www.journalmsr.com

Journal of Musculoskeletal Surgery and Research

Saudi Orthopedic Association

*Original Article*

# Effect of knee pain on muscles imbalance and physical limitation in individuals with bilateral knee osteoarthritis: A comparative cross-sectional study

Shabana Khan, MS SPT[1], Huma Waseem, BS DPT[1], Uzair Ahmad, MS OMPT[1]

[1]Department of Rehabilitation, Northwest Institute of Health Sciences, Peshawar, Pakistan.

***Corresponding author:**
Uzair Ahmad,
Department of Rehabilitation,
Northwest Institute of Health Sciences, Peshawar, Pakistan.

azmatuzair125@gmail.com

Received: 20 November 2023
Accepted: 11 January 2024
Epub Ahead of Print: 23 February 2024
Published: 30 April 2024

**DOI**
10.25259/JMSR_243_2023

**Quick Response Code:**

## ABSTRACT

**Objectives:** When osteoarthritis (OA) affects the knee, it causes muscle imbalance and physical limitations. This study aimed to determine the impact of knee pain on quadriceps strength, hamstring length, and physical limitations in individuals with bilateral knee OA.

**Methods:** A cross-sectional study at Khyber Teaching Hospital and Northwest General Hospital, Peshawar, included individuals aged 50–65, who met the American College of Rheumatology criteria. Subjects diagnosed with bilateral knee OA (grade II or greater on the Kellgren–Lawrence grading scale) and experiencing pain in both knees (numeric pain rating scale [NPRS] score ≥ 1) were selected through purposive sampling ($n$ = 70). Data collection involved the NPRS, modified belt stabilizer hand-held dynamometer, active knee extension test, and Western Ontario and McMaster Universities Arthritis Index (WOMAC) Urdu version questionnaire. Measurements from both knees assessed quadriceps muscle strength, hamstring length, and physical limitations.

**Results:** The median interquartile range (IQR) of quadricep strength for the more painful knee was 0.53 (0.36) Nm/kg and 1.35 (0.34) Nm/kg for the less painful knee showing a significant difference in quadriceps strength ($P$ < 0.01). In terms of hamstring length, the more painful knee had a median (IQR) of 29.0 (2.0) degrees whereas the less painful knee recorded 11.0 (6.0) degrees indicating a significant difference ($P$ < 0.01). Likewise, there was a significant difference in WOMAC scores between the less painful and more painful knees ($P$ < 0.01).

**Conclusion:** This study found that individuals experiencing more knee pain demonstrated decreased quadriceps muscle strength and increased hamstring muscle tightness. In addition, those with more painful knees exhibited greater physical limitations in bilateral knee OA.

**Keywords:** Degenerative joint disease, Flexibility deficit, Knee osteoarthritis, Muscle strength dynamometers, Strength deficit

## INTRODUCTION

Osteoarthritis (OA) of the knee joint accounts for nearly four-fifths of the global burden of OA, and its prevalence increases with age and weight gain.[1] Globally, knee OA constitutes 20% of all musculoskeletal burdens with its frequency rising as individuals age.[2] Globally, 9.6% of

**How to cite this article:** Khan S, Waseem H, Ahmad U. Effect of knee pain on muscles imbalance and physical limitation in individuals with bilateral knee osteoarthritis: A comparative cross-sectional study. J Musculoskelet Surg Res. 2024;8:119-24. doi: 10.25259/JMSR_243_2023

males and 18% of females aged 60 and above are impacted by symptomatic OA, according to the World Health Organization. Moreover, approximately 80% of individuals with OA experience restricted joint motion, and 25% of those with OA struggle to perform their daily activities. In Asia, the elderly population aged 65 and above reached 7% in 2008 with expectations that it will increase to 16% by 2040.[3] In Pakistan, the prevalence of knee OA is 28% in rural areas and 25% in urban areas.[4] This condition is more common among females and older individuals, particularly those aged between 45 and 65.[5]

The OA can affect any joint but most frequently affects the knee joint.[6] Knee OA can be characterized using the clinical-radiographic classification criteria established by the American College of Rheumatology, which includes knee pain followed by at least one of the following three symptoms in conjunction with the development of osteophytes visible on knee radiography: Stiffness in the morning lasting for a duration of <30 min, age >50 years, and crepitus during knee movements.[7] Knee OA has multiple risk factors including advanced age, genetics, overweight or obesity, female sex, knee joint trauma, overuse of the knee, poor muscular strength, low bone mineral density, and prolonged squatting and kneeling positions.[8]

The pain around the joint and disuse are major factors contributing to the development of muscle imbalance.[9] Muscle imbalance can also lead to impaired gait rhythm, decreased walking speed, and reduced walking duration in patients with chronic knee OA.[10] Among the muscles, the quadriceps is the most important in maintaining strength across the knee joint.[11] Quadricep muscle strength plays a key role in reducing the severity of knee OA, but their weakness can significantly contribute to the advancement of this condition.[12] The previous studies examining muscle weakness have found that individuals with lateral knee OA and/or medial knee OA are four times more prone to developing muscle weakness compared to healthy counterparts affecting both muscle flexors and extensors.[13]

A recent study uncovered that individuals with knee extensor weakness face a 1.65 fold increased risk of developing symptomatic knee OA and a 1.58 fold increased risk of radiographic knee OA. Extensor knee muscles provide joint stability and have a cushioning effect. However, reduced muscle power can result in alterations in the joint's mechanical strain contributing to the onset of knee OA.[14] Reduced muscle power can lead to abnormal knee joint mechanics. In middle age, the strength and force of knee extensor muscles decrease leading to knee extensor fatigue and reduced muscle activity. This reduction in knee extensor activity is strongly correlated with the advancement of knee OA. It changes the knee flexion angle during walking, especially in individuals with a higher probability of knee OA, post anterior cruciate ligament rupture or pre-existing knee OA.[15] In 2021, a study observed that patients experiencing knee pain exhibited decreased muscular strength and an increased body mass index (BMI).[16]

Prior research has predominantly examined the connection between knee pain and quadriceps muscle. Yet, there is a dearth of studies delving into the impact of knee pain on variables such as quadricep muscle strength, hamstring length, and overall physical limitations. This study seeks to address this gap by investigating the influence of knee pain on muscle imbalances and physical limitations, specifically in individuals diagnosed with bilateral knee OA.

## MATERIALS AND METHODS

### Participants

From January 2022 to June 2022, a comparative cross-sectional study was conducted at Khyber Teaching Hospital and Northwest General Hospital Peshawar, Pakistan. The sample size was calculated by the Open Epi tool. The parameters used to calculate the sample size were as follows: 95% confidence interval and population size ($n$ = 85). The calculated sample size was $n$ = 70. The purposive sampling technique was used to recruit the study participants. All the willing participants were briefed about the purpose and procedure of this study. The inclusion criteria were both sexes aged between 50 and 65 years based on the criteria by the American College of Rheumatology, known patient of bilateral knee OA with grade II or greater based on the knee radiographs confirmed by orthopedic doctor following Kellgren–Lawrence grading scale, pain experienced in both knees should be equal to or > 1 on the numeric pain rating scale (NPRS) with a minimum difference of 1 point on the NPRS between the two knees.[17] The exclusion criteria were known cases of polyarthritis, systemic inflammatory arthropathies, underwent lower extremity surgery within the past year (e.g., knee arthroplasty), participants used pain killers or supervised rehabilitation past week, participants received steroid injections in the knee joint in past month, known case of neurological and musculoskeletal related conditions, which affect their balance or movement and physical activity (Multiple Sclerosis, Parkinson disease, Osteomalacia, Meniere's disease, and Benign paroxysmal positional vertigo), and participants having history of malignancy or trauma.

### Outcome measures

Pain intensity was evaluated using the NPRS, which ranges from 0 to 10. Here, "0" signifies no pain, while "10" denotes pain of the most severe nature imaginable.[18] A Camry digital hand-held dynamometer (HHD) was employed to quantify the strength of the quadriceps muscle. A modified HHD is considered a valid and reliable tool for measurement.[19] For evaluation of knee extensor strength, the patient is asked to perform three to five repetitions of warm-up with 15–90 s of rest with each repetition. The warm-up protocols included marching on spot and half squats exercise. For testing, the patient was seated with 90° of knee flexion. A belt was attached to the leg and was positioned approximately 5 cm proximal to the distal aspect of the lateral malleolus. The other end of the modified belt-stabilizer was set up to position the HHD against the back of a treatment table leg using a flat attachment. When the participant extended his or her knee, the HHD was compressed against the table leg, and force was measured [Figure 1]. Torque is computed by multiplying the force by the distance, which is measured from the center of the knee to the fixation point of the dynamometer.[20] This torque formula was measured by an online application, "PhysioPhraxis" developed by Scot Morrison (A board-certified orthopedic physical therapist). When the knee is at a 90° angle, in elderly males, the combined torque for knee extension is around 1.77 Nm/kg.[21] During the assessment of quadriceps strength using HHD, precautions were taken to isolate the muscle group and minimize the influence of other muscles. Participants were positioned appropriately ensuring stabilization of the pelvis and restricting movements of non-target muscles. The HHD device was carefully placed on the distal part of the leg to measure the force generated by the quadriceps specifically. In this study, isometric muscle strength testing was conducted to evaluate the strength of the quadriceps.

The hamstring length was evaluated using the active knee extension (AKE) test. Participants were instructed to actively extend the knee with the foot in a relaxed plantar flexion. The test involved stretching the hamstring muscles, and the degree of knee flexion was then recorded by universal goniometer. The benchmarks for AKE angle differ between males and females with a threshold of >33.0° for males and >23.4° for females.[22] The participants' physical function was measured utilizing the Western Ontario and McMaster Universities Arthritis Index (WOMAC) Urdu version. This self-administered questionnaire comprises 24 items divided into three subscales: Pain, Stiffness, and Physical Function. Higher WOMAC scores indicate severe functional limitations.[23]

Official permission letters were obtained from the relevant hospitals for data collection. All willing participants were informed about the study's purpose and procedures. After obtaining consent, participants were screened based on inclusion and exclusion criteria. Measurements were taken from both knees of each individual. Using the NPRS, a composite pain score (ranging from 0 to 10 points) for both knees was acquired followed by individual scores for each knee to identify the leg experiencing more and less pain.

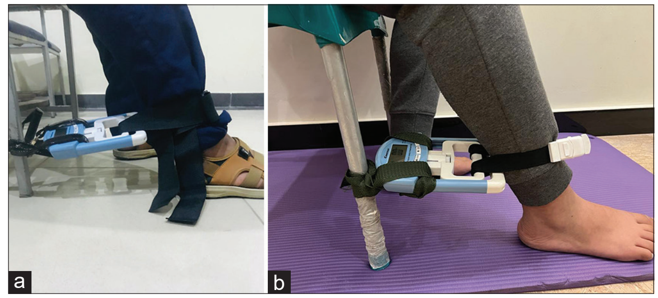


**Figure 1:** (a and b) Hand-held dynamometer setup for measuring quads strength.

**Table 1:** Characteristics of demographics ($n$=70).

| Variables | Frequency | Percentage | Mean (SD) |
|---|---|---|---|
| Age (*years*), mean (SD) | | | 55.25 (4.90) |
| Height (*feet*), mean (SD) | | | 5.54 (0.17) |
| Weight (*kg*), mean (SD) | | | 71.94 (10.22) |
| BMI, mean (SD) | | | 21.71 (3.08) |
| Sex | | | |
| Male | 18 | 25.7 | |
| Female | 52 | 74.3 | |
| More painful knee | | | |
| Right | 31 | 44.3 | |
| Left | 39 | 55.7 | |
| Knee grades (*Kellgren–Lawrence grading scale*), mean (SD) | | | |
| Right | | | 2.47 (0.65) |
| Left | | | 2.60 (0.54) |

SD: Standard deviation, BMI: Body mass index, *n*: Sample size.

Simultaneously, measurements were taken for quadriceps muscle strength, hamstring length, and physical limitations.

### Data analysis

The data was analyzed utilizing Statistical Package for the Social Sciences version 25. Knee pain was classified into two groups, namely, more pain and less pain, and subsequently compared with knee strength, hamstring length, and WOMAC scores. Normality was assessed using a Shapiro-Wilk test. An independent $t$-test was performed for normally distributed data to detect significant differences in variables between the less and more painful knees. In cases of non-normally distributed data, a Mann–Whitney U-test was applied.

## RESULTS

Seventy bilateral knee OA participants with a mean age of 55.25 ± 4.90 years were taken from the Orthopedic Department of Khyber Teaching Hospital and the physiotherapy department of Northwest General Hospital, Peshawar. Out of 70 participants, the frequency and percentage of males were 18 (25.7%) and females were 52 (74.3%). Among the cases

**Table 2:** Differences of variables between more and less painful knees.

| Variable | Group | N | Median (IQR) | Mean (SD) | *P*-value |
|---|---|---|---|---|---|
| NPRS (*0–10*) | More painful knee | 70 | 8.00 (1.00) | | [a]0.000 |
| | Less painful knee | 70 | 4.00 (2.00) | | |
| Quadriceps strength | More painful knee | 70 | 0.53 (0.36) | | [a]0.000 |
| (*Knee torque, Nm/kg*) | Less painful knee | 70 | 1.35 (0.34) | | |
| Hamstring length | More painful knee | 70 | 29.00 (2.00) | | [a]0.000 |
| (*Active Knee Extension Test, degree*) | Less painful knee | 70 | 11.00 (6.00) | | |
| WOMAC scores | More painful knee | 70 | | 50.17 (6.97) | [b]0.000 |
| | Less painful knee | 70 | | 18.47 (6.54) | |

Significance level: $P<0.01$, NPRS: Numeric pain rating scale, WOMAC: Western Ontario and McMaster universities arthritis index, [a]Mann–Whitney U-test, [b]Independent *t*-test, N: Number of participants, IQR: Interquartile range, SD: Standard deviation

of bilateral knee OA, the left knee was more painful with a frequency of 39 (55.5%), then right knee 31 (44.3%). The mean BMI of the participants was 21.7 ± 3.0. The left knee was more severe with a mean and standard deviation (Std) of 2.60 ± 0.5 grade than the right knee [Table 1].

The median interquartile range (IQR) of pain intensity in a more painful knee was 8.00 (1.00) while in a less painful knee was 4.00 (2.00). There was a significant difference between the pain intensity in a more painful knee and a less painful knee with $P < 0.01$ [Table 2].

The median (IQR) of quadriceps muscle strength in a more painful knee was 0.53 (0.36) while in a less painful knee was 1.35 (0.34). There was a significant difference between the quadriceps strength in a more painful knee and a less painful knee with $P < 0.01$ [Table 2].

The median (IQR) of hamstring length in a more painful knee was 29.00 (6.00) while in a less painful knee was 11.00 (6.00). A significant difference was found between the hamstring length in a more painful knee and a less painful knee with $P < 0.01$ [Table 2].

The mean (std) of WOMAC scores in a more painful knee was 50.17 (6.97) while in a less painful knee was 18.47 (6.54). There was a significant difference in WOMAC scores between a more painful and less painful knee with $P < 0.01$ [Table 2].

## DISCUSSION

Individuals with bilateral knee OA showed a significant difference in quadriceps muscle strength between less painful and more painful knees. The quadriceps muscle was weaker in patients having more pain. These findings were consistent with a study that found that there was a decrease in quadriceps muscle cross-sectional area and an increase in adipose tissue in patients with knee OA.[24] Another study clearly reported that patients with severe knee OA survivors showed a significant decrease in quadriceps rate of force development compared to those with early knee OA.[25] A previous study shows decreased quadriceps and hamstring strength in individuals with knee OA compared to normal individuals.[26]

Our study found a significant difference in hamstring length between a less painful knee and a more painful knee. The hamstring length was more compromised in patients having more pain. However, a previous study reported that flexibility of the iliotibial (IT) band and quadriceps muscle strength decreases in grade II and grade III radiographic knee OA. In addition, the flexibility of the IT band and quadriceps muscle strength was more compromised in grades II and III than in grade 0.[27]

Our study reported that physical limitation was more affected in patients with more knee pain. This finding was reported in a study that the strength of the quadriceps is significantly correlated with pain in the knee and disability of the community. However, psychological activation is considered.[28] A longitudinal study showed that knee pain was strongly related to quadriceps weakness.[29] Another study showed that patients with knee OA are associated with functional limitations along with knee instability.[30] Another study showed that functional limitation increases as muscle strength decreases. In knee OA, muscle weakness is caused by functional limitations.[31]

This study has certain limitations. First, this study measures the quadriceps strength at a 90° angle of knee flexion while the literature supports that the peak torque value is highest at 60° of knee flexion. Due to feasibility in the clinic, the knee flexion angle was selected at 90°. Second, this study used HHD for strength measurement while a biodex is more valid for measuring quadriceps strength. It is recommended that future studies focus on other muscles for imbalance and its effects on the radiographic severity of knee OA.

## CONCLUSION

This study found that individuals experiencing more knee pain demonstrated decreased quadriceps muscle strength and increased hamstring muscle tightness. In addition, those with more painful knees exhibited greater physical limitations in bilateral knee OA.

### Recommendations

In light of the study's findings, rehabilitation programs need to be tailored to address both quadriceps strength and hamstring flexibility acknowledging their significant roles in the context of bilateral knee OA. Early intervention strategies are crucial focusing on raising awareness among healthcare professionals and patients about the benefits of timely diagnosis and intervention in managing knee OA effectively. Further research is encouraged to explore the diverse effectiveness of interventions including pharmacological and non-pharmacological approaches in mitigating the complex interplay between knee pain, muscle imbalance, and physical limitations. In addition, investigating the long-term outcomes of tailored rehabilitation programs on overall quality of life could provide valuable insights for refining treatment approaches and enhancing patient outcomes.

## AUTHORS' CONTRIBUTIONS

SK and HW contributed to the design, literature search, clinical studies, and data acquisition. UA contributed to concepts, statistical analysis, and manuscript preparation and editing. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

## ETHICAL APPROVAL

The research/study approved by the Institutional Review Board at Northwest Institute of Health Science, Northwest General Hospital Peshawar, number 04/09/33/NWIHS-COPT/IRB/2022, dated 17/12/2021.

## DECLARATION OF PATIENT CONSENT

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for 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.

## USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY FOR MANUSCRIPT PREPARATION

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

## CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

## FINANCIAL SUPPORT AND SPONSORSHIP

This study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## REFERENCES

1. Cui A, Li H, Wang D, Zhong J, Chen Y, Lu H. Global, regional prevalence, incidence and risk factors of knee osteoarthritis in population-based studies. EClinicalMedicine 2020;29-30:100587.
2. Leyland KM, Gates LS, Sanchez-Santos MT, Nevitt MC, Felson D, Jones G, *et al.* Knee osteoarthritis and time-to all-cause mortality in six community-based cohorts: An international meta-analysis of individual participant-level data. Aging Clin Exp Res 2021;33:529-45.
3. Zamri NA, Harith S, Yusoff NA, Hassan NM, Qian Ong Y. Prevalence, risk factors and primary prevention of osteoarthritis in Asia: A scoping review. Elderly Health J 2019;5:19-31.
4. Iqbal MN, Haidri FR, Motiani B, Mannan A. Frequency of factors associated with knee osteoarthritis. J Pak Med Assoc 2011;61:786-9.
5. Taj S, Tayaba H. A comparison of health-related quality of life among knee osteoarthritis patients in two cities in Pakistan. Clin Surg Res Commun 2019;3:20-5.
6. Katz JN, Arant KR, Loeser RF. Diagnosis and treatment of hip and knee osteoarthritis: A review. JAMA 2021;325:568-78.
7. Lee S, Kwon Y, Lee N, Bae KJ, Kim J, Park S, *et al.* The prevalence of osteoarthritis and risk factors in the Korean population: The Sixth korea national health and nutrition examination survey (VI-1, 2013). Korean J Fam Med 2019;40:171-5.
8. Heidari B. Knee osteoarthritis prevalence, risk factors, pathogenesis and features: Part I. Caspian J Intern Med 2011;2:205-12.
9. McLeod K, Morley S, Matsushima A. Vibromyographic analysis of knee muscle imbalances in knee osteoarthritis. J Biomed Sci Eng 2012;5:190-7.
10. Gezginaslan Ö, Öztürk EA, Cengiz M, Mirzaoğlu T, Çakcı FA. Effects of isokinetic muscle strengthening on balance, proprioception, and physical function in bilateral knee osteoarthritis patients with moderate fall risk. Turk J Phys Med Rehabil 2018;64:353-61.
11. Noehren B, Kosmac K, Walton RG, Murach KA, Lyles MF, Loeser RF, *et al.* Alterations in quadriceps muscle cellular and molecular properties in adults with moderate knee osteoarthritis. Osteoarthritis Cartilage 2018;26:1359-68.
12. Segal NA, Glass NA. Is quadriceps muscle weakness a risk factor for incident or progressive knee osteoarthritis? Phys Sportsmed 2011;39:44-50.
13. van Tunen JA, Dell'Isola A, Juhl C, Dekker J, Steultjens M, Thorlund JB, *et al.* Association of malalignment, muscular

dysfunction, proprioception, laxity and abnormal joint loading with tibiofemoral knee osteoarthritis - a systematic review and meta-analysis. BMC Musculoskelet Disord 2018;19:273.
14. Krishnasamy P, Hall M, Robbins SR. The role of skeletal muscle in the pathophysiology and management of knee osteoarthritis. Rheumatology 2018;57:iv22-33.
15. Hafer JF, Kent JA, Boyer KA. Physical activity and age-related biomechanical risk factors for knee osteoarthritis. Gait Posture 2019;70:24-9.
16. Ericsson YB, McGuigan FE, Akesson KE. Knee pain in young adult women- associations with muscle strength, body composition and physical activity. BMC Musculoskelet Disord 2021;22:715.
17. Altman RD. Criteria for classification of clinical osteoarthritis. J Rheumatol Suppl 1991;27:10-2.
18. Young IA, Dunning J, Butts R, Mourad F, Cleland JA. Reliability, construct validity, and responsiveness of the neck disability index and numeric pain rating scale in patients with mechanical neck pain without upper extremity symptoms. Physiother Theory Pract 2019;35:1328-35.
19. Lesnak J, Anderson D, Farmer B, Katsavelis D, Grindstaff TL. Validity of hand-held dynamometry in measuring quadriceps strength and rate of torque development. Int J Sports Phys Ther 2019;14:180-7.
20. Hansen EM, McCartney CN, Sweeney RS, Palimenio MR, Grindstaff TL. Hand-held dynamometer positioning impacts discomfort during quadriceps strength testing: A validity and reliability study. Int J Sports Phys Ther 2015;10:62-8.
21. Šarabon N, Kozinc Ž, Perman M. Establishing reference values for isometric knee extension and flexion strength. Front Physiol 2021;12:767941.
22. Yıldırım M, Tuna F, Demirbağ Kabayel D, Süt N. The cut-off values for the diagnosis of hamstring shortness and related factors. Balkan Med J 2018;35:388-93.
23. Bellamy N, Wilson C, Hendrikz J, Whitehouse SL, Patel B, Dennison S, *et al.* Osteoarthritis index delivered by mobile phone (m-WOMAC) is valid, reliable, and responsive. J Clin Epidemiol 2011;64:182-90.
24. Mohajer B, Dolatshahi M, Moradi K, Najafzadeh N, Eng J, Zikria B, *et al.* Role of thigh muscle changes in knee osteoarthritis outcomes: Osteoarthritis initiative data. Radiology 2022;305:169-78.
25. Suzuki Y, Iijima H, Nakamura M, Aoyama T. Rate of force development in the quadriceps of individuals with severe knee osteoarthritis: A preliminary cross-sectional study. PLoS One 2022;17:e0262508.
26. Shukla M, Parmar L. Compression of hamstring and quadriceps muscles strength in patients with osteoarthritis of knee and normal individual. J Pharm Res Int 2021;33:1-7.
27. Moallem H, Barati AH, Shirzad Araghi E, Kazemnejad A. The comparison of knee joint muscles flexibility between women with and without radiographic knee osteoarthritis. J Rehabil Sci Res 2020;7:118-23.
28. O'Reilly SC, Jones A, Muir KR, Doherty M. Quadriceps weakness in knee osteoarthritis: The effect on pain and disability. Ann Rheum Dis 1998;57:588-94.
29. Glass NA, Torner JC, Frey Law LA, Wang K, Yang T, Nevitt MC, *et al.* The relationship between quadriceps muscle weakness and worsening of knee pain in the MOST cohort: A 5-year longitudinal study. Osteoarthritis Cartilage 2013;21:1154-9.
30. van der Esch M, Knoop J, van der Leeden M, Voorneman R, Gerritsen M, Reiding D, *et al.* Self-reported knee instability and activity limitations in patients with knee osteoarthritis: Results of the Amsterdam osteoarthritis cohort. Clin Rheumatol 2012;31:1505-10.
31. van der Esch M, Holla JF, van der Leeden M, Knol DL, Lems WF, Roorda LD, *et al.* Decrease of muscle strength is associated with increase of activity limitations in early knee osteoarthritis: 3-year results from the cohort hip and cohort knee study. Arch Phys Med Rehabil 2014;95:1962-8.