Original Article

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The Impact of Fatigue on Physical Statefluctuations in Men Withgenu Varumas Well as Normal Knees

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ABSTRACT

BACKGROUND AND OBJECTIVE: Genu varumis a risk factor for the knee osteoarthritis onset. Given the role of exhaustion on the physical condition, understanding physical state fluctuationsin people with genu varum, will give us a good insight for prevention of knee osteoarthritis. The aim of this study was to compare the effect of exhaustive fatigue on body state fluctuations of men with genu varumand normal knees.

METHODS: This quasi-experimentalstudy was performed on 40 healthy male students, including 20 with genu varumand 20 with normal knees (with the average q angle of 25.5±8.0 and 97.8±86.0, respectively). Genu varumdeformitywasmeasured using a caliper and goniometer. Bodyfluctuations were recorded using the force measuring diagram,and Strand modified protocol was used to inducefatigue.

FINDINGS: There was no significant difference between the two groups after exhaustion in terms of anterior-posterior stability, but there was a significant decrease in medial-lateral stability after exhaustion (genu varum 86.296 mm/sec and normal knee 38.200 mm/sec, pressurecenter shifting,respectively);comparinggenu varumto the normal knee, thesechanges were significant (p=0.04). Interior-exterior stability in both groups,10 minutes after exhaustion was fully recovered.

CONCLUSION: Inside displacementof the line of gravityin genu varumsufferercan lead to increased volatility of the lateral posture, and since genu varumdeformity causes internal rotation of the leg and turns it into pronation of the subtalar joint inthe weight-bearing position,therefore, these changes in footstructures cancause leg function alterationin control of the internal-external (lateral) balance.

KEY WORDS: *Fatigue, Posture, Genu varum.*

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Introduction

Daily physical activity and exercise require physical state control,definedas the ability to maintain balance and orientatethe body (2, 1); while potential of physical damage increase, is associated with imbalance. Increase inthe pressure center swingis considered to be associated with increased prevalence of injuries due to impaired neuro muscular control or balance (2). Sensory posture controlinput and movement systems are the basic means to maintain physical state (3). Fatigue is also one of the factors influencing body control, that is, if due to local (environmental) exhaustion, any of the visual sensory and atrial systems transfer inaccurate information, or due to general fatigue, central nervous system is disturbed and enforcement is not enough for compensation, the balance would be disrupted (4). Ageberg and colleagues reported that due to loss of the ability to maintainone footbalance, the risk of injury when exhausted is increased (5). Wang and colleagues' research on high school basketball players also showed that most of the lower extremity injuries occur during single leg weight-bearing (6). In a study, Reimer *et al* showed that controlling physical state while ina single-leg standing position, following fatigue, is of great importance (7). Lower limbs are responsible for absorbing pressure during ground contact and adjust the amount of weight (8). Genu varumis among abnormalities in the frontal knee plane withhigh prevalence among athletes and non-athletes (9). Genu varum shiftsthe path of the forces from the center of the knee to itsinternal part and transfers more pressure to the internal structure of the knee, suchthat the reaction force in the internal sector is around 5.3 times more than the outer part (10). Research shows that on one hand genu varumleads to the loss of cartilage in the tibialjoint, and on the other hand leads to the development of osteoarthritis (11). Some studies have mentioned genu varum as a risk factor for patellar femoral pain syndrome and as a predictor of the risk of damage to the ligaments of the knee-joint, including: anterior cruciate ligament injury (anterior cruciate ligament) and posterior cruciate ligament (posterior cruciate ligament) (11, 10). Given that the foot is conjunction of the body and the ground, structural distortions, especially knee injuries haveincreased risk, and may not be an obstacle to participation in activities byathletes (8). Genu varum abnormalities cause instability in weight bearing and physical state and changes in the quality of body control (11), by disrupting the orientation of the line of gravityto the base of support (1) andshiftingthe line of gravity from the center to the inside of the knee (12). Due to the impact of joint structural deformities, especially the knee, in increasing the risk of damage during physical and sport activities, and the need to raise awarenessof preventive factors of sport injuries, such as anterior cruciate ligament rupture (6), and increased risk of knee osteoarthritis in patients with genu varum, as well as the limited researchperformed in the area of the effects of fatigue on the control of physical state in people with genu varumdeformity, this study aimed to compare the effect of exhaustive activity fatigue on fluctuations of physical state and balancerecovery timein people with genu varum and normal knees.

Methods

This quasi-experimental study was conductedon the male students of Kharazmi University of Tehran, Faculty of Physical Education and Sport Sciences. An initialcaliper evaluation of the knee joint was performed on members of the study population. The following factors were regarded as exclusion criteria: professional athlete, injury inthe past six months, surgery and injuries inthe back and lower extremities, activity limitation onphysician's advice, lack of normal strength and full range of motion in the joints of the lower extremities, arthritis or rheumatoid arthritis, impairment due toneuro muscular disorders, actual leg length discrepancy of more than a centimeter through examination of participants,and having other abnormalities such as flat foot, hollow foot, etc. Due to the one-leg stand method of measurement of static balance, the Q angle of the dominant leg in participants was taken into account as eligible. If this angle wasless than 8 degrees, it designatedknee abnormalities, otherwise if this value was between 8 and 10, itwas considered normal (14). Finally, 40 subjects (20 patients with genu varum and 20 patients with normal knees) were selected using non-probability sampling, all of them were matched for age and weight. The feet with which subject kicked the ball was considered the dominant foot. After complete description of the study to the subjects, their consent for participating in research and their personal information such as age, history of sports, and the number of exercise sessions per week were collected. Using a force plate (model BERTEC, made in USA) physical state fluctuations during the one-leg stand (the dominant) with a sampling frequency of 400 Hz were recorded. In this test, the subjects looked at a certain point. During the test, the hands were placed on the trunk and the knee flexion angle of the non-dominant foot was equal to 90 degrees. Force plate data were recorded for 30 seconds, in order to avoid problems such as insufficient preparation and fatigue, only those incoming data between 5 and 25 seconds were recorded andused for analysis. The Strand altered protocol was used to inducefatigue (5). After anappropriate introduction, each subject was asked to warm up for 3 minutes on a non-inclinedtreadmill at a speed of 2 miles/hr (3.28km/h). At the end of the 3 minute warm up, speed was increased to 5 miles/hr (8.2 km/h) for the next 3 minutes. After 3 minutes of running, the slope was increased at a rate of 5.2% every 2 minutes, until the exhaustion protocol ended, in other words upto failuretocontinue with the protocol (16, 15). To maximize accuracy and minimize fatigue errors, Ageberg pressure perception and heart rate were used.

In accord with this protocol until reaching exhaustion, participantwas verbally encouraged to continue running. Minimum heart rate was to reach more than 60% of maximal heart rate and maintained for about 5 min; Ageberg scale was to reach14–17 (hard or very hard) to halt activities (5). The protocol was chosen because running, creates a situation similar to sports activities and tilt can localize the fatigue in lower limbseven more (5). After suspension of activity, the subjects were required to do a re-tests (first post-test). In order to determine the balance recovery time, every 5 minutes, i.e. 5, 10, 15 and 20 min after the fatigue protocol, static balance test was performed like the pre-test(second, third, fourth and fifth post-tests).

Fluctuations in the body condition were calculated usingthe Matlab version R2009a software. To describe the two groups, descriptive statistics, and to analyze the data, inferential statistics, were used. Given the normal distribution of the data, parametric tests were used to analyze the data.

Considering, there were two independent variables in the study group (with 2 significant levels of normal knee and genu varum), and two examination states (with 2 significant levels of pre and post-test) mixed method analysis of variance (Mixed ANOVA) was used. For inter-group comparison, the independent t-test, and for comparing with in groups, paired t-test (comparison tests with the pre-tests) were used, and $p<0.05$ was considered significant.

Results

In this study, both the genu varum and normal groups had an average age of 75±90.19 and 59.1±20 years, and body mass index was equal to 24.1±37.22 and 42.1±54.22 kg/m^2, respectively, also the distance between the internal knee breadth was 70.0±65.5 and 99.0±25.1 cm and Q angle was equal to 8.0±25.5 and 86.0±79.8°, respectively. Results from comparison of anterior-posterior stability index before and after the test showed that thisindex was not significantin the genu varum and normal groups.

But the results of the internal-external stability in the pre-test and post-test showed that thisindex was significant in both genu varum and normal groups (p=0.04) (table 1). Paired comparison of anterior-posterior dynamic stabilization index between pre-test and post-tests showed that there is no significant difference between the two groups (tables 2 and 3). While there was a significant difference in internal-external static stability index between the pre-test and post-test in the normal and genu varum groups. On the other hand no notable difference between the pre-test and the 3rd post-test of the genu varum and three other groups was observed.

Table 1. Before and after comparison of anterior-posterior stability and internal-external static test betweenthe genu varum and normal groups

Groups / variable	Mean±SD genu varum	Mean±SD Normal knee	T	p-value
Anterio-posterior static stability(mm/s)	26.5±26.14	37.6±25.14	83.0	42.0
Internal-external static stability index(mm/s)	45.7±86.30	83.6±38.20	18.2	04.*0

Table 2. Before and after comparison of the sagittal and medial-lateral static stability tests inthe genu varumgroup

Variables	The genu varum group					
	Pre-test	Post-test 1	Post-test 2	Post-test 3	Post-test 4	Post-test 5
Anterior-posterior static stabilityindex (mm/s)	52.108	78.113	71.112	51.110	93.109	57.108
withingroup test	-	23.0	29.0	54.0	67.0	71.0
Internal-external static stability index(mm/s)	44.134	30.164	30.156	77.139	56..136	71.135
Within group test	-	00.*0	00.*0	34.0	49.0	56.0

Table 3. Before and after comparison of the sagittal and medial-lateral static stability test in the normal knee group

Variables	Normal knee group					
	Pre-test	Post-test1	Post-test2	Post-test3	Post-test4	Post-test5
anterior-posterior static stability index(mm/s)	50.113	75.127	27.121	07.115	23.114	63.114
Within group test	-	19.0	23.0	34.0	58.0	79.0
Internal - external staticstability index	26.128	64.148	27.142	93.136	78.129	52.128
Within group test	-	00.*0	00.*0	27.0	41.0	68.0

Significance at the 0.05 level

Discussion

Thisstudy showed that compared with the pre-test, in the post-test, the anterior-posterior static stability indexfor the genu varum and normal groups was not significant; also the average differences in the two groups werenot significantly different. Nicolas and colleagues proved that lower limb local muscle exhaustion is the main reason for reduction of the balance; they stated the trunk extensor muscle fatigue as the main controlling factor (17). Bearing this in mind, the compensatory mechanisms of the lower limb neuromuscular performance can be the reasonbehindlack of changes in the balance of the individuals after the fatigue protocol (17).

The Vuillerme et al study showed that the waist neuromuscular system has an important role in controlling the standing posture on the legs, in fact athlete subjects attempt to adapt to fluctuating conditions, and this adaptation occurs in the anterior-posterior level (18). Vuillerme and colleagues, in their research concluded that the stability of the sagittal, in the over fatigue program isnot subject to changes, and stated its main reason, in case of general fatigue, as physical state maintenance musclesentering compensatory postural control before local fatigue mode and holding the balance. They also concluded that in the presence of the visual system the anterior-posteriorstatic variable is affected less (15).

Likewise, Greig et al in their study stated that due to fatigue, anterior-posterior stability, relative to the lateral-index, is less affected, and statedthe anatomical shape of bones and soft tissue structure as the cause (19). The results of this study are inconsistent with the results of Reimer et al (20) and Ageberg et al (5), probably due to differences in fatigue protocols and type of inducedexhaustion. The present study results showed that the static lateral stability indexfrom the pre-test to the post-test, in both normal and genu varum groups, showed a significant difference and the average change between groups was significant.

It can be concluded that fatigue due to exhaustive activities, decrease dlateral-stability in both groups, which was more evident in the genu varum group. Changes in the frontal plane knee alignment, automatically can disrupt the static balance in subjects with normal and symmetrical genovarum deformity, which can alter the joint weight distribution pattern. This asymmetric distribution of weight in the frontal plane can cause increased posture volatility in knees and ankles (21). Hence, this deformityin legstructure can cause functional changes in the structures set up to control the balance (21). The results of this part of the study arefully compatible with the results of Nardone et al (16) and Letafatkar et al (22) studies.

The present research findings, arepartly compatible and partly incompatible with the results of Reimer et al (20). Based on their findings the hip and ankle muscles fatigue (individually), both reduce the state stability in the anterior-posterior and internal-external directions (20). The difference between the two results may be duetothe fatigue and exhaustion protocols. Also, Greig and Walker-Johnson, reported lack of significant changes in the stability indices following the fatigue protocol (19). This lack of consistency can be attributed to the differences between research population (semi-professional football players), fatigue protocol (90 minutes of treadmillrunning) and the test method (single leg standing test on a moving platform).

Ageberg and colleagues also observedincreasein range of motion in the sagittal pressure center (anterior-posterior), followingcycling, but such a change in the transverse plane (internal-external) did not happen. They attributedthe reduced balance to reduced joint receptive activities, muscle spindles and Golgi tendinous organs (5).

According to the present study results, the anterior-posterior static stability statewas unchanged, while the stability of the internal-external static condition significantly decreased, and fatigue protocol was recovered within 10 minutes. Nardone et al (16), have reported a significant increase in body fluctuations following exhaustive exercise on the treadmill. One possible reason for this discrepancyis the difference criteria used to stop the fatigue protocol.

It seems that the inducedfatigue wasmore than in the presentresearch and naturally it required more time to recover, it is also possible thatenrollment of younger individuals (18–23years old) in the present study isthe reason forfaster recovery time. Yaggie and colleagues also showed temporary reduction of state control and a linear relationship between the direction of oscillation and oxygen consumption in subjects, following physical fatigue (23). Further more Bove et al mentioned that fast recovery of the consumed oxygen isone of the reasons for short-term volatility following exhaustion (24). The results of the present research wereconsistent with Yaggie and colleagues (23) and Bove et al (24), while theywere conflicting with Susco and colleagues (25), Khanna et al (4), and Fox and colleagues (26). The reason behind this disparity can be differencesin means of balance measurement, fatigue protocols and different post-tests.

Some studiesin the field of fatigue have included variables other than balance variables. Baker et al have reported anterior muscle strength recovery within 15 minutes afterlong-term fatigue protocol, and within 5 minutes after short-termfatigue protocol. They stated that while doing short-term activities, metabolic processes are activated and lead to fast recovery state, while during long term activities it is non-metabolic factors that delay the recoveryprocess (27). Balance recovery following the fatigue before exercise is very important, otherwise the effects of fatigue can lead to a decrease in performance and increase in the risk of injury. Recovery of muscle function depends on severity and duration of exercise and recovery time (4).

It seems that inner shiftingline of gravity in people withgenu varum can lead to increased lateral posture volatility, thus, this deformity in the leg structures can alter the leg function inbalance control. Wesuggest that this group of people be subject to balance control training exercise programs before physical activity in order to improve balance control. In order to gain a better understanding of the subject matter, it is recommended that a similar study onthree groups of genu varum, knock knee and normal be conducted and compared. Because gender affects various factors following fatigue, it is recommended to perform a similar study on women.

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