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A study to evaluate the effect of fatigue on knee joint proprioception and balance in healthy individuals

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Abstract. Balance and proprioceptive testing is more commonly used in clinical settings to evaluate injured athletes to return to activity. Muscle fatigue produces neuromuscular deficiency within the muscle, thus predispose a joint to injury and decrease the athletic performance. A finding of previous studies shows contradictory findings of effect of muscle fatigue on proprioception and balance. *Aims.* A study to investigate the effect of fatigue on knee joint proprioception and balance in healthy individuals. *Material and Methods.* An observational study was conducted on 30 healthy subjects (age 18-30 years) from Srinivas college of physiotherapy, Mangalore. Subjects was selected by simple random sampling techniques. Fatigue was induced in the subjects by cycling up to level of exceeding 60% of predicted maximal heart rate (HRmax). Subjects were tested to estimate reproduction error by using weight bearing joint position sense test at 30^0 of knee flexion, by goniometric evaluation accompanied by photographic method and the balance assessment was done on force platform with the measurement of anteroposterior (AP), lateral center of pressure (CoP) excursion and stability score in single limb stance, before and after fatigue protocol. *Results.* After inducing fatigue, significant reproduction error was found for perception of joint position sense (t=4.103) with significant changes were found in AP (t=3.997), lat CoP excursion (t=10.949) and stability score (t=11.785) at p>0.05. *Conclusion.* A study revealed that moderate exercises can reduce proprioception which affects the neuromuscular control of joint making individual more suspectible to injury.
Key words: *fatigue, proprioception, balance, dynamic stability.*

Introduction

Muscular fatigue is most often defined as an exercise induced reduction in the ability of a muscle to generate force (1). It is caused by a combination of different physiological mechanisms occurring at both the central through the impairment of central drive and peripheral level through the impairment of muscle function (2). The high incidence of injuries occur during later session of sports suggest that fatigue may predispose a joint to injury and decrease the athletic performance (3). The study of fatigue relative to performance of different skills in the sports has long been a subject of practical interest (4).

Since sports activities are strongly promoted, the risk of sport injuries is likely to increase. It is reported that knee joint injuries are the common injuries among all sports injury, 39.8% of all sports injuries involve the knee (5). It has been suggested that a higher incidence of injuries at the last third of match could be related to alteration of the lower limb neuromuscular control and altered ability to dynamically stabilize the knee joint but exactly how this impairment comes about is less clear (6). It is possible that one factor is reduced proprioceptive acuity (7).

In 1906, Sherrington defined proprioception as the perception of positions and movements of the body segments in relation to each other, without the aid of vision, touch or the organs of equilibrium (7). The importance of the proprioception in knee function, stability, injury prevention has been studied extensively in literatures. The current consensus is that the sense of proprioception originates in the simultaneous activity of a range of different types of receptors located in muscles, joints, and skin (8). Some of these receptors have been shown in animal studies to be affected by muscle fatigue (9) and/or by increased intramuscular concentrations of substances (Arachnoid acid, KCL, 5-HT, Bradykinin) released during muscle contractions (10) which have a direct impact on the discharge pattern of muscle spindles that represent the peripheral component of fatigue and efferent as well as afferent neuromuscular pathways are modulated with excessive fatigue via reflexes originating from small-diameter muscle afferents (group III and IV afferents) could modify the central processing of proprioception (11). Although it is reasonable to assume that these receptors are affected in a similar way in humans, comparably little is known about the fatigue effects on human proprioception (12).

The perception of movement or joint position in clinical measurements reflects the status of the whole system, or that measured proprioceptive defects are connected to functional disability (13). It is believed that the Central Nervous System (CNS) links together afferent proprioceptive feedback from multiple joints of a limb segment and redundancy of the afferent information can be used as an "error check" to improve proprioceptive feedback in order to maintain function (8). Reproduction ability is decreased, possibly due to increased sensitivity of capsular receptors from muscle fatigue-induced laxity (3). The assessment of potential injury risk before sports participation followed by intervention may decrease the relative injury incidence in athletes (14).

The integrity and control of the proprioceptive acuity is essential for the maintenance of balance (15). Balance is defined as person's ability to maintain an appropriate relationship between the body segments and between the body and the environment and to keep the body's center of mass over the base of support when performing a task (16). It is assumed that some form of muscle spindle desensitization or perhaps ligament relaxation and Golgi tendon desensitization occurs with excessive fatigue which leads to decreased efferent muscle response and poorer ability to maintain balance (17). Balance testing is more commonly used in the clinical setting to establish gains in the proprioceptive capacity of injured limbs and helps to evaluate injured athlete to return to activity (5). Measures of postural control such as center of pressure (CoP) excursion which may be a more sensitive measure of postural control that incorporates proprioception have been used clinically (18).

In humans, the effect of fatigue on proprioception has been investigated at various joints. Findings of disturbed proprioception and balance are frequent in the literatures, but together they are not conclusive. So the purpose of this study is to investigate the effect of muscular fatigue on proprioception and balance in healthy individuals.

Material and Method

Study design: Observational study design. *Sampling Technique:* Simple Random Sampling. *Sample collection:* 30 healthy subjects in age group of 18-30 years of both sex were taken for the study from Srinivas College of Physiotherapy, Mangalore. *Inclusion Criteria:* Age group: 18-30 years, both male and female were included. *Exclusion Criteria:* knee joint pathology, musculoskeletal disease of lower limb, neurological condition, respiratory and heart problem

Materials used: static cycle, reference markers, goniometer , video camera, heart rate (HR) assessment apparatus (Cardiovigil), two dimensional digitizing software of the peak measurement system (UTHSCSA Image Tool version 3), force platform (BERTEC, Columbus, OH 43229, U.S.A.)

Testing Procedure. The proposed title and procedure was being approved by ethical committee members, written consent was taken from subjects who fulfilled the inclusion and exclusion criteria and they were randomly selected. Subject's age, sex, height, weight, body mass index (BMI), resting heart rate was recorded prior to the test. Borg scale of perceived rate of exertion (PRE) was clearly explained to all the subjects before cycling. Right lower limb was used for measurement of proprioception and balance test.

Fatigue was induced by asking the subject to perform cycling on a static cycle as fast as possible, the level of fatigue was indicated and measured by using Borg's Rate of Perceived Exertion (RPE) scale and HR was monitored using Cardiovigil (multi-parameter patient monitor). Fatigue was induced in the subjects by cycling. When subjects reached up to level of exceeding 60% of predicted HRmax and a level of exertion of 14-17 on the RPE scale, immediately the subjects were asked to discontinue cycling (19).

Proprioception and balance tests were performed before and after fatigue protocol and scores were recorded. Subjects were tested to estimate reproduction error by using weight bearing joint position sense test at 30^0 of knee flexion, by goniometric evaluation accompanied by photographic method. The subject was given three trials to identify and reproduce knee joint position (30^0 knee flexion) initially with eyes open followed by eyes closed. After trials of test positions, reference markers were placed along the lateral aspect of the lower limb for photographic evalution: a) over the greater trochanter; b) over the iliotibial tract proximal to the superior border of the patella; c) over the neck of fibula (20). The balance assessment was done on force platform while the leg was flexed to 90° at the hip and knee joints, with both arms hanging relaxed at the sides in single-limb stance with the measurement of AP, lateral excursion and stability score in single-limb stance on the force platform after the joint position sense (JPS) test following fatigue protocol (21).

Results

The demographic data were analyzed using paired t-test for comparison of pre and post fatigue measurement. The data analysis was done using SPSS softwear package version 14.level of significance was set at ≤ 0.05 with Cl of 95%.

Table I. Distribution of age groups

Age	Frequency	Percent	Valid Percent
19	3	10.0	10.0
20	5	16.7	16.7
21	13	43.3	43.3
22	6	20.0	20.0
23	3	10.0	10.0
Total	30	100.0	100.0

Table II. Gender Proposition

	Frequency	Percent
male	21	70.0
female	9	30.0
Total	30	100.0

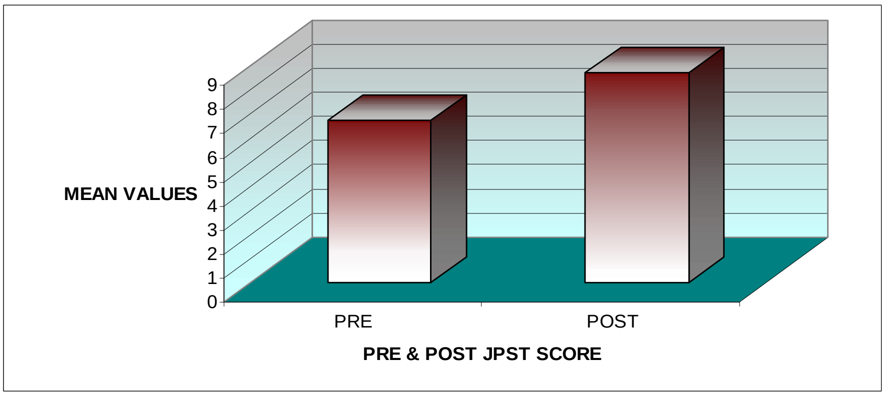
Table III. Comparison of pre and post fatigue joint position sense (JPS) test score, AP CoP excursion, Lateral CoP excursion and stability score

	Mean	Std. Deviation	Std. Error Mean	t	df	p
Pre fatigue JPS test score	6.7370	3.04761	.55641	-4.103	29	.000 VHS
Post fatigue JPS test score	8.7197	3.04767	.55643			
Pre fatigue AP CoP excursion	1.2777	.27712	.05060	-10.949	29	0.000 VHS
Post fatigue AP CoP excursion	1.7620	.32318	.05900			
Pre fatigue LAT CoP excursion	.4590	.32341	.05905	-3.997	29	.000 VHS
Post fatigue LAT C oP excursion	.6820	.44055	.08043			
Pre fatigue stability score	86.6090	2.84795	.51996	11.785	29	.000 VHS
Post fatigue stability score	81.7803	2.75167	.50238			

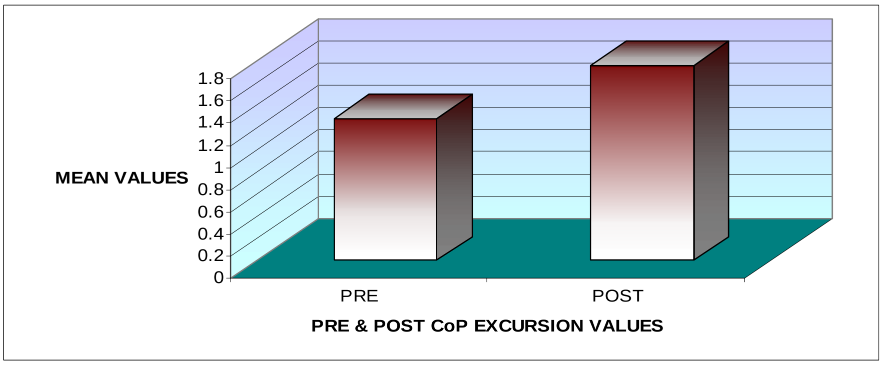
*VHS=very highly significant

The above table shows the mean of pre JPS test score i.e. 6.7370 ±3.04761 (SD) and post JPS test score i.e. 8.7197±3.04767 which shows significant differences (t = -4.103, p<0.05) (figure 1), mean of pre AP CoP excursion i.e. 1.2777±0.27712 (SD) and post AP excursion i.e. 1.7620 ±0.32318 which shows significant difference (t = -10.949, p < 0.05) (figure 2), mean of pre Lat Cop excursion i.e. 0.4590 ±0.32341 (SD) and post Lat excursion i.e.0.6820 ±0.44055 (SD) which shows significant difference (t = -3.997, p < 0.05) (figure 3), mean of pre stability score i.e. 86.6090 ±2.84795 (SD) and post stability score i.e. 81.7803 ±2.75167 (SD) which shows significant difference for pre and post stability score (t = 11.785, p < 0.05) (figure 4) for the present study.

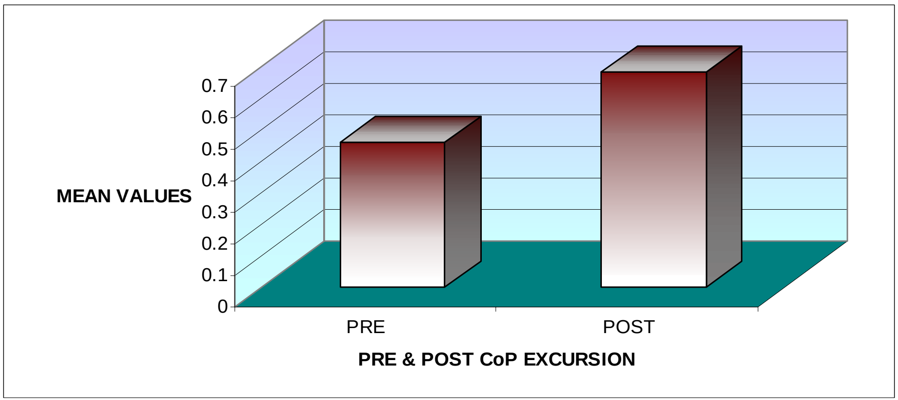
Graphic 1. Pre and Post fatigue joint position sense (JPS) test score



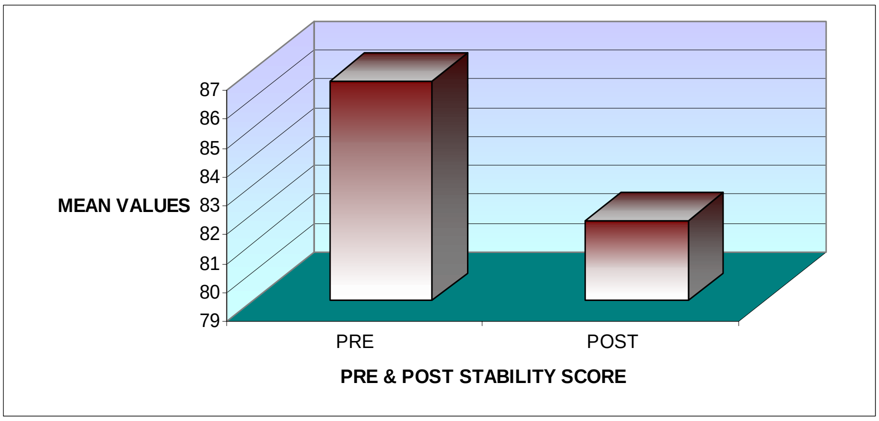
Graphic 2. Shows Pre and Post fatigue Antero Posterior CoP excursion



Graphic 3. Shows Pre and Post fatigue Lateral CoP excursion



Graphic 4. Shows Pre and Post fatigue stability score



Discussion

The results of the present study indicated that fatigue reduces knee joint proprioception i.e. higher reproduction error was found for perception of joint position sense (t = -4.103, p <0.05) thereby supporting the experimental hypothesis.

The findings of David Roberts et al. (2003) on healthy young persons, to estimate threshold for perception of movement before and after fatigue shows statically significant difference in threshold value, after inducing fatigue which support the results of our study (22). However, Marks and Quinney (1993) provided contradictory findings suggested that muscle fatigue had a negligible effect on knee JPS. However, they induced fatigue by having the subject contract the quadriceps muscle 20 times, which likely was less fatiguing and that mainly affected the anterior structures of the thigh. Therefore, the posterior structures, which are of afferent importance during extension, were probably less affected by fatigue (23).

An important issue here in this present study is, whether the effects of fatigue on position sense of knee can be attributed to central fatigue or to muscle fatigue. Central fatigue may have accompanied peripherally elicited effects, but there is a chain of evidence indicating that alterations in the proprioceptive inflow from peripheral muscle receptors have contributed considerably to the central fatigue effects (10). Djupsjobacka M. et al. (1995) suggested that muscle spindles are strongly affected by metabolic products, such as bradykinin, 5-HT, and lactic acid, the proprioceptive inflow from spindle afferents during the JPS test is likely to have been affected by fatigue (24).

Different methods have been used to assess proprioceptive acuity in various studies. Amongst them, Goniometric evaluation for measuring the angle accompanied by video films is an adequately accurate method of measuring the joint angle. Berry C. Stillman et al. (2001) explained that WB assessments of proprioception which is more functional might have greatest relevance in the area of sports medicine. Theoretically, fatigue may increase the time of reaction, which, in the present study, would be seen as higher reproduction error scores (20).

The results of the present study also indicated that fatigue reduces balance performance (t =11.785; p < 0.05). There are several possible reasons why muscular fatigue affects balance performance. It seems plausible that some form of muscle spindle desensitization or perhaps ligament relaxation and Golgi tendon desensitization occurs with excessive fatigue. The increased AP and Lat CoP excursion observed after cycling in the present study may be explained by a decrease in muscle response and a delay in muscle reaction and poorer ability to maintain balance (17). Eva Ageberg et al. (2003) found that short-term cycling decrease ability to maintain balance in single limb stance in healthy subjects (30) support the result of present study (21).

We found that a short period of moderate exercise can reduce proprioception, which may affect the neuromuscular control of the knee joint and significantly affects the ability of an individual to maintain balance on force platform device, thus, may make it more susceptible to injury.

Conclusion

Balance and proprioceptive testing can be used in the clinical setting to evaluate injured athlete to return to activity. The knee joint proprioception and balance are affected after fatigue in healthy individuals.

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