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Influence of obesity on proprioception of knee and ankle joints in obese prepubertal children

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Purpose
The aim of this study was to investigate the effect of obesity on proprioception of knee and ankle joints in obese prepubertal children.

Participants and methods
Forty-two prepubertal children of both sexes ranging in age from 8 to 12 years participated in this study. Among these children, there were 21 obese children, with BMI 30–35 kg/m^2, and 21 normal-weight child, with BMI 18–25 kg/m^2.The active angle repositioning test was used to assess the proprioception of the knee joint at 45° flexion and the ankle joint at 30° planter flexion using the Biodex System 3 pro isokinetic dynamometer.

Results
The statistical analysis showed that there was a significant increase in the repositioning error of the knee joint in obese children compared with normal-weight children as the mean values of repositioning errors were 6.35±1.2 for obese children and 3.91±0.98 for normal-weight children (P=0.0001), whereas there was no significant difference in proprioception of the ankle joint as the mean values of repositioning errors were 4.69±0.79 for obese children and 4.3±1.02 for normal-weight children (P=0.13).

Conclusion
Obese prepubertal children showed a decline in proprioception of the knee joint, which might be an important contributing factor toward the decreased postural control capacity in obese children as reported in the previously published works, because proprioceptive function is one of the most important components that contributes toward postural stability.

Keywords:
ankle proprioception, childhood obesity, knee proprioception

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Introduction

The incidence of overweight and obesity among children and adolescent has increased markedly in many parts of the world [1], and evidence indicates that obesity significantly accompanied with low levels of physical activity [2] and other clinical sequences including low-grade systemic inflammation, and various musculoskeletal disorders [3]. In addition, overweight or obesity particularly in childhood can result in a range of functional problems, including joint stiffness and pain (especially in the lower limb), muscle weakness, and postural deformities, which can affect postural control capacity and movement ability; this is because the childhood period is the most important period in growth and development [4].

Proprioception is a complex sense contributing to muscle sense, joint stability, and postural equilibrium. This occurs through mechanoreceptors located in the muscles, ligaments, tendons, joint capsules, and skin [5]. Thus, proprioception has been defined as an individual's ability to integrate the sensory signals from various mechanoreceptors to thereby determine body position and movements in space [6,7]. It is widely believed that during daily activities as well as during sports, the proprioceptive inputs are very important for normal individuals because it plays an essential role in the precise movement of joints to prevent excessive range of motion and joint damage through the proprioceptive reflex [8,9]. Thus, assessment of proprioceptive sensibility is valuable for the identification of any proprioceptive deficits that may be a major risk factor for recurrent injuries even after the restoration of injured muscles and ligaments [10].

Over the last 10 years, there has been greater emphasis on research on proprioception, focusing on various anatomical areas, but most commonly on the knee and the ankle joints. This is because both the knee and ankle joints play an important role in the integrity of the lower extremities' kinematics chain and any alternations in the proprioceptive awareness of these joints may have major effects on performance [11]. During locomotion, the major joints of the lower limb of normal-weight individuals are subjected to reaction forces about 3–6 times the body weight; consequently, the weight-bearing joints of obese individuals are exposed to greater absolute loads than normal-weight individuals [12]. In a study carried out by DeVita and Hortobagyi [13] to investigate the knee joint torques and power generated by obese participants during walking, they found that when participants walked at an identical speed, the obese participants showed a reduction in the knee extensor torques compared with normal-weight participants; they concluded that, during walking, the obese participants tend to reorganize their neuromuscular function to decrease the load on the knee joint. Therefore, the question raised is whether the greater loading will affect the functions of the proprioceptors in the knee and ankle joints in obese individuals.

Proprioceptors play an important role in dynamic joint stability and balance control [14,15]. Studies carried out on postural control of obese children have reported that postural stability and motor activity were decreased in obese children compared with nonobese children [16]. McGraw *et al.* [17] studied the static postural stability in obese and nonobese prepubertal boys in two postures with two standardized foot positions (normal and tandem). They reported that there were significant differences in measures of postural stability between obese and nonobese boys in both anterior–posterior and medial–lateral directions, with the most significant difference in the measurements reported in the medial–lateral direction, and they concluded that postural stability in obese boys was diminished. Also, in a study carried out by Hills and Parker [18] to compare the gait pattern of 10 obese children and 10 nonobese children at three different walking speeds (normal, slow, and fast), it was found that the obese participants showed longer cycle duration, lower cadence, lower relative velocity, and longer stance period than the normal-weight participants at all speeds. They suggested that the extended periods of support observed in obese children were indicative of underlying postural instability.

The need for this study emerged from impaired postural control in obese children, which has been reported in the previous clinical studies; proprioception is one of the most important components of the sensorimotor system that contributes to postural control. There is a gap in knowledge of the extent to which the proprioceptors of the knee and ankle joints can be influenced by the greater loading in obese children. Thus, the aim of this study was to investigate the effect of obesity on proprioception of knee and ankle joints in obese prepubertal children.

Study sample

This study was carried out in the isokinetic laboratory of the Faculty of Physical Therapy, Cairo University, from April 2017 to June 2017. Forty-two prepubertal children of both sexes ranging in age from 8 to 12 years were recruited from the primary schools to participate in this study. Weight and height for each child were measured; then, according to the child's BMI, he/she was included in one of two groups: Group A included 21 normal-weight children (11 boys and 10 girls), with BMI 18–25 kg/m^2, and group B included 21 obese children (11 boys and 10 girls), with BMI 30–35 kg/m^2. Some studies have reported that although there has been no evidence to recommended a specific criterion in defining obesity in children, it was recommended that BMI should be the standard measure for children [19,20]. All children were chosen on the basis of their willingness to participate in the study and they were excluded if they had any history of neuromuscular, musculoskeletal, or vestibular system disorders, any traumatic conditions, or had undergone previous surgery of the lower limbs, leg-length discrepancy, any sensory problems, or flat foot. Before participating in the study, all children and their parents signed an institutionally approved informed consent form that was approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University (PT REC/012/001584).

Sample size

The sample size of the current study was 42 children on the basis of Cohen's medium effect size 0.25 at F tests multivariate analysis of variance (MANOVA) with power 80 % and probability 0.05.

Design of the study

This was a between-subject cross-sectional study that included one independent variable (tested group) and two measured dependent variables (absolute angular errors of repositioning accuracy of knee and ankle joints). Repositioning accuracies of the knee and ankle joints for both groups were assessed for only the right lower extremity of each child to facilitate the testing setup and because previous studies reported no proprioceptive differences between dominant and nondominant extremities [21]. The active repositioning test for knee joint was performed to examine the ability of children to actively reproduce a preset angle (45°) knee flexion; this angle is believed to be in the working range of the knee during daily weight-bearing activities [21], whereas the active repositioning test for ankle joint was carried out to examine the ability of children to actively reproduce a preset angle (30°) ankle planter flexion. This particular angle is chosen because it is commonly used in the relevant literature [22]. The measurement velocity during the test was set at 60°/s for the knee joint [23] and 30°/s for the ankle joint [24].

Instrumentation

Biodex System 3 proisokinetic dynamometer

A Biodex System 3 promultijoint system isokinetic dynamometer (Biodex Medical Inc., Shirley, New York, USA) was used to measure the proprioception accuracy of the knee and ankle joints. The Biodex isokinetic dynamometer had been found to be a valid and reliable device for position measurements [25].

Weight and height scale

Weight and height scales were used to measure the participants' weight and height to calculate the BMI for each child.

Procedures

At first, the weight and height for each child were measured, and then before testing, each child performed two familiarization trials with the test procedures for each joint [26]. Each child participated in two assessment sessions: the first session involved measurement of the knee joint active repositioning test and, after a brief rest period of 15 min, we started the second session, which involved measurement of the ankle joint active repositioning test. During the entire assessment, the child was blind folded to eliminate any visual feedback [27] and auditory input was limited by keeping the room silent during the test. The test was repeated three times, with a rest period of 30 s. between trials. The angular difference between the targeted angular position and the participant's perceived end-range position (absolute angular error) was recorded in degrees. The average of the three trials was calculated and used in the statistical analysis [28].

Knee active repositioning accuracy test

Each child was asked to sit on the chair of the Biodex System in an upright sitting position (back at ~80°) and the knee of the tested extremity was aligned with the axis of the dynamometer and positioned in 90° flexion (the starting position); then, the child was stabilized by straps around the trunk, pelvis, and thigh, and the tibial pad was secured to the shank 3 cm proximal to the lateral malleolus as shown in Fig. 1. During the test procedure, the children were asked to wear shorts to negate any external skin sensation from any clothing at the knee area. Initially, the anatomical reference angle was set at 45° of knee flexion and then the child's leg was returned to 90° flexion. Subsequently, the child actively moved the limb to the target angle of 45°flexion, and then the leg was held for 10 s as a teaching process and enabled the child to memorize the target position; afterward, the limb was allowed to return to the starting position by the apparatus. After a 5 s rest, the examiner pressed the start key and the main test was initiated by asking the child to move his/her limb to the target angle (45°) actively and when the child felt that he/she reached the target angle, he/she would stop the apparatus using the hold/release button, and at that time, the child was not permitted to modify the obtained angle [29,30].

Ankle active repositioning accuracy test

Each child was seated on the dynamometer chair in a relaxed position with the hip joint slightly flexed and the knee flexed about 45° so that the fulcrum of the dynamometer corresponded to the axis of the participant's ankle joint with the foot resting on the ankle attachment in a neutral position between dorsi flexion and planter flexion; standard toe straps were used over the foot. Also, two straps were wrapped around the extremity proximal to the patella and the pelvis to minimize movements of the trunk, hip, and knee during testing, which would interfere with the ankle measurement as shown in Fig. 2. Initially, during the testing procedure, the anatomical reference angle was set at 30° of ankle planter flexion, and then the child's foot was returned to the neutral position; after that, the child actively moved the limb to the target angle of 30° planter flexion and then the foot was held for 10 s as a teaching process and enabled the child to

Figure 1

Measurement of knee joint proprioception.

memorize the target position. Afterward, the foot was allowed to return to the starting position by the apparatus. After a 5 s rest, the examiner pressed the start key and the main test was initiated by asking the child to move his/her foot to the target angle (30°) planter flexion actively and when the child felt that he/she had reached the target angle actively, he/she would stop the apparatus using the hold/release button and then the participant was not permitted to modify the obtained angle.

Statistical analysis

All statistical tests were performed using the statistical package for the social sciences (SPSS) version 19 for Windows (IBM, Chicago, Illinois, USA). The Shapiro–Wilk test was carried out to test the normal distribution of data. Descriptive statistics and *t*-test were carried out for comparison of participants' characteristics between both groups. One-way MANOVA was carried out to investigate the effect of obesity on the active repositioning accuracy of knee and ankle joints. The level of significance for all statistical tests was set at *P* value of less than 0.05.

Figure 2

Measurement of ankle joint proprioception.

Results

Normal distribution of data

The normality of data for each dependent variable was tested using the Shapiro–Wilk test and the results showed that there was no significant deviation from normal distribution for all variables in both groups ($P>0.05$).

Participantcharacteristics

There was no significant difference between both groups in the mean age ($P=0.63$), whereas there was a significant increase in the mean BMI of group B compared with that of group A ($P=0.0001$) as shown in Table 1.

Active repositioning error between the control and study groups

The MANOVA identified a significant group effect [Wilks' $\lambda=0.39$; $F_{(2, 47)}=35.49$; $P=0.0001$]. As shown in Table 2, there was a significant increase in the active repositioning error of the knee joint in group B compared with that of group A ($P=0.0001$), whereas there was no significant difference in the active repositioning error of the ankle joint between both groups ($P=0.13$).

Discussion

The results of the current study suggest that obese prepubertal children show decreased knee joint proprioception function as there was a significant increase in the active repositioning error of the knee joint in obese children compared with that of normal-weight children ($P=0.0001$). However, there was no significant effect of obesity on proprioception of the ankle joint.

The current findings are in agreement with those of a study carried out by Moravveji *et al.* [28] to evaluate the proprioception of the knee joint in obese athletes and nonobese athletes, and they found that the obese group had poorer proprioception acuity in the knee joint

Table 1 Comparison of the mean age and BMI between both groups

	Group A (mean±SD)	Group B (mean±SD)	MD	*t*-Value	*P*-value
Age (years)	10.08±1.49	9.88±1.45	0.2	0.47	0.63
BMI (kg/m^2)	21.66±0.98	31.45±0.7	−9.79	−40.37	0.0001**

**Signifcant.

Table 2 One-way multivariate analysis of variance for the active repositioning error between both groups

	Group A (mean±SD)	Group B (mean±SD)	MD	*F*-value	*P*-value
Active repositioning error					
Knee	3.91±0.98	6.35±1.2	−2.44	61.04	0.0001**
Ankle	4.3±1.02	4.69±0.79	−0.39	2.25	0.13

**Signifcant.

movement than the nonobese group. Thus, according to the result of our study and their study, we can suggest that obesity has an effect on the proprioception of the knee joint because parallel to the poorer proprioception acuity reported in obese adults, there is a decline in the proprioception function of knee movement in obese children.

Appropriate muscle strength is essential to ease the loading of joints and it is believed that in individuals who are overweight, the dampening capability of muscles is impaired because of muscle weakness and the resistance offered by body weight, thus increasing the rate of joint loading [31]. Also, according to the result reported by Blimkie *et al.* [32], the muscular strength per mass ratio decreased with increasing BMI. This reduction in muscle strength may be associated with poor proprioception [33] as proprioceptors provide the central nervous system feedback about the rate, degree, and the amount of stretch and contractile force of muscles [34]. Thus, the effect of obesity on muscle strength as reported in previously published works may be an explanation for the higher reduction in the knee repositioning accuracy in obese children than normal-weight children in the current study.

Mechanoreceptors are sensory receptors present across the surface of chondrocytes, and evidence indicates that mechanical overload and joint stress from excessive body mass lead to activation of these mechanoreceptors and this consequently promotes cartilage damage, subchondral bone hypertrophy, and osteophyte formation, and results in progression of knee joint degeneration [35,36]. This was confirmed by Anderson and Felson [37], who reported that women with BMI of 30–35 kg/m^2 are more likely to be exposed to knee osteoarthritis than women with BMI of 18–25 knee osteoarthritis, and they stated that joint overstressing resulting from overweight and obesity increases the rate of knee osteoarthritis. Therefore, the decline in proprioception of the knee joint in obese children in the current study may be because of overstressing and undue loading of the knee joint, which might become a mechanical stimulus for the proprioceptors in the joint ligaments, tendons, and capsule.

Proprioception plays a fundamental role in maintaining joint stabilization and postural stability during both static and dynamic activities [38]. Numerous clinical researchers have shown that individuals with proprioception and neuromuscular response deficits are less capable of maintaining postural stability and equilibrium [39–41], whereas other several studies that were carried out on the postural control of obese prepubertal children have shown that the postural stability is decreased either during walking or standing or different static positions, and suggested that the dynamic postural stability of obese prepubertal boys is affected by their larger body mass [17,18]; however, on the basis of findings of the current study, we can suggest that the decline in proprioception of obese children may be a critical contributing factor to the change in their postural control capacity as reported in the previously published works and the decreased postural control capacity in obese children may not only be related to their excess body weight but may also be a result of alternation in their proprioception. Therefore, according to the results of the present study, we can provide an important recommendation to physical therapists and trainers that they design an exercise program that would consider proprioception training to improve the proprioceptors of the knee joint of obese children.

Limitation of the study

This study was limited only to obese prepubetal children; thus, further research should be carried out on different age groups.

Conclusion

Obese prepubertal children showed poorer proprioception in knee flexion movement, and this alternation in the proprioception might be one of the reasons leading to the decreased postural control capacity in obese prepubertal children found by previously published works.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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