Biomedical & Pharmacology Journal Vol. **8** (March Spl Edition), 139-145 (2015)

The Effect of Lateral Trunk Motion on the Severity of Knee Osteoarthritis

KAMRAN AZMA[1], EHSAN MAHDAVI[2]* , ALIREZA HOSSEINI[3], IMAN NASEH[4] and ALI GHOLESTANPOUR[5]

[1]Department of Physical Medicine and Rehabilitation, Clinical Biomechanical and Rehabilitation Engineering research center, AJA University of Medical Sciences, Tehran, Iran.
[2]PhD student at University of Tehran in Mechanical Eng.
[3]Researcher Physician, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.
[4]Researcher Physician, Clinical Biomechanics & Rehabilitation Engineering Center, Aja University of Medical Sciences, Tehran, Iran.
[5]Researcher Physician, Young Researchers and Elite club, Tabriz Branch, Islamic Azad University, Tabriz, Iran.
*Corresponding author Email Ehsanmeasam@gmail.com

DOI: http://dx.doi.org/10.13005/bpj/570

(Received: February 10, 2015; accepted: March 10, 2015)

ABSTRACT

The loading of knee joint is highly influential in progress of osteoarthritis, so there have been various studies on the dynamic loading of knee in different motions. Some have focused on the gait of people with OA. The proper method to measure and analyze people's gaits is to analyze gaits through synthetic and systematic data. After referring to a specialist, their height and weight were measured and they filled the WOMAC questionnaire. T-test was used to determine the difference between OA and healthy group. In order to determine the shape and discrepancy in the motion range, the three principles of PCA have been used. These principles represent the major changes which are used for analyzing the differences between groups. In this study, 10 healthy people and 16 patients were participated. The greatest differences between the healthy and OA group were observed in weight, BMI, and pace of walking, whereas there were no significant differences between their age, height and length of their steps (p d" 0.05). OA group showed an increased range of motion in the static phase for both TTL and TTP ($p < 0.05$). The knee and hip torques demonstrated greater values in the OA group. Based on the results, it is not clear that these changes could improve the quality of life among these patients. However, there are some benefits. Despite the long-term effects of this gait are not clear, it seems that it might prevent excessive progress of OA.

Key words: Osteoarthritis, Motion, Knee joint

INTRODUCTION

Due to the fact that the loading of knee joint is highly influential in creation and progress of osteoarthritis (OA), there have been various studies conducted on the dynamic loading of knee in different motions. Most investigations were done on walking on flat and steep surface, going up and down the stairs and returning from squatting position[1-7]. The trend of dynamic loading which changes with the progress of the disease needs to be investigated through longitudinal studies. However, considering the high costly and time-consuming nature of such studies, few longitudinal studies have been conducted. In many cases, cross-sectional studies could be an appropriate replacement for longitudinal studies. The majority of the researches conducted on the trend of dynamic loading changes of the knee joint are among the cross-sectional ones[2,4]. In these studies, the dynamic parameters of different motions in patients with different degrees and severity of the disease have been investigated. In addition, these patients have been compared and contrasted with each other, and with healthy people. In many of these papers, an important parameter which has been compared and contrasted between and among different people is the exterior adduction torque which is exerted on the axis of knee. It can be understood from these papers that the amount of this torque is increased as the interior osteoarthritis increases[5]. Other papers have investigated synthetic parameters and concluded that with the increase of the severity of the disease, the patient would exert lower flexion-extension torque around their knee joint to minimize pain while walking or doing other motions[1, 2, 4]. People with knee osteoarthritis (OA), tend to change their gait to avoid pain and reduce forces on the affected knee[8, 9]. Among these changes, the lateral trunk motion in the frontal plane could be mentioned[10]. While walking, such a motion will result in replacing the center of pressure outward the knee in the *static organ* and theoretically, it moves the reaction force vector towards out of the knee, and consequently shortens the lever arm[11]. Such a gait is clinically observed among patients with knee OA. It has been proposed as a mechanism to reduce and minimize load on the knee joint[10, 11]. It has been reported that in case of mild OA, the lateral trunk motion has been effective in reducing and minimizing the load on the knee and thereby knee pain[11]. This pattern allows OA patients to control the load on the interior part of knee, and the risk of the progress of the disease[12]. The lateral trunk motion reduces the forces exerted on the interior part of the knee, but in the long run, it causes muscle weakness, and development of OA in other joints[13]. However, it seems that, patients with higher severity of OA do not have the necessary hip abductor muscle strength; hence, the other hip during the swing phase will droop. This causes the lateral trunk motion to be done far away from the static limb which is similar to the Trendelengburg gait. The increased distance between the body's center of gravity and the center of knee and Varus alignment seems to create an increased adductor torque in these patients[11].

Considering a wide range of people who are suffering from OA, and regarding the health principle of the society members, achieving strategies and solutions which can predict the sources of this disease and provide solutions to the problems seems pivotally important. This is particularly important because with the increase of age, the normal trend of life for such population is distorted. In WHO-ILAR COPCORD study in 2008 and on 10291 of Tehran inhabitants in Iran, a city which covers one ninth of the whole population, the prevalence of OA was reported to be 15.3%. It is worth mentioning that if these people intend to treat their disease, they need to undergo exorbitant treatment costs.

A longitudinal study demonstrated that the weakness in knee quadriceps increases the risk of knee radiographic OA progress in women[14]. However, there is a clear lack of prospective studies to support its preventive effects. Knees afflicted with OA have weaker quadriceps compared with knees without OA. This is particularly the case when there are symptoms (which might be because of the atrophy due to not using the muscle); however, weakness may exist in knees with no pain[15]. While the strength of quadriceps in protecting the knee and preventing the progress of OA is not clear, a study indicated that having a strong quadriceps does not necessarily reduce the progress of OA[16].

On the other hand, a study with a more precise look at this issue indicated that stronger quadriceps are associated with progressive OA in knees with Varus or Valgus knee deformity or knees with interior or exterior looseness[17]. While the strength of quadriceps is effective in fighting the progress of OA, this per se, depends on other situational variables which influence load distribution. There have been some studies which have focused on the gait of people with OA. The proper method to measure and analyze people's gaits is analyzing gaits through synthetic and systematic data.

MATERIALS AND METHOD

Data collection

After referring the patients to a specialist physician, their height and weight were measured and they were asked to fill out the WOMAC questionnaire. Another phase of data collection was related to kinematic and synthetic data. To do this section it was required to go through the following stages:

Measurements

The required physical measurements for the analysis included the length and width of right and left leg. The correct length of leg is the distance between Anterior Superior Iliac Spines and the Medial Malleolus from the knee joint. The width of the knee is the distance between the interior and exterior epicondyle of thigh.

Positioning the markers

Proper positioning of markers is essential for obtaining exact responses. Therefore, in this section, we have tried to describe the positions and types of markers as much as possible. It should be noted that the markers related to the upper limbs or trunk would be discussed. The trunk markers would be placed directly on the Anterior Superior Iliac Spines, and on the anterior tip of the acromion frills (Table 1).

Statistical analyses

Statistical analysis would be done on the acquired information from groups. These analyses would be categorized into the following sections (calculation of mean in 20% to 80% of static phase):

a) The amount of first peak in the static phase
b) The amount of second peak in the static phase
c) The median of static status and comparison of groups

T-test was used to determine the difference between OA and healthy group. In order to determine the shape and discrepancy in the motion range, the three principles of PCA have been used. These principles represent the major changes which are used for analyzing the differences between groups. In this study, 10 healthy people and 16 patients have participated.

RESULTS

The biggest differences between the healthy group and OA afflicted group were observed in weight, BMI, and pace of walking, whereas there was no difference observed in their age, height and length of their steps ($p \leq 0.05$). A summary of this analysis is demonstrated in table 2.

Table 1: Abbreviations of markers for upper trunk

C7	7th Cervical Vertebrae	Spinous process of the 7th cervical vertebrae
T10	10th Thoracic Vertebrae	Spinous Process of the 10th thoracic vertebrae
CLAV	Clavicle	Jugular Notch where the clavicles meet the sternum
STRN	Sternum	Xiphoid process of the Sternum
RBAK	Right Back	Placed in the middle of the right scapula. This marker has no symmetrical marker on the left side. This asymmetry helps the auto-labeling routine determine right from left on the subject.
LSHO	Left shoulder marker	Placed on the Acromio-clavicular joint
LUPA	Left upper arm marker	Placed on the upper arm between the elbow and shoulder markers. Should be placed asymmetrically with RUPA
LELB	Left elbow	Placed on lateral epicondyle approximating elbow joint axis
LFRA	Left forearm marker	Placed on the lower arm between the wrist and elbow markers. Should be placed asymmetrically with RFRA
LWRA	Left wrist marker A	Left wrist bar thumb side
LWRB	Left wrist marker B	Left wrist bar pinkie side

Table 3 demonstrates that the hip adduction and knee torques are significantly higher in OA patients in comparison with healthy group in the first and second peak in the intermediate phase. In addition, the measures in pelvis or pectoral deformity do not show statistically different features between groups; their size is bigger in OA patients though.

Using Principle Components Analysis (PCA) in the statistical analysis can reduce the input variables. In order to investigate the differences in the range and shape of motion, PCA was used. The three principles represent the major changes in the information indicating significant differences between groups. Significant differences are those with *p-value* less than 0.05. Each of these PCAs is completely distinct from the others. The first PC is related to the loading vectors which have positive coefficients in the static phase for the pelvis and pectoral deformities. Accordingly, PC1 shows the average size of the angle in static position which is variable from one person to another. Significant differences were not observed between groups in PC1. PC2 is a description of clear and significant differences between groups in the TTL and TTP tilts. According to this principle, the OA group showed an increased range of motion in the static phase for both TTL and TTP ($p < 0.05$). The third statistical principle is PC3 which depicts the positive and negative peaks which were observed in both groups.

The knee and hip torques which were statistically analyzed demonstrated greater values in OA group. However, if we intended to compare the pectoral and pelvic tilts between groups, we could not observe a considerable continuous

Table 2: Comparison among different parameters in groups

	Groups	Number	Age	Height	Weight (kg)	BMI	Speed (m/s)
Mean(SD)	Control	10	female	1.61(0.09	69.8(11)	24(3.2)	1.12(0.19)
	OA	16	female	1.58(0.11)	82.3(20)	27.4(5.6)	1.00(0.2)
P-Value			0.61	0.26	0.001	0.0023	0.007

Table 3: Comparison of separated parameters among groups

Groups	Mean(SD)		
	Non-Patient	Patient(OA)	P-value
Knee Adduction Moment(Nm/Kg)			
First Peak	0.3(0.1)	0.52(0.15)	p<0.001
Midstance	0.26(0.1)	0.39(0.15)	p<0.001
Second Peak	0.29(0.11)	0.43(0.15)	p<0.001
Hip Adduction Moment(Nm/kg)			
First Peak	0.77(0.11)	0.79(0.12)	P=0.37
Midstance	0.56(0.1)	0.64(0.11)	
P=0.002			
Second Peak	0.67(0.1)	0.72(0.12)	P=0.02
Thoracic Tilt-Lab(Deg)			
First Peak	1.9(1.6)	1.9(0.2)	P=0.92
Midstance	0.8(1.8)	0.9(2.2)	P=0.88
Thoracic Tilt-Pelvis(Deg)			
First Peak	3.2(5.5)	4.1(3.3)	P=0.32
Midstance	1.3(5.3)	2.4(3.3)	P=042
Second Peak	1.9(5.3)	3.3(3.5)	P=0.18

difference. PCA, anyway, found a significant difference between the ranges of motion of these tilts which indicate the existence of differences between two groups. In addition, people with a higher severity level of OA showed a higher 2nd peak in knee adduction torque compared to people with lower level and severity of OA. However, if we intended to draw a comparison between healthy group and mild level of OA group, the value was higher in the healthy group. On the other hand, the intermediate static phase is a better criterion for comparison which is because of its independence of speed.

Pelvic and pectoral tilts

The investigation of trunk and pelvis motion in knee OA patients showed a higher mean and peak compared with the healthy group; the difference was not considerable though. The positive values in *a* and *b* indicated a motion outward from the static motion.

Knee and hip abduction/adduction torque

The hip and knee adduction torque, similar to pelvic tilts and TTP, have two separate peaks. There is no observable separate and distinct 2nd peak for lateral motion in TTL. The hip and knee adduction torque in patients was significantly higher than the healthy group in the 20 to 80 percent, the intermediate static phase, and in the 1st and 2nd phase.

Considering the obtained results from the knee OA patients, the rate of load increase in wrist, and hip was observed in the frontal plane, which was similar to the one of knees. In addition, a drastic difference was observed between the 1st and 2nd peak of knee adduction torque between people with level 3 of OA and healthy people. On the other hand, the value of the 1st hip abduction torque in OA patients was less than healthy and normal people.

Using a compensatory method, which is to increase the trunk lateral motion, has a great impact on the reduction of knee adduction torque. In addition, this method has a direct relation with the value of the 1st and 2nd peak of this torque when compared with the kinematic of OA patients. On the other hand, the lateral motion angle is four times as much as the pelvic tilt. The knee adduction torque is among the essential parameters in the biomechanical discussion of OA patients. The reason lies in the relation of this parameter with the severity of the disease. The impact of trunk lateral motion could be observed in the knee adduction peak. Results indicated that hip abduction torque reduces the abnormal growth of OA. In addition the weakness of hip abductor muscle could rise the drooping in the hip in the swing phase, and cause a change in the center of mass outward its center. This causes load increase to the central part of knee. The amount of two hip adduction torques was reduced with the progress of the disease. Its reason is that the abductor muscle in healthy people has the required strength to tolerate the lateral trunk motion and changes, whereas in OA patients, the strength of this muscle dwindles and consequently the hip and knee adduction torque is higher in the 1st peak.

DISCUSSION

The statistically investigated knee and hip torques had higher values in OA patients. However, if we wanted to compare the pectoral and pelvic tilts between groups, we could not observe a continuous difference. PCA, however, found a statistically significant difference between the range of motion of these two tilts which is indicative of the difference in tilt amounts between two groups. This finding also existed in Mundermann et al (2005) study. Also, people with higher level and severity of OA have a higher 2nd peak in the knee adduction torque compared to people with lower and milder level OA, and healthy people. However, if we intended to draw a comparison between healthy group and mild level of OA group, the value was higher in the healthy group.

On the other hand, the static intermediate phase could be a better criterion for comparison because of its independence of speed. As previously observed in table 3, its amount was higher in OA patients. However, the magnitude of pelvic external torque is higher during the static phase in all non-continuous parameters except for the 1st peak in knee OA patients. Determining the pelvic tilt has been totally various in different studies. A suggestion was that an alternation of optimum pelvic rotations around rotation axis, trunk tilt and transient tilt should be used so that they could be cautiously compared against anatomical parameters. Baker suggested that measuring pelvic lateral motion in proportion with the height of hip is better than using transient pelvic tilt, lateral motion, or similar ones. In the present study, we have used this method. The information related to the lateral pelvic motion indicated that the pelvic tilt amount beyond the static standard reaches its maximum point in the first 25 percent of this phase, and the second highest tilt, i.e. 2nd peak happens in the 75 percent of the static phase, or the swing phase. This was similar to the results obtained by Hunt et al (2008). In addition, combination of pelvic and trunk and thorax was higher in OA patients when compared with the laboratory coordinate system. However, if we measure the motion of thorax against pelvic measures, its value is higher among healthy people in the static phase. This is a reason why OA patients move their trunk and pelvis more than healthy people. The results helped us conclude that the trunk lateral motion was affected by the pelvic and pectoral tilt, in a way that minor changes in them could exert a major change of load on the knees.

When the pelvic movement and motion was compared among groups, the most important question which arose was that the importance of speed and pace of walking. Therefore, the groups were asked to walk at the speed they wished.

Considering the notions put forward with regard to hip adduction torque, OA patients with mild levels and severity of the disease were able to considerably decrease the knee adduction torque through employing a compensatory strategy (reducing the hip adduction torque). However, as previously mentioned, this strategy in the long run might lead to weakening of hip abductor muscles and it cannot be used as a treatment method. The intermediate level OA patients have a higher adduction torque in the middle of the support phase, an issue which has been mentioned in similar studies. It seems that the increase in hip torque in these patients has considerably prevented the increase of knee adduction torque. Hence, strengthening the hip abductor muscles can be used as a long term treatment method.

CONCLUSION

As it is observed, patients who are suffering from OA have employed different gaits to reduce the pain of their joints. According to the obtained results from this study, it is not clear that these changes can be considered as a mechanism to improve the quality of life among these patients or not. However, we can mention some of the benefits of this lateral motion; it is not possible to suggest a generalization for this case. In addition, the long-term effects of this gait are not clear. It seems, however, that this gait in the long run might prevent excessive progress of this disease.

REFERENCES

1. Felson, D.T., Lawrence, R.C., Dieppe, P.A., Hirsch, R., Helmick, C.G.,Jordan, J.M., Kington, R.S., Lane, N.E., Nevitt, M.C., Zhang, Y.,Sowers,M., McAlindon, T., Spector, T.D., Poole, A.R., Yanovski, S.Z.,Ateshian, G., Sharma, L., Buckwalter, J.A., Brandt, K.D., Fries, J.F., Osteoarthritis: new insights. Part 1: the disease and its risk factors. *Annals of Internal Medicine* 2000; **133**: 635–646.
2. Goldring S.R., and M.B. Goldring. The role of cytokines in cartilage matrix degeneration in osteoarthritis. *Clin. Orthop. Relat. Res.* **427** (Suppl):S27–S36 (2004).
3. Timothy M. Griffin, The role of mechanical loading in the onset and progression of OA. Exercise and Sport Sciences Reviews, (2005).
4. Flores RH., definition and classification of osteoarthritis. Edited by Brandt KD, Doherty M, Oxford: Oxford university press, **1** (1997).
5. Flores RH., op. cit. pp. 2-11
6. Oliveria SA. Incidence of symptomatic hand, hip, and knee osteoarthritis among patients in a health maintenance organization. *Arthritis Rheum* **38**: 1134-41 (1995).
7. Kallman, D., et al., The longitudinal course of hand osteoarthritis in a male population. *Arthritis & Rheumatism,* **33**(9): 1323-1332 (1990).
8. Seedhom BB. Conditioning of cartilage

during normal activities is an important factor in the development of osteoarthritis. *Rheumatology* **45**: 146-149 (2006).

9. Roos EM. Joint injury causes knee osteoarthritis in young adults. *Curr Opin Rheumatol* **17**: 195-200 (2005).
10. Andriacchi TP, Dyrby CO. Interactions between kinematics and loading during walking for the normal and ACL defficient knee. *J Biomech* **38**: 293–298 (2005).
11. Georgoulis AD, Papadonikolakis A, Papageorgiou CD, Mitsou A, et al. Three-dimensional tibiofemoral kinematics of the anterior cruciate ligament defficient and reconstructed knee during walking. *Am J Sports Med* **31**: 75-79 (2003).
12. Kenton R. Kaufman. Gait characteristics of patients with knee osteoarthritis. *Journal of Biomechanics*. **34**: 907-915 (2001).
13. A. J. Baliunas. Increased knee joint loads during walking are present in subjects with knee osteoarthritis. *Osteoarthritis and Cartilage*. **10**: 573–579 (2002).
14. Gyry AN, Chao EYS, Stauffer RN. Functional evaluation of normal and pathologic knees during gait. *Arch Phys Med Rehabil* **57**: 571–7 (1976).
15. Brinkman JR, Perry J. Rate and range of knee motion during ambulation in healthy and arthritic subjects. *Phys Ther* **65**:1055–60 (1985).
16. Messier SP, Loeser RF, Hoover JL, Semble EL, Wise CM. Osteoarthritis of the knee: effects on gait, strength, and flexibility. *Arch Phys Med Rehabil* **73**: 29–36 (1992).
17. Messier SP, Gutekunst DJ, Davis C, *et al*. Weight loss reduces knee-joint loads in overweight and obese older adults with knee osteoarthritis. *Arthritis Rheum* **52**: 2026-2032 (2005).