen and Shultz 2007). This finding disagrees with Rahman and Badahdah (2011) who revealed a non-significant difference in TFA between boys and girls at age 8 to 12 years in a study of 300 of normal children in Saudi, also Fakoor et al. (2009), Martenlli et al. (2011) and Baruah et al. (2017) found no significant differences between the TFA in normal girls and boys. Moreover, there were significant differences between boys and girls in ICD in normal children, the boys had ICD more than girls in normal children. This comes in agreement with Fakoor et al. (2009) who found a significant difference between both sexes for ICD. Also, Cahuzac et al. (1995) found that European boys between 10 to 16 years were more bow-legged than girls. Furthermore, there were non-significant difference in IMD between boys and girls in the 3 groups. This finding disagrees with Fakoor et al. (2009) and Arazi et al. (2001) who found significant differences in IMD between both sexes.

Limitations: The limitation of this study includes small sample size, which makes it difficult to make generalization of the results. Therefore, further study with a large sample size is necessary to generalize these findings. Future studies are needed to investigate how controlled BMI could improve knee joint alignment in overweight and obese children.

Conclusion

From the obtained results of this study, it could be concluded that uncontrolled obesity during childhood could lead to knee deformities in the form of genu valgus and genu recervatum which may progress later in life and need intense medical or surgical interventions.

Conflict of Interest: The authors reported no conflict of interest.

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