Sex differences of knee joint repositioning accuracy in healthy adolescents

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Introduction

Sex differences in the knee joint have long been known and impaired proprioceptive accuracy is an important risk factor that could be associated with knee joint injury. This study was conducted to compare the accuracy of knee repositioning between healthy male and female adolescents.

Participants and methods

A total of 64 healthy adolescents (32 males, 32 females) aging from 15 to 18 years participated in this study. Active angle repositioning test was used to assess the proprioceptive accuracy of the right knee joint at 45° knee flexion by using a Biodex system 3 pro-isokinetic dynamometer.

Results

The statistical analysis revealed that the repositioning accuracy of the knee joint was significantly lower in female participants than in males, as the mean values of repositioning errors were 3.54±1.20 for males and 4.76±1.29 for females ($P <$ 0.05).

Conclusion

Sex-based difference in the accuracy of knee joint proprioception may imply that knee proprioceptive sensitivity might potentially contribute to the high incidence of knee injury in females compared with males, particularly during adolescence.

Keywords:
Biodex isokinetic system, healthy participants, knee joint, proprioception, sex

Introduction

Proprioception is defined as the input information responsible for limb awareness, position, force, and heaviness, which is received from muscle spindles, joint receptors, cutaneous receptors, and Golgi tendon organs through peripheral afferent impulses, thus leading to perception of the joint position and movement [1–3].

Proprioceptive inputs are very important for normal individuals during daily activities as well as during sports. It plays an important role in the complex process of coordination and in the precise movement of joints to prevent joint damage and excessive range of motion through the proprioceptive reflex. In addition, it mediates the deep sensation required to stabilize joints within the body during static positions and dynamic movements. Therefore, proprioceptive rehabilitation constitutes the basic element for neuromuscular and coordination training plans [4–6].

Knee joint is highly susceptible to injuries [7]. Alteration of normal neuromuscular function is one of the main causes that contributes to knee injuries, which leads to weakness and atrophy of the quadriceps muscle group [7,8]. One of the factors responsible for this atrophy is arthrogenic muscle inhibition, a process in which the ongoing neural inhibition prevents the quadriceps from being fully activated [9].

There are several factors that may contribute to activation failure such as swelling [10], pain [11], inflammation [12], and damage to joint receptors [13]. For these reasons, restoration of neuromuscular function (proprioception) represents a fundamental aim of postinjury rehabilitation. Neuromuscular patterns in males and females differ during maturation as males demonstrate maturational changes including increase in power, strength, and coordination, whereas females change little throughout maturation [14].

Studies have examined sex-based differences of the knee joint in terms of cartilage thickness, volume, and articular surface areas as potential causes for increasing incidence of female knee injuries [15]. However, there is a gap in the literature concerning sex differences in the knee joint proprioception. Although biomechanical and hormonal differences between males and females are suspected to be

responsible for increasing this incidence, the exact cause is still unknown [16].

The purpose of this study was to compare the repositioning accuracy of the knee joint between healthy male and female adolescents, which may provide an understanding of the potential causes for increased incidence of knee injuries among females compared with their male counterparts.

Participants and methods

Participants

Individuals with history of knee pain, knee musculoskeletal deformities, and regularly performing athletic activities were excluded from the study. The age range was 15–18 years and the BMI ranged from 20 to 25kg/m^2. In total, 64 healthy adolescents participated in this study (32 males and 32 females). Participants were recruited from the secondary schools and students of Faculty of Physical Therapy, Cairo University. All participants signed a written consent. The study was approved by the ethical committee of the Faculty of Physical Therapy.

Study design

An ex post-facto design was implemented for the current study. Absolute angular error of repositioning accuracy was the dependent variable, whereas sex was the independent variable. Repositioning accuracy was assessed for only the right lower extremity of each participant to facilitate the testing setup and because previous studies have shown that no proprioceptive differences exist between dominant and nondominant extremities [17]. The active repositioning test was carried out to examine the ability of participants to actively reproduce a preset angle (45°) at which the joint had been placed in a non-weight-bearing position. Movement velocity was set at 60°/s and the anatomical reference angle was set at 45°. Three trials were recorded for each participant.

Instrumentation

A Biodex system 3 pro-isokinetic dynamometer (Biodex Medical Inc., Shirley, New York, USA) was used for measuring the active knee repositioning accuracy.

Procedures

Measurement procedure

Each participant was asked to sit on the chair of the Biodex system with the knee of the tested extremity aligned with the axis of the dynamometer and positioned in 90° flexion (the starting position). The participant was then stabilized by straps around the trunk, pelvis, and thigh. The tibial pad was secured to the shank 3 cm proximal to the lateral malleolus [18].

Pretesting and familiarization

Before data collection, each participant underwent two familiarization trials, first with the eyes closed as the tested extremity was allowed to passively move to the target angle (45°) [18], and then, it was held for 10 s as a teaching process for the participant so that he or she could memorize the position. The limb was then allowed to return to the starting position by the apparatus [19].

Knee repositioning accuracy test

After a 5-sec. rest, the lower leg was passively moved to 45° of knee flexion. The limb was held at this angle for 10 s and then passively returned to the starting point. The participant was instructed to actively replicate the same joint angle. When the participant felt that the target angle had been reached actively, he/she would stop the apparatus using the hold/release button, and then the participant was not permitted to correct the angle [18,20]. The test was repeated three times with a rest period of 30 sec. 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 for statistical analysis. The participant was asked to close the eyes during the testing procedures to eliminate visual feedback [21] (Fig. 1).

Statistical analysis

Statistical analysis of the data was carried out using the mini tab software for medical statistics version 15 (Inc.,

FIGURE 1

Knee active repositioning accuracy test.

Chicago, Illinois, USA). Unpaired *t*-test was used to compare the sample's age and BMI between males and females. The same test was also used to compare the knee repositioning accuracy between males and females. The significance level was set at *P*-value less than 0.05.

Results

Participants characteristics

The study sample consisted of 64 healthy individuals divided equally into two groups of males and females. The males group had a mean age and BMI of 16.69 ± 1.31 years and $22.99 \pm 1.54 \, \text{kg/m}^2$, respectively. The females group had a mean age and BMI of 17.13 ± 1.01 years and $22.45 \pm 1.72 \, \text{kg/m}^2$, respectively. The unpaired *t*-test proved that there was no significant difference between their ages ($P=0.14$) and BMI values ($P=0.19$). Demographic characteristics are presented in Table 1.

Table 2 demonstrates the knee repositioning error measurements for the study groups. There was a significant difference ($P<0.001$) in the knee joint repositioning errors between males and females. The mean $\pm$ SD values for males and females were 3.54 ± 1.20 and 4.76 ± 1.29, respectively.

Discussion

This study was conducted to compare the accuracy of knee repositioning between healthy male and female adolescents, which was measured using a Biodex system 3 pro-isokinetic dynamometer. The results showed that knee repositioning errors were greater in females than in males at 45° of knee flexion ($P<0.05$).

The higher reduction in the knee repositioning accuracy in females compared with males may be explained by one of the following mechanisms. First, the muscles, tendons, ligaments, and capsules have estrogen receptors, which are responsive to female sex hormones [14]. Increased estradiol concentrations decrease collagen synthesis and fibroblast proliferation as estrogen has measurable direct effects on soft tissue strength, muscle function, collagen metabolism, and behavior. This mechanism could have indirect effect on the neuromuscular system, which controls the proprioception awareness [22–24].

Second, females have different biomechanics, gait, structural, and morphological properties of tendons and ligaments from males [25,26]. A female's anterior cruciate ligament is smaller in size than that of males [27]. Females also have smaller cartilage volumes than do males, where the percentage difference ranges from 19.9% in the patella to 46.6% in the medial tibia. Therefore, the number of knee joint receptors could possibly be lesser in females than in males [28].

To the best of our knowledge, sex-based differences in knee proprioception have not been previously examined; however, other joints have also been examined. The current findings go in line with those of a study by Nagai *et al.*[29], who examined sex differences in knee internal/external rotation proprioception measurements; it was found that women demonstrated more diminished threshold of passive motion detection toward internal rotation as compared with men.

On the other hand, our findings do not agree with those of Schmidt *et al.*[30] who compared arm position sense between different ages, sexes, and arms. They have stated that they did not find sex-specific difference in arm position sense, and that this result contradicted the widely shared assumption that males have better spatial skills as compared with females. Limb position sense imposes demands on the proprioceptive system in the personal space and might require the same underlying cognitive abilities in males and females that activate the same type of processes for solving the task in both sexes, explaining the lack of any sex effects in arm position sense [30].

The findings of this study were in disagreement with those of Vafadar *et al.*[31], who examined 28 healthy individuals (14 females and 14 males) for absolute repositioning error of the shoulder joint and found that there was no significant difference between men

Table 1 Demographic data of participants

Points of comparison	Male ($n=32$)	Female ($n=32$)
Age (years)		
Mean ± SD	16.69 ± 1.31	17.13 ± 1.01
t-Value	−1.50	
P-value	0.139	
BMI		
Mean ± SD	22.99 ± 1.54	22.45 ± 1.72
t-Value	1.33	
P-value	0.187	

Table 2 Knee repositioning error measurements for study groups

Knee joint repositioning error	Male ($n=32$)	Female ($n=32$)
Mean ± SD (deg.)	3.54 ± 1.20	4.76 ± 1.29
t-Value	−3.92	
P-value	<0.001	

and women. Moreover, Artz et al.[32] examined 40 healthy volunteers aged 19–59 years for repositioning errors in upright and flexed neck postures during tests performed in 25, 50, and 75% cervical flexion; none of these measures were influenced by sex.

Limitation of study
This study was limited by its small sample size, because of which we could not generalize the results. Moreover, only adolescents were included in the study. Further research should be carried out with a larger sample size, on different age groups, and also using different angles to achieve better understanding of sex differences in knee proprioception.

Conclusion
On the basis of the finding of this study, female knee proprioception is statistically less accurate compared with male healthy adolescents, and this may imply that knee proprioceptive sensitivity might potentially contribute to the high incidence of knee injury in females compared with males, particularly during adolescence. Exploring possible sex differences in proprioception can increase our knowledge about sex differences in mechanisms of knee injury, assist clinicians in developing more effective knee injury interventions programs by focusing on proprioception training during rehabilitation especially for females, and provide scientists a framework for answering important questions related to knee injuries, prevention, and treatment.

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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