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Research Article

Impact of Knee Pathology on Performance of Functional Tests

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Abstract

Background and Purpose: Knee pain and increasing difficulty in performing basic tasks such as kneeling or squatting can affect quality of life and cause disability. This study examined the ability in performing functional tasks in patients with different levels of knee joint pathology.

Methods: This was a cross-sectional comparative study. Patients with advanced osteoarthritis (OA) of the knee joint were compared with workers with an occupational knee injury and healthy volunteers. Subjects were asked to complete tall and full kneeling. Half kneeling compared general core stability between injured workers and the control group. Double knee squat documented depth and quality of weight-bearing knee flexion. Static and dynamic balance tests examined the neuromuscular integrity. All tests are reported to be valid clinical tests for functional assessment. All subjects provided consent and approval for use of human participants was obtained from the Research Ethics Board of the Sunnybrook Health Sciences Centre. Statistical differences examined group differences using Fisher's Exact tests.

Results: Data of 30 subjects (10 in each group) were used for analysis. The OA group was older (74 years of age, $p < 0.0001$) without a statistically significant difference between injured workers and the control group (48 vs. 41, $p = 0.23$). The OA group showed inferior results in all functional tests (p values ranging from 0.02 to < 0.0001) with no statistically significant differences between workers and the control group in squatting, half kneeling or static balance tests. Statistically significant differences between workers and the control group was in full kneeling ($p = 0.02$), reaching forward while kneeling ($p = 0.02$), and clockwise dynamic test ($p = 0.04$) in favor of the control group.

Conclusion: The results of this study indicates deficiency in joint mobility, muscular strength and neuromuscular coordination in older patients with OA of the knee joint. Patients with work-related knee injuries appear to have a relatively well-preserved ability to perform majority of the functional tests. Administration of knee functional tests may help to diagnose those who would benefit from a more comprehensive rehabilitation program, focusing on mobility and neuromuscular coordination.

Keywords: *Functional Tests; Neuromuscular; Kneeling; Squatting; Compensable Injury*

Background

Osteoarthritis (OA) of the knee joint is a disabling condition leading to joint replacement in advanced cases. Inability to kneel or squat is a sequel of progressive OA with continuous deterioration of the static and dynamic balance. Difficulty in performing functional activities is related to progressive changes in joint surface loading, muscle strength and voluntary activation, muscle size, and neuromuscular deficits, which are associated with age-related degenerative changes of the knee joint [1-5]. Research has demonstrated that proprioception of the patients with articular cartilage lesions of the knee joint is significantly poorer compared to that of the control group [1]. The OA related lesions affect different structures such as articular cartilage, periarticular muscles, synovium, and joint capsule stiffness. Geng., *et al*. report that internal factors such as inflammation, metabolism, hormonal changes in addition to mechanical overload play important roles in accelerating the progression of arthritis in the knee joint [4]. Systematic reviews have shown that knee OA is associated with decreased motor cortex activation during a force matching motor task and dysfunction of the quadriceps and triceps surae muscles [2].

Traditional functional performance tests in patients with OA of the knee joint are the 30 second sit to stand and walking within a certain distance [6]. These functional tests, however may not be optimal to measure the neuromuscular control of the knee joint in isolation. Kneeling and squatting are validated and perhaps better indicators of the overall functional stability of the joint [7,8] and core and trunk stability [9,10]. The static and dynamic balance tests are also accurate tests for assessing neuromuscular impairment secondary to a wide spectrum of the musculoskeletal and neurological disorders [11-13].

Purpose of the Study

The purpose of this study was to examine the impact of knee pathology on ability to perform kneeling, squatting and balance activities.

Methods

This cross-sectional study compared three groups of subjects. Group 1 were patients with radiographic signs of OA of the knee joint who were attending a structured rehabilitation program to delay or prevent joint arthroplasty. Group 2 were individuals who had sustained a compensable knee injury and were receiving rehabilitation. The assessment of groups 1 and 2 was conducted prior to initiation of the rehabilitation program. Group 3 were healthy volunteers without any recent history of low back pain or lower extremity conditions. All patients with chronic, generalized joint pain, fibromyalgia, history of fracture, dislocation, inflammatory arthritis, or infection were excluded. All subjects provided consent and approval for use of human participants was obtained from the Research Ethics Board of the Sunnybrook Health Sciences Centre.

Functional tests

Functional tests included kneeling, squatting, and static and dynamic balance tests. All subjects were asked to complete tall kneeling that occurs in upright position at 90° of knee flexion and full kneeling, which occurs with knee flexion with full heel-gluteus contact. Patients who could achieve full kneeling were then asked to reach forward with their arms in front of the body (Figure 1-3).

Half kneeling as the most challenging test was performed only by the injured workers and the control group and assessed general core stability in the younger age groups. During this test, subjects folded their arms across the chest. Three pieces of tape were placed parallel to each other, at 15 cm apart. A red tape was for the resting leg and the two parallel black tapes were for the opposite leg. To achieve a half kneeling posture, the knee of the resting leg was placed down at a 90-degree angle directly under the hip with the leg and back of the

Figure 1: *Tall kneeling, subject assumed and maintained position for 10 seconds while crossing arms in front of the chest. This was rated as no/yes with or without difficulty.*

Figure 2: *Full kneeling: Subject was asked to sit with full heel-gluteus contact. This was rated as no/yes with or without difficulty.*

Figure 3: *Full Kneeling with reaching forward. Subject reached forward with arms in front of the body after completion of full kneeling. This was rated as no/yes with or without difficulty.*

foot rested on the floor. Initially, the opposite side foot was about 30 cm lateral to the rested leg. In the second stage, it was brought to 15 cm to the rested foot and finally, both feet were placed on the red tape to assess the ability to meet a greater balancing challenge (Figure 4-6). This test was rated as able/unable to perform.

Figure 4-6: *Half-knelling test examined core stability in injured workers and controls. Subject placed the resting leg on a red tape and the opposite foot on parallel tapes. Ability to achieve three positions was rated as able/not able.*

Double knee squat documented depth and frontal/sagittal alignment of the knee flexion. Subjects could use a bar for support in front of them as needed. Subjects were encouraged to stand with feet shoulder width apart, maintaining a good posture with chest up, shoulders back, and a normal arc in the lower back throughout the movement. The knees did not go ahead of the toes. Subjects were then asked to squat as much as tolerated without discomfort with their heels flat on the floor and return to standing position slowly. Depth was documented as < horizontal, =horizontal, and >horizontal. Deviation of the trunk in frontal and sagittal planes was documented as yes and no (Figure 7-9).

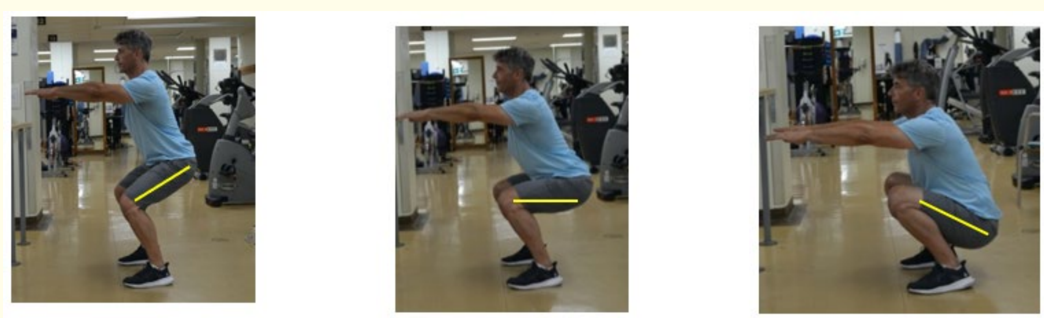

Figure 7-9: *Double leg squat test examined depth (<horizontal, =horizontal and >horizontal) and alignment in sagittal and frontal planes. Subjects squatted within their comfort level using an external support as necessary.*

Static and dynamic balance tests examined the balance of the stance leg, while reaching with the opposite side foot. Subjects were asked to extend their right foot on each line as far as they could comfortably reach and return to the central square each time. The test direction order, relative to stance leg was performed in clockwise and counter-clock wise directions. The result was categorized in two groups: 1) able to maintain steady balance/ minimal postural sway without support, and 2) loses balance with moderate postural sway/ unable to perform (Figure 10 and 11).

Figure 10 and 11: *Static and dynamic balance tests examined the steadiness and balance of the subject in the clockwise and counterclockwise directions on five lines respectively. In the dynamic test, the subject was asked to avoid touching the floor with the toes. The test was rated as A: able to maintain steady balance without support/Maintains balance with minimal postural sway without external support, B: requires support, has postural sway/Unable to perform.*

Statistical analysis

Descriptive statistics were performed for variables of interest. Statistical differences were calculated between three (all groups) and two (workers and control) groups using Fisher's Exact tests. Statistical results are reported using 2-tailed p values with significance set at $p < 0.05$. Statistical analysis was performed using SAS® version 9.4 (SAS® Institute, Cary, NC).

Results

Data of 30 subjects (10 in each group) were used for analysis. Injured workers had a variety of diagnoses, involving ligamentous and muscle structures (4 ligamentous injuries, 6 meniscus tears, and 8 muscle tears/strains) with overlapping injuries. The job demands were distributed evenly in injured workers (3 light/sedentary, 4 medium, and 3 heavy) with the control group having three light/sedentary and seven medium physically demanding jobs.

Table 1 demonstrates group differences among all three groups and between the injured workers and control group. The OA group was older without any statistically significant differences between the injured workers and control group (48 vs. 42 years of age). While the percentage of female/male in the OA and control groups was identical, majority (60%) of the injured workers were males.

With respect to tall, full, and reaching forward while kneeling, the OA group showed inferior results in all activities (Table 1). Injured workers and healthy volunteers had similar abilities to perform tall kneeling. There was a statistically significant difference between workers and the control group in full kneeling and reaching forward in favor of the control group.

Double knee squat was limited to ≤ 90° in nine (90%) of the OA patients. This was variable in other groups, showing that passing beyond horizontal might not be a feasible ability even in healthy individuals. Sagittal and frontal deviation while descending was affected in the OA patients. There was no significant difference in frontal or sagittal alignment between workers and healthy volunteers.

The OA group showed inferior results in static and dynamic balance as compared with other groups. The injured workers were not different from the control group in static balance tests but had more difficulty in clockwise dynamic test, showing poorer balance (Table 1).

Variables	OA Group	Injured Workers Group	Control Group	Statistics, P value 3 groups	Statistics, P value 2 groups
Age, y, mean (SD)	73 (8)	48 (13)	42 (10)	F value = 25.05, p < 0.0001	F value, 1.53, P = 0.23
Sex, No. (%)					
Female/Male	9/1	4/6	9/1	FET = 0.003, p = 0.02	FET = 0.01, p = 0.056
Kneeling (yes/no)					
Tall kneeling	3/7	8/2	10/0	FET: 0.002, p = 0.003	FET: 0.23, p = 0.47
Full kneeling	0/10	3/7	9/1	FET: 0.0001, p = 0.001	FET: 0.09, p = 0.02
Reaching forward	0/10	3/7	9/1	FET: 0.0001, p = 0.001	FET: 0.09, p = 0.02
Half kneeling					
• Stage 1	N/A	8/2	10/0	N/A	FET: 0.23, p = 0.47
• Stage 2		7/3	10/0		FET: 0.10, p = 0.21
• Stage 3		8/2	10/0		FET: 0.23, p = 0.47
Squatting					
Support (descending)					
• No	3	8	10		
• Yes, light	4	0	0	FET: 0.0001, p = 0.002	FET: 0.23, p = 0.47
• Yes, full	3	2	0		
Depth					
• <Horizontal	9	5	3		
• = Horizontal	1	3	1	FET: 0.0001, p = 0.012	FET: 0.03, p = 0.29
• >Horizontal	0	2	6		
Frontal deviation (yes)	2	0	0	FET: 0.103, P = 0.31	£
Sagittal deviation (yes)	4	0	1	FET: 0.014, P = 0.90	FET: 0.50, P = 1.00
Balance tests					
Static (A/B)					
• Clockwise	6/4	10/0	10/0	FET: 0.008, P = 0.02	£
• Counterclockwise	6/4	9/1	10/0	FET: 0.01, P = 0.09	FET: 0.50, P = 1.00
Dynamic					
• Clockwise	2/8	6/4	10/0	FET: 0.0001, p = 0.001	FET: 0.1, p = 0.04
• Counterclockwise	1/9	8/2	10/0	FET: < 0.0001, P < 0.0001	FET: 0.23, p = 0.47

Table 1: *Demographics of the sample (N = 30) by group allocation.*

Statistical differences are calculated between three (all groups) and two (workers and control) groups.

£: No statistics were computed due to fewer than 2 levels.

Balance test: A: Able to maintain steady balance without support/Maintains balance with minimal postural sway without external support, B: Requires support, has postural sway/Unable to perform.

Discussion

This study demonstrated that patients with OA of the knee joint have significant limitations in kneeling and squatting with compromised balance both statically and dynamically. In our study, majority (90%) of the OA patients could not perform tall kneeling and none was able to perform full kneeling. There is minimal information on kneeling abilities in arthritic knees. In a similar study to ours, Calvert., *et al*. [14] compared different kneeling positions in healthy volunteers, patients with OA of the knee joint, and patients following total knee arthroplasty (TKA) or ligament reconstruction. The authors reported that the OA group performed worse than other groups. In that study, full keeling had a better discriminant validity among different conditions than tall kneeling [14]. Previous investigators [15,16] have shown differences in loading of these two forms of kneeling. In tall kneeling that occurs at 90° of knee flexion, the loading is through the patellofemoral joint and the tibial tuberosity, where in full kneeling, which occurs at ≥ 110° of knee flexion, majority of the load is being felt on the tibia. Pollard., *et al*. [17] reported less load on soft tissues in full kneeling with heel-gluteus contact than other kneeling positions such as tall kneeling and calf-thigh kneeling. However, despite lower forces in this position, higher internal tibial rotation can create loading on the medial meniscus and articular cartilage, increasing the risk of pain aggravation in patients with medial compartment osteoarthritis.

The injured workers in this sample had a variety of pathologies. Their performance in tall kneeling, however was comparable to healthy controls with inferior results in full kneeling and reaching forward. While shortening of the quadriceps muscles and joint stiffness may contribute to inability to assume full kneeling, there may be a component of fear of further damage in patients who have sustained an injury to their knee joints. Motivation and pain behaviors may also play a role in the successful performance of certain functional tests and need to be taken into consideration.

As it relates to squats and deep weight-bearing flexion, a greater force is applied on medial compartment of the arthritic joint [18,19] which, explains limitation in the depth of the squats seen in elderly subjects included in the present study. Similarly, in a study by Pollard., *et al*. [17] squatting created the highest level of forces as compared with different types of kneeling. During squatting, subjects exhibited significant internal tibial rotation, which may be the primary cause of the increased varus moments and loading on the medial compartment.

In terms of static and dynamic balance, while the OA group showed inferior results, the injured workers performed well and had comparable results with healthy volunteers in static (clockwise and counter clockwise) and dynamic (counterclockwise) balance tests. This indicates that apart from pathology, age plays an important role in the neuromuscular performance and balance of the individual. Advanced age is accompanied by loss of innervated muscle fibers, reduction in fiber size of the motor units, and reduced contractile speed of muscle fibers. Hunter., *et al*. [20] highlight a steady decline in muscles with advancing age, which leads to slower, less powerful, less steady, and more fatigable muscles during high-velocity dynamic tasks in elderly population.

The literature indicates that excessive compressive muscle forces during repetitive deep kneeling and prolonged squatting contribute to cartilage damage [21]. Recent systematic reviews [22] however, show that most original studies on the subject have low to moderate quality design/analysis. Therefore, while repetitive and prolonged squatting and kneeling are likely to contribute to aggravation of the OA symptoms, structured stretching and proper loading of the knee joint may actually help to preserve joint mobility and muscle strength of the knee joint in elderly [23,24]. Quadriceps muscle strengthening, via eccentric contractions during squats and kneeling may be more effective before severe changes in the bone and joint structures are established [25].

In summary, the differences observed between the OA group and others in this study appear to be the result of a complex interaction between presence of degenerative changes and normal age-related decline in muscle strength, range of motion, and neuromuscular performance and need to be further investigated. Considering the importance of improving the independence of elderly with OA of the knee joint and the significant correlation between pre and post arthroplasty range of motion and function, improving kneeling ability, muscular strength, and neuromuscular coordination prior to arthroplasty may help to delay surgery or better facilitate recovery after arthroplasty.

Conclusion

The results of this study indicates deficiency in joint mobility, muscular strength and neuromuscular coordination in older patients with OA of the knee joint. Patients with work-related knee injuries appear to have a relatively well-preserved ability to perform majority of the functional tests. Administration of knee functional tests may help to diagnose those who would benefit from a more comprehensive rehabilitation program, focusing on mobility and neuromuscular coordination.

Conflict of Interest

Authors have no conflict of interest. This study was funded by the Practice Based Research and Innovation funds of the Sunnybrook Health Sciences Centre.

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