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Proprioception of Knee Joint in Athletes and Non-Athletes Obese

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Abstract

Background: Proprioception plays an integral role in the neuromotor control of the knee joint. The objective of this study was to evaluate the relationship of knee joint proprioception deficit and regular exercise activities with obesity.

Material/Method: In this case control study, we had 60 participants, aged 18 to 35 in four groups (15 athletes obese; 15 athletes with normal weight; 15 non-athletes obese; 15 non-athletes with normal weight). The average Body Mass Index for the obese groups was 33.50±(3.10) kg/m^2 and for the normal weight groups was 23.77±(2.94) kg/m^2. We used a Biodex Multi-Joint System 4 Isokinetic Dynamometer to examine proprioception acuity as the amount of a subject's error when trying to reproduce a test knee extension angle (a measure of the joint position sense). We tested proprioception actively (active reproduction test; AAR) and passively (passive reproduction test; PAR) in the right leg.

Results: The non-athlete obese group had significantly poorer proprioception acuity in the knee extension movement compared to the normal weight groups and also compared to the athlete obese group. For knee active angle reproduction test AAR, a significant difference was found (p=0.011). The results for passive angle reproduction test PAR, revealed no significant differences between the four groups (p=0.596).

Conclusions: The obese groups showed a deficit in the proprioception function in knee extension movement. Furthermore, the findings suggest that doing regular weight bearing training is associated with better proprioceptive function, even in obese groups. It could manifest that the deleterious effect of obesity on the knee joint proprioception might be stronger than the beneficial influence of exercise training.

Keywords: obesity, proprioception deficit, knee osteoarthritis, AAR, PAR

1. Introduction

Obesity is a major health problem in many parts of the world and its incidence is rising at an alarming rate (Waxman, 2003). Obese people expend approximately 0.7% to 2.8% of their countries total healthcare costs which is almost 30% more than their normal weight peers (Withrow & Alter, 2011). Most of the major chronic diseases, such as diabetes mellitus, coronary heart disease, chronic obstructive pulmonary disease, and musculoskeletal conditions occur with a higher incidence in obesity. Knee osteoarthritis as a chronic musculoskeletal condition is indirectly influenced by obesity and is associated with diminished normal joint function and pain; Consequently, both conditions affect quality of life (Dominick et al., 2004).

The study's main goal was to examine the possible relationship of the knee joint proprioception deficit with obesity and the second aim was to evaluate the likelihood of the improvement of proproception acuity with regular exercise activities.

Proprioception is defined as the sensory feedback contributing to muscle sense, postural equilibrium, and joint stability. Proprioceptors are mechanoreceptors that are located in the skin, muscles, tendons, ligaments, and joint capsules (Lephart et al., 1997).

Clinical studies have shown that proprioception deficit due to injuries, lesions, and joint degeneration in lower limbs, significantly affect the ability to maintain postural control stability (Garn & Newton, 1988; Cornwall & Murrell, 1991). Since the knee and ankle are two important joints in the lower limb kinematic chain integrity, any proprioceptive acuity changes in these joints may have dramatic influences on the functional activity (Garn

& Newton, 1988). It is hypothesized that exercise programs that mainly focus on joint proprioception are important to improve proprioception acuity and functional activity of the lower limb (Jan et al., 2008; Cuğ et al., 2012).

Obesity is believed to be the most modifiable risk factor for knee OA, Anderson and Felson et al. (1988) found that, the risk of osteoarthritis increased up to about 4 times in women with (BMI) of 30-35, compared to women with BMI less than 25. Joint overloading due to excess weight and obesity is the likely pathway for developing knee OA. Overstressing the joint possibly triggers cartilage breakdown and causes the progression of knee joint degeneration (Hoops, 2011). patients with knee OA suffered from greater proprioceptive impairment compared to their normal peers (Hurley et al., 1997). Impaired proprioceptive acuity possibly causes weak balance, overloading to the knee during gait initiation or may speed up joint degeneration (Hurley, 1999).

Whether or not the impaired proprioceptive acuity influences the increased rate of knee joint OA or weak balance in obese individuals, was the question that motivated us to seek for the possible answers in this study. What was discovered was that there was a shortage of sufficient studies on this subject. To the extent of our knowledge, there is only one study that investigated the relationship between obesity and proprioception deficit. Lin Wang et al. (2008).

Examined the proprioception deficit in the ankle and knee joints of obese boys that demonstrated poorer proprioception in knee flexion movement.

In the present study, we investigated the possible proprioception impairment in the knee joint of obese adults. We hypothesized that greater loading will damage the joint structures and consequently affect the functions of the proprioceptors in the joints of the lower extremities. A further aim of the study was to examine whether there was any difference in the proprioception acuity of athlete or non-athlete obese individuals compared to athlete or non-athlete normal weight individuals.

2. Material and Methods

2.1 Subjects

Four groups of 15 people in the age range of 18-35 years including obese athletes, obese non-athletes (with mean BMI of 33.50±3.10 kg/m^2), normal weight athletes and normal weight non-athletes (with mean BMI of 23.77±2.94 kg/m^2) participated in the study. The participants were matched based on the age and gender factors.

Participants signed a consent form and information was obtained about their body weight, height, age, any vision or hearing impairments, and a history of any underlying diseases. We assessed all the subjects to make sure they were symptom free before the test; any individual with a history of neuromuscular, musculoskeletal or vestibular system disease, or any knee pain or injury to this joint in the recent six months were excluded from the study. The athlete groups were performing weight bearing exercises for a minimum duration of one hour a day, 3 times a week for the past three months. The exercise program included: Using a treadmill, elliptical or jogging plus some weight bearing muscle strengthening exercises and balancing exercises.

The study was sanctioned by Shiraz Medical University ethics committee under the number of Ec-92-6570.

3. Method

The right knee joint kinaesthesia was assessed by the electrogoniometer of a Biodex Multi-Joint System 4 Isokinetic Dynamometer (Biodex Corp, Shirley, NY), which was sensitive to 1̊ increment. Data were processed using Biodex Advantage Software™ 4.0. Before starting each session, the system was calibrated in accordance with the manufacturer's instructions. To apply equivalent sensory input to the lower limb of each subject a custom made inflatable ankle cuff was provided and inflated to 20 mm Hg and fix it around the shin-dynamometer's tibial pad contact area. Visual cues were omitted by blindfolds, and the subjects wore shorts to negate any unwanted skin sensation from any clothing at the knee area. We calculated BMI by measuring subjects' stature using a stadiometer and body mass by a digital weighing scale while they were barefooted and in light clothing.

3.1 Measurement of Proprioception

According to the previous studies there are two ways to evaluate proprioception acuity consciously; firstly, by measuring the sensations of movement and secondly by assessing the joint position sense. The methods chosen in our study were passive angle reproduction (PAR) (Perlau et al., 1995) active angle reproduction (AAR) tests (Fridén et al., 1996). As the former studies have demonstrated there were no differences proprioceptive measures between dominant and non-dominant limbs, and so the right leg of each subject was selected to ease the testing setup (Jerosch & Prymka, 1996).

3.2 Procedures

Each subject sat on a testing adjustable chair with hip flexion at 90°. We applied a tibial pad 3 cm superior to the lateral malleolus. Each subject participated in the two tests of measurement of Passive Angle Reproduction and, Active Angle Reproduction. Each test included 3 trials.

To lessen the learning effect and minimizing the proprioception transferring to the next test, test order was randomly selected for each participant and the subjects were asked to leave the test seat and walk around the room for a few minutes after each test. The tests were done in a light and well conditioned room.

3.3 Passive Angle Reproduction

The knee starting position was at 90° of knee flexion and the target angle was 45°, this angle is believed to be in the working range of the knee during daily weight-bearing activities (Jerosch & Prymka, 1996). In the first trial, the lever arm passively extended the test limb, to the target angle of 45° without resistance to the movement. In order to limit reflexive muscle contractions we set the angular velocity to 2°. Participants were asked not to voluntarily contract their muscles. As soon as the limb achieved the target angle, the lever arm stopped automatically for 10 seconds and onscreen voice cue prompted the subject to remember the position. After the limb was passively returned to the starting position, the examiner pressed the start key and the main test began and the same procedure was performed again. This time the subject pressed the manual stop button when felt the target angle had been attained. Once the button was activated, patients were not allowed to correct the angle. The onscreen goniometer demonstrated and saved the perceived angle.

Three tests were taken, and for each reading, the absolute difference between the achieved angle and the target angle was calculated.

3.4 Active Angle Reproduction

The procedure was totally the same except that the subject actively moved the limb to the target angle of 45° of flexion. The leg was held automatically there for 10 seconds, and an onscreen voice cue prompted the participants and enabled them to memorize the target position, and then returned to 90° of knee flexion. After five seconds pause, the examiner pressed the start key and the main test began; then the participant moved the lower limb actively at an angular velocity approximating 2° and ceases the test by pushing the button when he or she reckoned the target angle had been achieved. Individuals were not permitted to modify the obtained angle. The absolute difference between the achieved angle and the target angle was calculated for each test.

3.5 Data Analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences for Windows (version 21, IBM SPSS Inc, Chicago, IL). One way ANOVA tests were performed for each proprioception test. The level of probability was set at ($p<0.05$). To calculate the mean joint position sense error for both PAR and AAR tests; we used the measures of absolute differences between the target angle and the actual angle.

4. Results

4.1 Active Angle Reproduction

One way ANOVA test showed that for the AAR test, there is a significant difference in the mean joint position sense error between the study groups ($p=0.011$). The smallest mean error was found (3.01 degrees) for the normal weight athlete group and the largest mean error belonged to the non-athlete obese group (6.21 degrees), normal weight non-athletes mean error was (4.94) and the result for obese athletes was (5.11). The two obese groups showed greater joint position errors compared to their normal weight peers. The athlete and non-athlete obese groups had significantly larger joint position sense errors compared to the normal weight groups. In addition, the normal weight athletes had significantly lower mean errors compared to the normal weight non-athlete group (Table 1). In order to compare the measurements between each two groups, further analysis using pair wise (LSD) post-hoc tests was performed .The results of (LSD) post-hoc tests showed that both factors of obesity and regular exercise were significantly correlated with proprioception acuity the correlations were significant between normal weight non-athletes and normal weight athletes ($p=0.043$), normal weight athletes and obese non-athletes ($p=0.001$) and between normal weight athletes and obese athletes ($p=0.028$) (Table 2). However, there was no interaction between these factors.

Table 1. Results for active angle reproduction test

Groups	Mean	Sd. Deviation	P-value
Normal weight non-athletes	4.94	2.15	0.011
Normal weight athletes	3.01	1.81	
Obese non-athletes	6.21	3.78	
Obese athletes	5.11	1.96	

Table 2. Pair wise comparison for active angle reproduction test (LSD) Post Hoc

Group I	Group J	Mean Difference (I-J)	Sig.
Normal weight non-athletes	Normal weight athletes	1.93	0.043
	Obese non-athletes	-1.27	0.179
	Obese athletes	-0.17	0.853
Normal weight athletes	Obese non-athletes	-3.19	0.001
	Obese athletes	-2.10	0.028
Obese non-athletes	Obese athletes	1.09	0.246

4.2 Passive Angle Reproduction

Similar to the pattern found for the AAR test, the results of the study for the PAR test showed that the normal weight athlete group had the lowest mean error (3.78 degrees), and the highest mean error belonged to the non-athlete obese group (4.85 degrees). However, the One way ANOVA test revealed that the differences between the study groups were not statistically significant (P=.598) (Table 3).

Table 3. Results for passive angle reproduction test

Groups	Mean	Sd Deviation	P-value
Normal weight non-athletes	4.5587	1.83876	0.598
Normal weight athletes	3.7800	2.38783	
Obese non-athletes	4.8533	2.14105	
Obese athletes	4.3113	2.33960	

5. Discussion

Several studies have shown that postural stability in obese prepubertal children is diminished either during walking, standing or different static postures (Hills & Parker, 1991; McGraw et al., 2000).

Wang et al. (2008) showed a relationship between obesity and proprioception deficit. The results of our study confirms the findings of the Wang et al. report and suggests that similar to the poorer proprioception acuity observed in obese children, there is a proprioception deficit in the knee joint movements of obese adults.

The exact mechanism underlying the observed deficit in postural stability and proprioception acuity in obese objects is unknown; however, it has been suggested that the change in stability is primarily effected by an excess body size and weight (Hills & Parker, 1991; McGraw et al., 2000) The role of proprioception is fundamental in maintaining postural stability and joint stabilization during both dynamic and static postures. Fitzpatrick R. et al. (1994). Explained that signals from proprioceptive receptors located in the lower extremities are essential for detecting the postural sway of the ankles (Fitzpatrick et al., 1994) joint receptors include Pacinian corpuscles, Ruffini endings, and free nerve endings distributed throughout the articular structure. It is believed that muscle spindles are the most important proprioceptive receptors of the knee (Lephart et al., 1997; Sharma, 1999). For example, it could be suggested that skin mechanoreceptors which can be found in the plantar surface of the foot and the muscles around the ankle and/or knee joint function differently between obese and non-obese individuals. According to recent studies put forward plantar mechanoreceptors sensitivities may possibly differ in heavier subjects. Greater body mass in heavier individuals, due to the hyper activation of the plantar mechanoreceptors, leads to a diminished plantar sensitivity (Hue et al., 2007). Results of Isokinetic testing revealed that obese children have less relative strength(Sun et al., 2015).

The sport and orthopedic medicine pays special attention to the role of proprioception feedback impairment in generating injuries, such as ankle injury and anterior cruciate ligament injury. These injuries also lead to excessive or inappropriate loading of a joint (Noyes et al., 1991). Therefore we can conclude that any impairment in proprioception signaling or any mechanism which damage the proprioceptors throughout the articular structures might cause joint degradation and/or postural instability (Sun et al., 2015).

Another consequence of having higher BMI is the increased susceptibility to injuries from low-energy trauma more severely. Ligament injuries may lead to loss of joint stability, proprioception, and injury to cartilage and subchondral bone (Peltola et al., 2009).

It is hypothesized that a capsular lesion could affect the conduction of afferent impulses from the joint; however the main probable effect is changing in the afferent neural code that was transmitted to the CNS (Riemann & Guskiewicz, 2000).

Mechanoreceptors are presented across the surface of chondrocytes; the activation of mechanoreceptor may express the secretion of growth factors, metalloproteinases and cytokines. These substances might produce mediators such as prostaglandins or nitric oxide (Guilak et al., 2004). Mechanical overload might trigger both cartilage degradation and inhibition of matrix synthesis under some conditions. It has been suggested that joint overstress exerted in obese subjects probably leads to cartilage damage through the activation of these mechanoreceptors. Similarly, mechanoreceptors located on osteoblasts, might be associated with the impaired response of chondrocytes to overloading in obesity (McGarry et al., 2005).

It is unknown whether the alteration in postural stability in obese people is a consequence of excessive joint loading that affects the proprioceptors in the joints of the lower extremities, or the observed instability in obese individuals is the mere influence of larger body mass.

The present study aimed to investigate the correlation between obesity, proprioception impairment and weight bearing exercises, in one single study.

Based on a narrative review by Knoop et al. (2011) exercise therapy, including proprioceptive exercises (both non-weight bearing and weight bearing) and weight bearing muscle strengthening exercise seemed to be the most effective exercises in improving proprioceptive accuracy .On the other hand , non-weight bearing exercise program was not effective in improving proprioception deficit. The influence of exercise therapy may be due to the possible increase in muscle spindle sensitivity, or through the stimulation of articular mechanoreceptors. The better influence of weight bearing exercises may be explained by an increase in intra-articular pressure which may lead to enhanced proprioceptive accuracy via stimulating Ruffini nerve endings (Knoop et al., 2011).

Hyeon Jeong Noh et al. carried out a 12 week study on obese elderly women in order to examine the effects Proprioceptive Neuromuscular Facilitation (PNF) and elastic band exercise on the physical functions and blood lipids of the subjects.

In the investigation it was discovered that PNF was more effective than elastic band exercise in improving the physical functions (cardiovascular endurance, strength of the lower extremity, muscular endurance, flexibility, balance, and agility) ($p<.05$) and blood lipid levels of obese elderly women (Noh & Kim, 2015).

A study performed by Paschalis et al. evaluated how proprioception at rest and after muscle damaging eccentric exercise is affected by being overweight and underweight. Up to 3 days after the exercise, muscle damage indices and proprioception were analyzed. They discovered that the baseline outcomes figures for proprioception of overweight and underweight were less than the lean group. Moreover, in the overweight and underweight groups, proprioception was affected more after eccentric exercise (Paschalis et al., 2013).

We aimed to investigate the difference in proprioception of knee joint in athlete and non-athlete obese compared with their normal weight peers. We also investigated the possible effects of regular weight bearing training on improving the proprioception deficit between the four mentioned groups. The results showed that the obese groups had poorer proprioception acuity in the knee extension movement than the normal weight groups; this indicates a probable deficit in the proprioception function of the knee joint in the obese groups.

Furthermore the results revealed that both athletes groups manifested better outcomes for proprioception acuity. For knee extension AAR test, a significant result was found between four groups ($P=0.011$). This may indicate that deleterious effects of obesity on knee joint proprioception might be stronger than the beneficial influence of exercise training in obese individuals.

Although the results for PAR test, revealed no significant differences between the four study groups ($P=0.598$), the observed trend in our data (the highest mean for errors belonged to the non-athlete obese group, 4.85), might imply that the result for PAR was consistent with the result for AAR test. One possible explanation for the difference of our findings for AAR and PAR might be the fact that, passive movements do not reflect real life movement or function. When we ask people to actively reproduce their limb position angle, this will maximizes sensory input to the central processing systems as they repeat a normal movement which is mostly active and is much closer to real life proprioceptive acuity measures. When a person performs a passive technique it demands cognitive skills and concentration, which might interfere with the proprioceptive acuity estimation. It has been suggested that there is not a strong correlation between the assessment of proprioceptive acuity in active and passive movements (Felson et al., 2009).

An implication of the findings of the present study for trainers and physical therapists would be design an exercise regime that would consider proprioception training for obese individuals.

The question raise from this study is, whether the decline in proprioception in obese people is a consequence of overloading to the joint or the effect of adiposity. Further research with a longitudinal study design and a larger sample size is required to answer this question.

6. Conclusions

Obese individual manifested poorer proprioception in knee extension movement, and weight bearing exercises are associated with a better proprioceptive acuity in obese individuals.

7. Limitations

In order to limit reflexive muscle contractions we set the angular velocity to 2°. Participants were asked not to voluntarily contract their muscles during the passive tests and the thigh was fixed to the table by a strap in addition any contraction was monitored by the examiner. Although the lack of EMG, during the passive tests, to ensure that no muscle activity was present, is a limitation to this study.

Although we investigated the asymptomatic knees but the participants were obese with the BMI>30 that would increase the relative risk of developing knee OA by 2-10 fold (Felson et al., 1988; Spector et al., 1994). On the other hand, the lack of any X-ray findings, is another reason for uncertainty of the possible onset of OA in obese groups.

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Competing Interests Statement

The authors declare that there is no conflict of interests regarding the publication of this paper.

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