Effect of Weight Bearing Versus Non-Weight Bearing Strengthening Exercises on Dynamic Balance in Knee Osteoarthritis Patients: Randomized Controlled Trial

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ABSTRACT: Background: knee osteoarthritis (OA) is one of the most aging problems that causes many problems such as pain, reduced balance, difficulty of walking, up & down stairs and may result in inability to move and dependency. Dynamic balance has been found to be affected in patients with knee OA. Purpose: The aim of this study was to evaluate and compare the effect of weight bearing (WB) and non-weight bearing (NWB) strengthening exercises on dynamic balance, pain and proprioception in knee OA patients. Subjects & Methods: Sixty patients from both genders, diagnosed with bilateral knee OA mild to moderate (according to Kellgran and Lawrence classification) divided equally into three groups G I (control), G II (WB) and G III (NWB), their mean value of age were 59.7 ± 4.5, 60.6 ± 4 and 60.1 ± 4.9 years respectively and body mass index were 28.8 ± 1, 28.6 ± 0.8and 28.2 ± 1.6 kg/m2 respectively. G I received conventional treatment (TENS and stretching exercises for quadriceps, hamstring and calf muscles), G II received the conventional treatment and WB strengthening exercises while G III received the conventional treatment and NWB strengthening exercises. Interventions were performed for 12 sessions (3 sessions/ week) over a period of four weeks. Outcomes were assessed at the beginning and at the end of the fourth week using biodex balance system for dynamic balance, visual analogue scale (VAS) for pain intensity and bubble inclinometer for joint repositioning error (JRE) for measuring proprioception. Result: G II was improved in all measurements with significant difference between the pre and post measurements of all measured variables, while G II were significant difference of BBS and VAS and G I there was significance difference of VAS only. There were significance differences between G II and G I in VAS, BBS and JRE measurements and between G II and G III in VAS and JRE only with superiority to G II, while there were significance differences between G I and G III in VAS and BBS with superiority to G III. Conclusion: Both WB and NWB exercises are effective in improving dynamic balance and pain in patients with knee OA. With superiority to WB exercises in improving proprioception.

Keywords: Knee osteoarthritis, dynamic balance, weight bearing exercises, non-weight bearing exercises.

INTRODUCTION:

The most prevalent type of arthritis is osteoarthritis (OA), which most commonly affects the knees. OA is a major factor in functional impairment among middle-aged and older people [1]. In North America, arthritis is the main factor causing disability. In the United States and Canada, OA is the most prevalent type of arthritis [2,3]. In about half of these subjects with knee OA, symptoms like joint pain, stiffness, effusion, muscle weakness and restricted joint motion will be present [4]. These symptoms usually make performing daily tasks challenging and reduces functional capacity [5]. Patients with OA frequently express pain when moving, which typically starts when the patient moves or starts to walk. The pain is frequently described as a dull ache [6].

A local factor in the onset and development of Knee OA has been proposed to be impaired proprioceptive accuracy of the knee. In addition, patients with knee OA may experience knee pain or activity restrictions due to proprioceptive impairments [7]. Exercise is suggested as a successful method in conservative treatment in international clinical guidelines that take the management of knee OA into account more generally. Exercise has three main goals: to lessen pain, enhance physical function and health status, and stop the disease from getting worse [8].

Patient education, exercise therapy, and weight control are recommended as core treatments for all patients with knee OA in most international guidelines [9]. Based on the effectiveness of strength training as demonstrated in clinical trials, clinical guidelines recommend it for patients with knee osteoarthritis [10]. Numerous exercise interventions, such as aerobic and strength training, have been shown to be successful in reducing pain and disability in knee OA patients. Strength training is recommended as a crucial part of exercise interventions in addition to its positive effects on symptoms because decreased muscle strength is typical in this patient group [11].

The capacity to maintain one's center of gravity within one's base of support is known as balance [12,13]. Dynamic balance is a crucial component of overall balancing ability and includes control of balance while movement is present. People with knee osteoarthritis have been found to have poor balance control, which increases the risk of falling [14]. To perform daily tasks effectively, a good balance must be maintained [15]. Due to their impaired balance, patients with knee OA must maintain knee stability in order to avoid falling and suffering unintentional injuries [16]. Patients with knee OA perform less well in both static and dynamic balance as well as functional mobility [17].

Weight bearing (WB) exercises are used more frequently in the clinical setting as a result of their advantages. With feet fixed on a stable object, WB exercises of the lower extremity are typically performed, creating compressive forces in the hip, knee, and ankle joints. Young athletes' lower extremity muscle strength and neuromuscular control have been shown to increase with WB exercise. The distal extremity is free to move during non-weight bearing (NWB) exercises, which are thought to increase muscle strength rather than proprioception during knee flexion and extension [18].

The aim of this study was to determine the efficacy of weight bearing and non-weight bearing exercises on the dynamic balance of patients with knee osteoarthritis and comparing both effects together to validate the best intervention for this problem.

MATERIALS AND METHODS:

Study design, setting and participants:

This study was designed as pretest and post-test randomized controlled study. Sixty patients with mild-to- moderate Kee OA from the faculty of Physical Therapy outpatient clinics- Cairo university in Egypt were enrolled in the study. The sample size was calculated using the G*power software (version 3.0.10). F-test MANOVA within and between interaction effect was selected. Considering a power of 0.95, an α level 0.05 and effect size of 0.405; three groups and response variables of three, a generated sample size of at least 20 participants per group was required, total sample size is 60.

Before enrolling in the study, the subjects were evaluated based on the established eligibility criteria and signed a written consent form. The patient's age > 50 years [17], body mass index (BMI) was from 20 to 30 kg/m2 , knee pain > 3 cm on a 10 cm visual analog scale (VAS) on most days of the previous week [17], with a Recent radiographs confirming the presence of knee OA, grade II-III (mild to moderate) Kellgren Lawrence [19] and met the American college of rheumatology clinical criteria for mild to moderate knee OA [20]. Patient was excluded if there was Congenital or acquired inflammatory or neurological (systemic or local) diseases involving the knee [20], mental or cognitive illness that interfere their ability to perform the exercises or the evaluation tests [21], hip or knee joint replacement surgery and intra articular knee injection of steroids in the past 6 months [22] and rheumatoid arthritis [20].

Based on the eligibility criteria, 60 patients with bilateral knee OA were identified and requested to participate in this study. Patients were divided equally and randomly into three groups: group I (control group CG), group II (weight bearing group WBG) and group III (non-weight bearing group NWBG). The randomization sequence was drawn up and kept off-site by a statistician who was not aware of the study aims, using a random number generator.

Interventions:

The participants underwent three exercise sessions per week for 4 weeks. The three groups performed TENS for 20 min first [21]. The CG performed stretching exercise for quadriceps, hamstring and calf muscles. The WBG performed forward and lateral step up & down, up on toes and terminal knee extension from standing exercises as well as the exercises performed in the CG. The NWBG performed knee extension from sitting, hip abduction from side lying, hip extension from prone and planter flexion from supine as well as the exercises performed in the CG.

Participants were positioned on their side with stretched legs on top during rectus femoris stretching. The hip and knee of the bottom leg were bent. The anterior portion of the distal thigh of the leg being stretched was covered by one therapist's hand, and the iliac crest was covered by another therapist's hand. The patient felt a stretch in the anterior region of the thigh after the therapist performed hip hyperextension with full knee flexion [23].

The subjects were positioned in the supine position for hamstring stretching. One therapist held the distal portion of the leg that needed to be stretched, and the other held the anterior side of the thigh to maintain the extended knee position. Up until the patient felt a stretch discomfort in the hamstrings, the hip was flexed in a straight leg lift position while maintaining the hip in a neutral position [23].

Participants were positioned in the supine position for calf stretching. The other hand held the patient's calcaneus while the therapist's forearm was placed along the plantar surface of the foot. The therapist applied pressure with the thumb, fingers, and forearm in a superior direction close to the heads of the metatarsals to dorsiflex the subject's ankle, drawing the calcaneus in an inferior direction until the calf muscles were stretched [23].

Strengthening exercises for the NWBG:

The subjects were positioned prone with a pillow under their stomachs to strengthen their hip extensors. The leg was actively raised with the knee extended [5].

The subjects were side-lying with their bottom leg's hip and knee in flexion during the hip abductor strengthening exercises. Their upper leg was actively abducted, slightly extended, and hip rotation was absent [5].

For knee extensor strengthening, while resistance was applied with a sandbag around the ankle, the patient extended their knee from 90 degrees of flexion to full extension while seated [24].

The patient was in the supine position for strengthening of the plantar flexors. The patient held an elastic band looped under the forefoot, plantarflexed the foot against the resistance, maintained the plantar flexion position, and then returned to the starting position [24].

Strengthening exercises for WBG:

Forward step up & down: The patient was standing in front of a wall when they noticed a gymnastic step with a 20 cm height between them and the wall. The patients put their entire foot on the step and lifted and lowered their body with ease. One leg of the patient was supported on the step while the other was in the air and not attached to it [24].

Lateral step up & down: the procedures of forward step while the wall and the gymnastic step were not facing the patient put lateral to him [24].

Terminal knee extension from standing: Patient was standing, elastic resistance looped around the distal thigh (the back of the knee) of the involved extremity and secured to the plinth. The patient actively performed terminal knee extension while bearing weight on the involved extremity [24].

Up on toes: patient was standing in front of wall. Patient stood up on his toes bilaterally by raising up his heels, hold the position then return to starting position [24].

Outcome measures:

The intensity of knee pain was assessed by VAS. The score was based on the degree of discomfort, with 0 cm signifying no pain and 10 cm signifying the greatest degree of discomfort. The VAS was used in this study to measure the precise level of pain that participants felt on a daily basis. VAS was proofed to be valid and reliable scale to test pain intensity [25].

Biodex balance system (BBS) was used to measure the dynamic balance of patients. BBS is a simple, efficient balance system screening and training tool which was manufactured in (Shirley, NY, USA). BBS is shown to be valid and reliable in measuring balance [12, 26, 27, 28, 29].

For measuring the dynamic balance, Patient information was entered on the BBS screen after the device was opened. Patient was asked to stand on the BBS platform with their feet exactly medial and lateral to the device platform's zero-angle line, while the platform was stable and immobile. The next button was pressed on the device's screen, which displayed a field made of four zones with a cursor that represented the patient's center of gravity. The platform then became mobile and tiltable up to 20 degrees, allowing the patient to adjust the position of his or her feet while maintaining the feed's initial position with zero angle deviation exactly in the middle of the platform and reposition his body weight by shifting his body between both feet and between the heels and the forefeet on the platform till the cursor is centralized on the device monitor, Then the movable platform stabilized once more after pressing the button on the screen, and the patient was then prepared to begin the measurement. The test period was 20 second and the BBS gave the results immediately after finishing the test in the form of number which represented the overall stability index (OSI) where zero is the best balance result, and the increasing the OSI means bad balance.

Finally bubble inclinometer was used to measure the joint repositioning error (JRE), which is the most used proprioceptive measure and presents a reliable and feasible measure for clinical use [30].

While the therapist was explaining the test to the patient, the patient was seated on the plinth in a comfortable position with one knee on the edge of the plinth, pared feet that were not in contact with the floor, and the Bubble inclinometer taped just above the lateral malleolus of the patient's ankle. The patient was instructed to extend his knee fully. The therapist then performed a passive knee flexion to 30 degrees (test angle) in a slow, 10-degree-per-second motion, held the position of 30 degrees flexion for four seconds, and returned to the full extension knee passively in the same slow motion. This movement was repeated five times while the patient closed his or her eyes. at the end of the last time the patient was asked to keep his knee fully extended actively and reproduce the target position actively with the same limb [31]. The difference between the reproduced angle by the patient actively and the test angle was calculated to be statistically analyzed later as the JRE which is the indicator of the proprioception acuity.

Data analysis:
Data were screened for normality assumption, homogeneity of variance, and presence of extreme scores. Shapiro-Wilk and Kolmogorov-Smirnov tests for normality showed that all measured variables were normally distributed, so MANOVA was used to analyze these data. Statistical analysis was conducted using SPSS for Windows, version 20 (SPSS, Inc., Chicago, IL). Alpha level set at 0.05.

RESULTS:
This study included 60 patients with bilateral knee OA. There was no significant difference between the patients of the three groups in the age, BMI and sex distribution (Table, 1). So, the groups were well matched at the entry

TABLE 1. General characteristics of subjects of three groups.

	Group I	Group II	Group III	f- value	p-value	Sign
Age (years)	59.7 ± 4.5	60.6 ± 4	60.1 ± 4.9	0.225	0.799	NS
BMI (kg/m2)	28.8 ± 1	28.6 ± 0.8	28.2 ± 1.6	1.47	0.238	NS
Sex Females Males	12 (60%) 8 (40%)	10 (50%) 10 (50%)	12 (60%) 8 (40%)	$\chi 2 = 0.543$	0.762	NS

Within groups comparisons (table 2):

Effect of treatment on OSI: There was no significant difference in mean value of OSI in CG post study compared with that pre study (p = 0.540) with percent of change 3%. While in there was significant differences in the mean value of OSI of post compared with pre study in both WBG and NWBG (p = 0.001) and percent of change 36% and 16.7% respectively.

Effect of treatment on pain: there was significant difference in the three groups when comparing post and pre study with (p = 0.001) and the percents of change of CG, WBG and NWBG were (14 & 16.7%), (37 & 42%) and (28.6 & 34%) respectively and the first percent in each bracket for the right knee.

Effect of treatment on proprioception (JRE): there was no significant difference between the post and pre study in CG and NWBG with (p = 0.001) and the percent of change (9 & 9%) and (15 & 15.7%) respectively and the first percentage in each bracket for the right knee. While there was significant difference between the post and pre study in WBG with (p = 0.001) and the percent of change for the right and left knee were (83 & 80%) respectively.

TABLE (2): Comparison between pre- and post-study mean values of OSI, pain and joint reposition between and within groups

Measured variables	Group I	Group II	Group III	f-value	P value
OSI					
Pre-study	3.2 ± 0.9	3.3 ± 0.7	3 ± 0.7	0.489	0.616
Post-study	3.1 ± 0.8	2.1 ± 0.4	2.5 ± 0.7	13.6	0.001*
% of change	3%	36%	16.7%		
(P-value)	0.540	0.001*	0.001*		
Pain right side (cm)					
Pre-study	7.1 ± 1.1	6.7 ± 1.2	7 ± 1	0.770	0.468
Post-study	6.1 ± 1.3	4.2 ± 1.3	5 ± 1.1	12.2	0.001*
% of change	14%	37%	28.6%		
(P-value)	0.001*	0.001*	0.001*		
Pain left side (cm)					
Pre-study	6.6 ± 1.2	6.7 ± 1	6.5 ± 1.2	0.084 7.55	0.919
Post-study	5.5 ± 1.4	3.9 ± 1.3	4.3 ± 1.1	7.55	0.001*
% of change	16.7%	42%	34%		
(P-value)	0.001*	0.001*	0.001*		
Joint reposition (degrees)					
Right side Pre-study	13 ± 6	11.7 ± 5	9.7 ± 5	1.72	0.187
Post-study	11.8 ± 6	2 ± 1.2	8.2 ± 4	22.32	0.001*
% of change	9%	83%	15%		
(P-value)	0.188	0.001*	0.098		
Joint reposition (degrees)					
Left side Pre-study	8.6 ± 4	10.9 ± 3.8	8.3 ± 4	2.13	0.127
Post-study	7.8 ± 1	2.2 ± 1.3	6.7 ± 3.6	14.88	0.001*
% of change	9%	80%	15.7%		
(P-value)	0.275	0.001*	0.054		

Data is represented as mean ±SD p-value: probability value *: significant

Between groups comparisons (table 2):

For OSI: there was no significant difference between groups pre study. While post study there was significant difference between WBG and CG, the same as between NWBG and CG with favor of WBG and NWBG on CG.

There was no significant difference between WBG and NWBG (table, 2).

For pain: There was significant difference post study for the right knee between CG and WBG (P=0.001) in favor to WBG and between CG and NWBG (P=0.011) in favor to NWBG also between WBG and NWBG (P=0.025) in favor to WBG. For left knee, there was significant difference between CG and WBG (P=0.001) in favor to WBG and between CG and NWBG (P=0.008) in favor to NWBG. While there was no significant difference between WBG and NWBG (P=0.315).

For proprioception (JRE): For right knee post study, there was significant difference between CG and WBG (P=0.001) in favor to WBG and between WBG and NWBG (P=0.001) in favor to WBG. While there was no significant difference between CG and NWBG (P=0.050). For left knee post study, there was significant difference between CG and WBG (P=0.001) in favor to WBG and between WBG and NWBG (P=0.001) in favor to WBG. While there was no significant difference between CG and NWBG (P=0.308).

DISCUSSION:

The purpose of this study was to determine and compare the effect of WB strengthening exercises and NWB strengthening exercises on dynamic balance, pain and proprioception in knee OA patients, the finding of this study confirm that both WB exercises and NWB exercises were effective in improving dynamic balance and pain while WB exercises only was effective in improving proprioception, for our known this study was the first study that compare the effect of WB exercises and NWB exercises on dynamic balance in knee OA patients.
Our study found that the pain was decreased in all groups. Which can be explained by the positive effect of TENS on pain as it can reduce the perception of pain at the central nervous system through the gate control theory [32], also TENS stimulates the opioid receptors which produce b-endorphin [32, 33], TENS found to be effective in reducing deep tissue pain by OA [34] and reducing pain during movement [35]. Stretching exercise can improve the pain by lowering muscle tension and improving joint metabolism in patients with musculoskeletal problems [5], it also has inhibitory effect on the muscle causing muscle relaxation which lead to pain reduction by stimulating the Golgi tendon organ [36].

Weight bearing & NWB groups had superiority on the CG in pain relief as adding strengthening exercises provide more flexibility for the muscles and joints [37 & 38], plus its main function that improving muscle strength which helps in supporting the joint better leading to reduce the pain [39] and by increasing the muscle strength the pain reduced in knee OA [40]. We also found that WBG had more effect of pain relief than NWBG, which may be because in the WB exercises more proprioceptors stimulated which led to more activation for the proprioceptive than in the NWB exercises [41]. Ju, found that there was greater reduction in the pain in the patients with knee osteoarthritis when the treatment includes exercises that improve the proprioception than others where muscles strengthening is the only aim [42].

Our study finding that WBG and NWBG both had a positive effect on improving the dynamic balance in knee OA patients while the CG not, as muscles strength is a variable that has great effect on balance [43], so, by adding strengthening exercises to the program of treatment it should have a n effect on balance. In the study performed by Elneil, they found that WB exercise and NWB exercises both increased the muscle girth and strength in patients with knee OA [44] and in another study other researchers found that WB exercises had a greater effect in improving muscle strengthening than NWB exercises which also improve muscle strength in knee OA patients [22].

The result of this study found that proprioception measured JPE had been improved in the WBG only, which may be due to in WB exercises facilitate knee joint proprioceptors by increasing intraarticular pressure and thereby stimulating Ruffini nerve endings, which are sensitive to changes in intracapsular fluid volume [45], also, there is most likely less activation of the related sensory nerves with NWB exercises than WB exercises, which can explain why there was no improvement in the JRE in the NWBG [18].

Girgin compared the effect of WB exercises and NWB exercises and they found improvement in both groups in pain, physical function and quality of life with no significance between both groups [21]. In another study they found that both WB and NWB exercises are effective in improving the functional performance and reducing the symptoms of the patients with knee osteoarthritis while WB exercises had a leading effect in improving the proprioceptive deficits in this type of patients [46].

Daskapan found in his study that both WB and NWB exercises improved pain and functional activity, but this improvement was more significant in WB exercise which is more functional exercises [47]. Jan compared the effect of WB exercise and NWB exercise on function and proprioception and they found that both type of exercises was effective in improving the function with only the WB exercises improved proprioception [18].

In study compared the effect of WB exercise and NWB exercise and the combination between both on pain and function in knee OA, they found that the combination between both types of exercises had the best improvement on pain and function, while WB exercise and NWB exercise improved pain and function with superiority of WB exercise in its effect [48]. The same author compared the effect of the same types of exercises of the previous study on muscle strength and girth and they found significant improvement in the three groups with no difference between them [20].

In conclusion, for patients with knee osteoarthritis both WB exercises and NWB exercises are effective on improving dynamic balance and pain. While WB exercises are only effective in improving proprioception.

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DOI: https://doi.org/10.15379/ijmst.v10i3.1984