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RESEARCH

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# The effect of combined balance and strength exercise program in patients with different grades of primary knee osteoarthritis

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## Abstract

**Background** Knee osteoarthritis (KOA) is a degenerative disease that affects all parts of the joint including the surrounding ligaments, tendons, and muscles. Biomechanical changes that occur in KOA cause aggravation of symptoms with further joint damage. Thus, modifying the biomechanics of the knee joint may help in the prevention and treatment of KOA. For that reason, our aim was to assess the effect of combined balance and strengthening exercise programs in patients with different grades of primary KOA.

**Results** All studied groups showed comparable significant improvement in quadricep muscle strength, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score (< 0.001), time-up and go score (< 0.001), 6-m walk time (< 0.001), and dynamic balance (< 0.001) at the end of exercise program. Furthermore, patients with mild-moderate KOA showed a significant improvement in pain, physical function, total WOMAC scores, and dynamic balance compared to those with more severe KOA.

**Conclusion** Combined balance and strengthening exercise programs may help improve pain, physical function, and dynamic balance in patients with KOA regardless of its severity. However, following exercise patients with milder forms of KOA may show greater improvement compared to patients with severe KOA.

**Keywords** Primary knee osteoarthritis, Strengthening exercise, Balance exercise, Modified Star Excursion Balance Test, Kellgren and Lawrence grading scale

## Key points

- This study signified the importance of exercise in the management of patients with KOA regardless of its severity.
- It highlights the multimodal improvement in several aspects of the disease symptoms following exercise therapy.
- Patients with milder degrees of KOA showed better pain, physical function, and dynamic balance improvement than patients with more severe degrees of KOA

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## Introduction

Primary knee osteoarthritis (KOA) is the most common joint disease with growing incidence [1] due to increased aging and spreading of obesity [2]. One of the identified modifiable risk factors for KOA is the biomechanical

characteristics, which predispose to the development of symptoms and structural joint damage [3].

Modifying the biomechanics of the knee joint is an integral part in the prevention and treatment of KOA. This could be accomplished by acting on intrinsic factors such as muscle strength and lower limb axis [3]. Indeed, wasting of the quadricep (Q) muscle is considered both a risk factor and a consequence due to the inactivity of the affected painful limb [3], which in turn leads to poor balance. Furthermore, it has been proved histologically that there are reduced numbers of mechanical sensory receptors in the ligaments of osteoarthritic joints [4, 5]. Pain and impaired proprioception are other causes responsible for the increased falls. Moreover, fall prevalence has been found to be higher among KOA patients than in healthy individuals of the same age [6].

In turn, increased falls may lead to serious injuries, physical and psychological dependence, and social losses. Decreasing the incidence of falls among KOA patients is crucial in every treatment protocol [6]. This could be achieved by improving balance and muscle strength [3, 6]. For that reason, we tried to assess the effect of combined balance and strengthening exercise programs in patients with different grades of primary KOA.

## Methods

This non-randomized interventional study enrolled patients with symptomatic KOA from a single institute.

### Study population

#### *Inclusion criteria*

All eligible patients with primary symptomatic KOA diagnosed according to the 2010 EULAR evidence-based recommendations for the diagnosis of KOA [7] were recruited to participate in the study.

Patients were then classified into four equal groups based on the Kellgren and Lawrence (KL) grading scale of KOA [8]: group 1 included patients with grade (G)1 KOA (mild KOA), group 2 included patients with G2 KOA (mild-moderate KOA), group 3 included patients with G3 KOA (moderate-severe KOA), and group 4 included patients with G4 KOA (severe KOA).

#### *Exclusion criteria*

Patients were excluded if they failed to fulfill stage one of the exercise program, had lower limb bony and/or joint problems, or had secondary KOA [9]. Moreover, patients with health problems that influenced postural balance, diabetes mellitus [9], morbid obesity (BMI > 40 kg/m$^2$) [10], visual acuity, and inner ear and neurological problems were also excluded [9]. Patients who received any knee intervention 3 months prior to the initial evaluation were excluded from the study [9].

### Ethics approval and consent to participate

All participants were informed about the nature of the study and a written informed consent was taken from all of them. The ethical committee Faculty of Medicine, Alexandria University approved the study, serial number: 0105852. The research was prospectively registered in ClinicalTrials.gov: NCT04227860 on 9th of January 2020. The research was conducted in accordance with the Declaration of the World Medical Association of Helsinki.

### Study design

Enrolled patients were subjected to a recording of the demographic data, anthropometric measurements, complete history (including duration of symptoms, fall, and stability history), and musculoskeletal examination (including clinical assessment of local tenderness, effusion, and quadriceps wasting) [11, 12]. Standing plain X-rays of both knees in antero-posterior and lateral views were done. Radiological severity was assessed using the KL grading scale [8]. The index knee (predominately affected knee) was chosen according to the most painful knee according to patients' complaints, if the degree of pain was similar in both knees the most affected knee by plain X-ray was chosen as the index knee.

### Outcome measures

The following tests have been performed for each of the studied patients before engaging in the exercise program and after its fulfillment. When comparing groups with each other as regards the outcome measures, two variables were selected; the mean difference and the percentage of change.

#### *Quadricep (Q)-muscle strength*

The Q-muscle strength was assessed by the Q-chair through measuring a 10-repetition maximum (RM) and predicting the patient's 1-RM [13]. The 10-RM was reassessed every week to modify weights used during the program.

*1-RM was predicted using the following equation (where X = the number of repetitions performed):*

$$\text{Predicted1} - \text{RM} = \frac{\text{WeightLifted}}{1.0278 - .0278\text{X}}$$

#### *Physical function assessment*

*Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [14]* This questionnaire consists of three subscales. The pain subscale contains five questions, the stiffness subscale two questions, and the physical function subscale 17 questions. Each subscale was summated with the following possible ranges for pain

(0–20), stiffness (0–8), and physical function (0–68). The total WOMAC score was created by summing the items from all three subscales. Higher scores indicate the worst outcome.

*Timed up and go (TUG) test [15]* The TUG test measures the time (in seconds) taken by the patient to rise from a standard armchair (42-cm seat height and 62-cm arm height), walk 3 m, turn, walk back to the chair, and then sit down. Patients wore their regular footwear and were allowed to use their walking aids. Patients performed a practice trial to confirm that they understood the test, followed by two trials, and the faster was recorded.

The patients were recorded by the video recording application of the mobile phone during the performance of the test and further analysis was done.

*Six-meter (6 m) walk time [15]* It was calculated from the sum of the two walking times of the TUG test in seconds per 6-m walk distance.

#### *Dynamic balance assessment by Modified Star Excursion Balance Test (MSEBT) [16]*

The MSEBT measures dynamic balance. During the test, the patient stood on a single leg (stance leg) in the center of an inverted Y-shaped line marked on the floor using adhesive tape. The patient reaches with the other leg as far as possible along the three reach lines in the three directions of the Y-shaped line. The three reach lines are named relative to the stance leg as anterior (A), posteromedial (PM), and posterolateral (PL). The angle between the PM and PL lines was 90°, and two angles of 135° were between the A and PM lines and between the A and PL lines (Fig. 1).

The position of the foot of the standing foot differed during the test as follows:

a) For the anterior reach, the standing foot was placed so that the tip of the big toe was at the center point of the Y-shaped line.
b) For PL and PM reach, the standing foot was placed so that the edge of the back of the heel intersected the center point of Y-shaped lines.

Patients were barefooted and asked to keep both hands on the hips. Patients were asked to reach as far as possible over each of the three directions, make a light touch on the tape with the most distal part of the big toe where a permanent ink pen mark was placed on the ground, and then return back to the center while sustaining balance by the other leg. Three attempts were carried out in each direction, for each leg.

The patients repeated the trial if they (1) lost control while returning back with the reaching foot to the starting point, (2) transferred weight to the reaching foot, (3) removed their hands from hips, and/or (4) moved the stance foot or lifted the heel or the forefoot of the stance foot from the floor.

The average distance in centimeters of the three successful attempts for each reach direction was calculated and normalized to leg length. Normalization was achieved by dividing the mean reach distance by the patient's leg length in centimeters and then multiplying by 100%.

#### The balance and strengthening exercise program

All patients performed the following modified exercise program adopted from Diracoglu et al. [17] with 3 regular supervised morning sessions per week for 6 weeks (18 sessions):

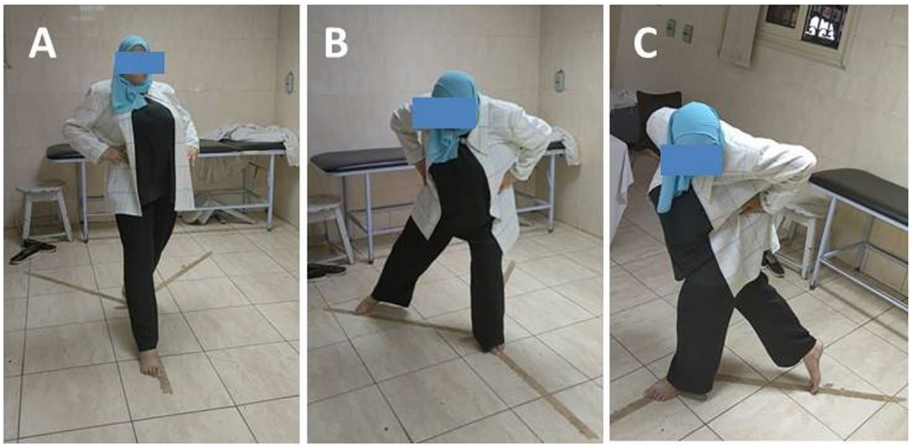


**Fig. 1** Modified star excursion balance test performance standing on left leg. **A** Anterior direction. **B** Posteromedial direction. **C** Posterolateral direction

### Lower extremity kinesthesia and balance exercise program [17]

This program was performed in two phases, each of them for 3 weeks as detailed in Table 1, Fig. 2.

### Strengthening exercise program [17]

This program was performed in 3 phases, 2 weeks each as detailed in Table 1.

### Statistical analysis of the data

Data were analyzed using IBM SPSS (20.0) (Armonk, NY: IBM Corp). The number and percentage were used to describe qualitative data. The mean and standard deviation were used to describe normally distributed quantitative data, while the median and range (minimum and maximum) were used to describe abnormally distributed quantitative data after verifying the normality of distribution using the Kolmogorov–Smirnov test. The significance of the obtained results was judged at the 5% level.

To compare categorical variables in different groups, the chi-square test was used. Fisher's exact or Monte Carlo correction was used for the correction of chi-square when more than 20% of the cells had an expected count of less than 5. To compare normally distributed quantitative variables in more than two groups, an *F* test (ANOVA) was used and a post hoc test for pairwise comparisons, while a paired *t* test was used to compare between two periods.

To compare between more than two studied groups in abnormally distributed quantitative variables, the Kruskal–Wallis test was used, and post hoc (Dunn's multiple comparisons test) for pairwise comparisons, while the Wilcoxon signed-ranks test was used to compare between two periods.

**Table 1** Kinesthesia, balance, and strengthening exercise program with its phases

| **Kinesthesia and balance exercise program (3 times per week for 6 weeks), Fig. 2** | |
|---|---|
| **Stage 1 (3 weeks)** | 1. Modified Romberg exercise (standing in balance with eyes closed)<br>a. On hard ground<br>b. On soft ground<br>2. Retro walking (25 m)<br>3. Walking on heels (25 m)<br>4. Walking on toes (25 m)<br>5. Walking with eyes closed (25 m)<br>6. Standing on one extremity for 30 s<br>(repeated in both extremities)<br>▪ Leaning forwards, backwards, and sideways on one extremity (eyes open)<br>▪ Leaning forwards, backwards, and sideways on one extremity (eyes closed)<br>▪ Sitting down and standing up from a high chair slowly |
| **Stage 2 (3 weeks)** | **Stage 1 exercises plus the following:**<br>1. Exercise with a balance board<br>2. Sitting down and standing up from a low chair slowly<br>3. Plyometric exercise (crossing a height of 15 cm by jumping)<br>4. a. Walking slowly, wide circle (D:120 cm)<br>b. Walking quickly, wide circle (D:120 cm)<br>c. Walking slowly, narrow circle (D:45 cm)<br>d. Walking quickly, narrow circle (D:45 cm) |
| **Strengthening exercise program (3 times per week for 6 weeks)** | |
| **Stage 1 (2 weeks)** | 1. 5-min fixed bike exercise without resistance<br>2. ROM exercise<br>3. Quadriceps muscle isometric strengthening exercise<br>4. Hamstring muscle isometric strengthening exercise<br>*Isometric exercises: 8 repetitions of 6-s maximum isometric voluntary contraction with 2-s rest* |
| **Stage 2 (2 weeks)** | **Stage 1 exercises plus the following:**<br>1. Short-arc terminal extension exercise with weight for the knee joint<br>2. Isometric exercise for the adductor muscles of the hip joint<br>3. Isometric exercise for the abductor muscles of the hip joint<br>*Isotonic exercises: short arc extension of the knee with a step placed as support. Applied as 10 repetitions with one third weight of the 10-RM, 10 repetitions with two thirds weight of the 10 RM, and 10 repetitions with the full weight of the 10-RM* |
| **Stage 3 (2 weeks)** | **Stage 1 and 2 exercises plus the following:**<br>1. Short-arc terminal extension exercise with resistance for the knee joint<br>2. Isometric exercise with resistance for the hamstring muscles<br>*Isotonic exercises: against the resistance of a standard rubber bandage* |

*m* meter, *cm* centimeter, *s* second, *D* diameter, *RM* repetition maximum, *ROM* range of motion

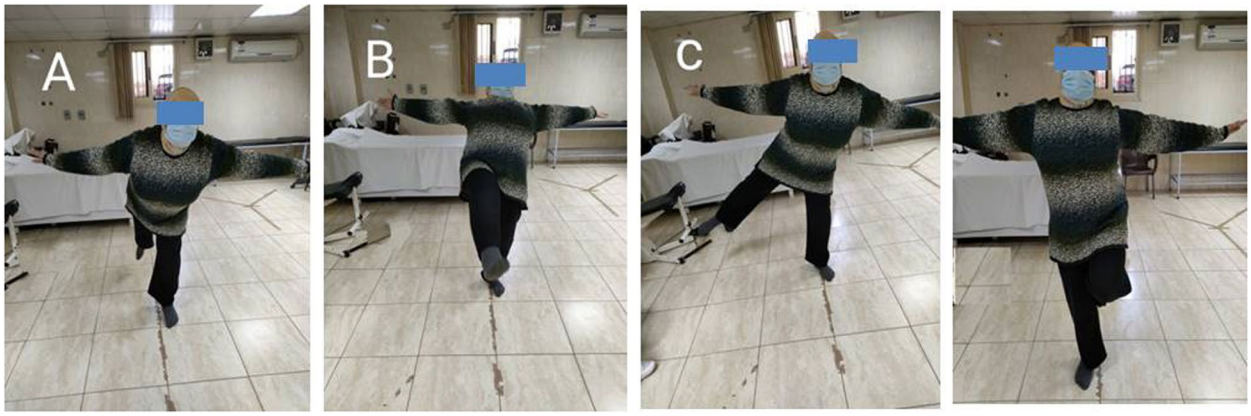


**Fig. 2** Demonstrating balance exercise while standing on one limb. **A** Leaning forward. **B** Leaning backward. **C** Leaning to the side. **D** Standing on one extremity for 30 s

### Power calculation

In a one-way ANOVA study, sample sizes of 20, 20, 20, and 20 were obtained from the 4 groups whose means were to be compared. The total sample of 80 subjects achieves 80% power to detect a total WOMAC score difference of at least 2 between the 4 groups, using an *F* test with a 0.050 significance level. The common standard deviation within a group was assumed to be 6.00 using PASS software version 12.0.2 [18–21].

## Results

This non-randomized interventional study enrolled 114 patients with symptomatic KOA. Thirty-four patients (29.8%) dropped out of the study. Nineteen patients (55.9%) stopped attending during the COVID-19 pandemic, ten patients (29.4%) could not complete stage 1 of the exercise program as they lived far away from the hospital and found it difficult to commit 3 exercise sessions per week at the hospital, and five patients (14.7%) were not satisfied with the exercise program alone without additional physical modalities and refused to complete the program, Fig. 3.

The final patient count that completed the exercise program and underwent pre- and post-exercise assessment was 80 KOA patients divided into four groups (20 patients each) based on the KL grading scale. All the patients that were included in the final analysis completed all 18 sessions of supervised morning exercise. All 80 patients adhered to the exercise program, although some found it difficult due to the regular sessions and effort done in them. However, the positive effects that they noticed from the sessions helped with a continuation of the sessions for a full 6 weeks.

Most KOA patients enrolled in the 4 groups were housewives, with no statistically significant difference between groups with regard to occupation ($X^2 = 12.702$, $^{MC}P = 0.180$). Demographic data and anthropometric measurements are represented in Table 2. Group 4 patients had the highest mean age and BMI in comparison to the other groups.

The duration of the disease and fall history are summarized in Table 2. Group 4 patients had the longest median disease duration and worst fall history. Furthermore, three patients in group 4 needed a cane as an assistive device during walking, but none of the included patients needed personal assistance.

All patients in G1 had isolated KOA. The majority of patients in G2 and G3 had isolated KOA (70% and 75%, respectively). On the contrary in G4, the majority of patients had generalized OA (65%).

The left knee was predominately affected (index knee) in G1, G2, and G3 in 55 to 60% of patients, while the right knee was predominantly affected in G4 patients (65%). Moreover, most patients (80–100%) had isolated medial compartmental OA in G1, G2, and G3, while only half of G4 patients had isolated medial compartmental KOA and the other half had either combined medial and patellafemoral KOA or the whole knee involved.

Patients in G4 had the highest statistical frequency of clinical findings (Table 2) and knee joint ROM limitation compared to the other studied groups ($F = 4.338$, $P = 0.007$). All G1, G2, and G3 patients had full extension ROM, while G4 patients had incomplete extension in eight patients with a mean value of $-4.50 \pm 6.67°$.

### Outcome measures

#### *Quadricep muscle strength*

As shown in Table 3, at the end of the exercise program, all studied groups showed comparable significant improvement in the Q-muscle 1-RM.

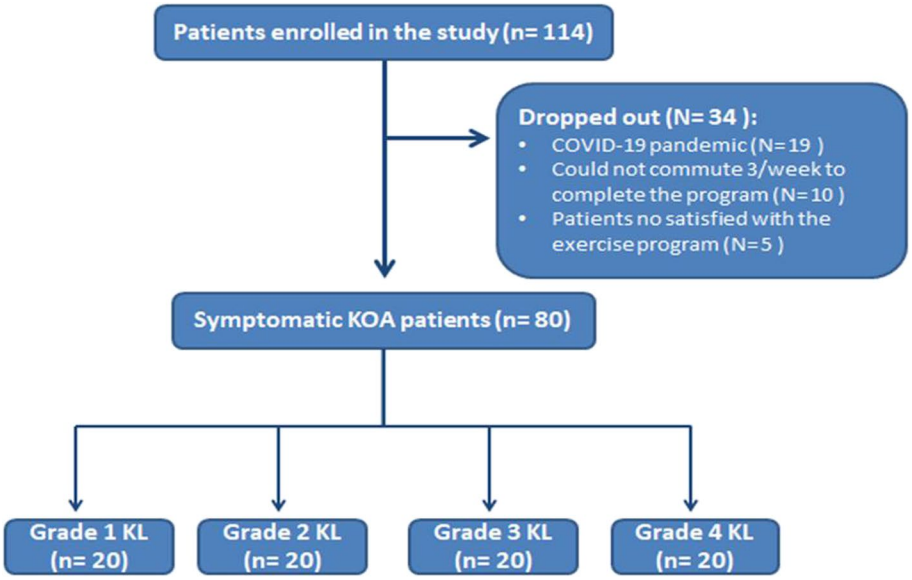


**Fig. 3** Flow chart representing enrollment and dropout of patients from the study

***Physical function assessment***

1. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).

On comparing WOMAC scores in each group before and after the fulfillment of the exercise program, a statistically significant improvement was found in the total WOMAC score and its 3 subscales of pain, stiffness, and physical function in all 4 groups (Table 4).

Furthermore, G1 and G2 showed a significant improvement in the percentage of change in pain, physical function, and total WOMAC scores compared to G4. Also, G1 showed a significant improvement in the percentage of change in physical function and total WOMAC scores compared to G3.

2. Timed up and go test.

As shown in Table 5, at the end of the exercise program, all studied groups showed comparable significant improvement in the total score and all 5 intervals of the TUG test.

3. Six-meter (6 m) walk time.

At the end of the exercise program, all studied groups showed a comparable significant improvement in the 6-m walk time (Table 5).

### Dynamic balance

As shown in Table 6, all the studied patient groups who fulfilled the exercise program showed a significant improvement in all directions of MSEBT at the end of the exercise program.

In testing of the A direction, G1 showed a statistically significant improvement in the mean difference and percentage of change compared to G4.

In testing the PM direction, G1, G2, and G3 showed a significant improvement in the mean difference and percentage of change compared to that of G4.

## Discussion

In the current work, 114 patients were enrolled with symptomatic KOA. The dropout rate was relatively high in this study (29.8%) compared to other similar studies by Duman et al. (0%) [22], Braghin et al. (0%) [9], Pazit et al. (6.7%) [23], Diracoglu et al. (9.1%) [17], and the highest being 18% by Hurley et al. [24]. Although the study design and aim were thoroughly explained to all participants, several factors hindered their continuation in the current study with a high dropout rate; the COVID pandemic was a major reason for dropout followed by the low socioeconomic status of enrolled patients and lack of insurance coverage to exercise programs for KOA patients with high financial burden for these patients to commute back and forth to the hospital from rural and far places. Furthermore, there were some cultural and preconceived concepts that lead to the dissatisfaction of some patients to be enrolled in an exercise program with no medical treatment prescription which has been reported in similar exercise-based programs [24]. At end of the study, 80 symptomatic KOA patients with different grades of KOA completed

**Table 2** Comparison between the different studied groups according to demographic data, anthropometric measurements, and disease characteristics

| | Group 1 ($n=20$) | | Group 2 ($n=20$) | | Group 3 ($n=20$) | | Group 4 ($n=20$) | | Test of sig | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| | No | % | No | % | No | % | No | % | | |
| **Sex** | | | | | | | | | | |
| Female | 19 | 95 | 19 | 95 | 20 | 100 | 20 | 100 | $\chi^2=2.162$ | ${}^{MC}p=1.000$ |
| Male | 1 | 5 | 1 | 5 | 0 | 0 | 0 | 0 | | |
| **Mean age** (years) | 49.25 ± 6.98 | | 48.65 ± 6.43 | | 54.85 ± 7.62 | | 60.15 ± 3 | | $\boldsymbol{F=14.821^*}$ | $\boldsymbol{<0.001^*}$ |
| **Sig. between groups** | $p_1=0.99$, $\boldsymbol{p_2=0.030^*}$, $\boldsymbol{p_3<0.001^*}$, $\boldsymbol{p_4=0.013^*}$, $\boldsymbol{p_5<0.001^*}$, $\boldsymbol{p_6=0.044^*}$ | | | | | | | | | |
| **Mean BMI** (kg/m$^2$) | 29.43 ± 3.39 | | 31.21 ± 3.99 | | 30.27 ± 4.21 | | 34.39 ± 5.01 | | $\boldsymbol{F=5.351}$ | $\boldsymbol{0.002^*}$ |
| **Sig. bet. grps** | $p_1=0.538$, $p_2=921$, $\boldsymbol{p_3=0.002^*}$, $p_4=$,0.893 $p_5=0.086$, $\boldsymbol{p_6=0.014^*}$ | | | | | | | | | |
| **Median duration of symptoms** (years) | 2 (0.25–5) | | 4 (0.17–10) | | 5 (2–12) | | 9 (2–12) | | $\boldsymbol{H=38.423^*}$ | $\boldsymbol{<0.001^*}$ |
| **Sig. between groups** | $\boldsymbol{p_1=0.008^*}$, $\boldsymbol{p_2<0.001^*}$, $\boldsymbol{p_3<0.001^*}$, $p_4=0.259$, $\boldsymbol{p_5=0.001^*}$, $\boldsymbol{p_6=0.021^*}$ | | | | | | | | | |
| **Fall history** | | | | | | | | | | |
| No | 16 | 80 | 14 | 70 | 11 | 55 | 5 | 25 | $\boldsymbol{\chi^2=15.787^*}$ | $\boldsymbol{{}^{MC}p=0.007^*}$ |
| Due to the knee giving way | 4 | 20 | 6 | 30 | 7 | 35 | 11 | 55 | | |
| While walking | 0 | 0 | 0 | 0 | 2 | 10 | 4 | 20 | | |
| **Sig. between groups** | $p_1=0.465$, ${}^{MC}p_2=0.23$, $\boldsymbol{{}^{MC}p_3=0.001^*}$, ${}^{MC}p_4=0.45$, $\boldsymbol{{}^{MC}p_5=0.005^*}$, ${}^{MC}p_6=0.141$ | | | | | | | | | |
| **Sense of insecure walking** | | | | | | | | | | |
| Absent | 7 | 35 | 0 | 0 | 0 | 0 | 1 | 5 | $\boldsymbol{\chi^2=13.782^*}$ | $\boldsymbol{{}^{MC}p=0.001^*}$ |
| Present | 13 | 65 | 20 | 100 | 20 | 100 | 19 | 95 | | |
| **Sig. between groups** | $\boldsymbol{{}^{FE}p_1=0.008^*}$, $\boldsymbol{{}^{FE}p_2=0.008^*}$, $\boldsymbol{{}^{FE}p_3=0.044^*}$, $p_5=1.000$, ${}^{FE}p_6=1.000$ | | | | | | | | | |
| **Number of falls in the last year** | | | | | | | | | | |
| Non-fallers | 16 | 80 | 14 | 70 | 11 | 55 | 5 | 25 | $\boldsymbol{\chi^2=16.086^*}$ | $\boldsymbol{{}^{MC}p=0.006^*}$ |
| 1-Time fallers | 1 | 5 | 1 | 5 | 0 | 0 | 3 | 15 | | |
| Frequent fallers | 3 | 15 | 5 | 25 | 9 | 45 | 12 | 60 | | |
| **Sig. between groups** | ${}^{MC}p_1=0.846$, ${}^{MC}p_2=0.089$, $\boldsymbol{{}^{MC}p_3=0.001^*}$, ${}^{MC}p_4=0.328$, $\boldsymbol{p_5=0.015^*}$, ${}^{MC}p_6=0.056$ | | | | | | | | | |
| **Wasting** | | | | | | | | | | |
| Absent | 19 | 95 | 13 | 65 | 10 | 50 | 6 | 30 | $\boldsymbol{\chi^2=18.75^*}$ | $\boldsymbol{<0.001^*}$ |
| Present | 1 | 5 | 7 | 35 | 10 | 50 | 14 | 70 | | |
| **Sig. between groups** | ${}^{FE}p_1=0.044^*$, $p_2=0.001^*$, $p_3<0.001^*$, $p_4=0.337$, $\boldsymbol{p_5=0.027^*}$, $p_6=0.333$ | | | | | | | | | |
| **Tenderness** | | | | | | | | | | |
| No | 20 | 100 | 18 | 90 | 17 | 85 | 10 | 50 | $\boldsymbol{\chi^2=16.568^*}$ | $\boldsymbol{{}^{MC}p<0.001^*}$ |
| Yes | 0 | 0 | 2 | 10 | 3 | 15 | 10 | 50 | | |
| **Sig. between groups** | ${}^{FE}p_1=0.487$, ${}^{FE}p_2=0.231$, $\boldsymbol{p_3<0.001^*}$, ${}^{FE}p_4=1.000$, $\boldsymbol{p_5=0.006^*}$, $\boldsymbol{p_6=0.018^*}$ | | | | | | | | | |
| **Effusion** | | | | | | | | | | |
| No | 20 | 100 | 19 | 95 | 18 | 90 | 13 | 65 | $\boldsymbol{\chi^2=10.782^*}$ | $\boldsymbol{{}^{MC}p=0.007^*}$ |
| Yes | 0 | 0 | 1 | 5 | 2 | 10 | 7 | 35 | | |

**Table 2** (continued)

| | Group 1 ($n=20$) | | Group 2 ($n=20$) | | Group 3 ($n=20$) | | Group 4 ($n=20$) | | Test of sig | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| | No | % | No | % | No | % | No | % | | |
| **Sig. between groups** | $^{FE}p_1=1.000$, $^{FE}p_2=0.487$, $^{FE}\mathbf{p_3=0.008}^{*}$, $^{FE}p_4=1.000$, $^{FE}\mathbf{p_5=0.044}^{*}$, $^{FE}p_6=0.127$ | | | | | | | | | |

*H* Kruskal–Wallis test, *F* ANOVA test, *t* paired *t* test, $\chi^2$ chi-square test, *MC* Monte Carlo correction, *Sig.* significance, *BMI* body mass index

*p*: *p* value for comparing between the studied groups

$p_1$: *p* value for comparing between group 1 and group 2

$p_2$: *p* value for comparing between group 1 and group 3

$p_3$: *p* value for comparing between group 1 and group 4

$p_4$: *p* value for comparing between group 2 and group 3

$p_5$: *p* value for comparing between group 2 and group 4

$p_6$: *p* value for comparing between group 3 and group 4

$^{*}$ Statistically significant at $p \leq 0.05$

**Table 3** Comparison between the different studied groups according to 1-RM

| | Group 1 ($n=20$) | | Group 2 ($n=20$) | | Group 3 ($n=20$) | | Group 4 ($n=20$) | | *H* | *p* |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | | |
| **1-RM (kg)** median (min.–max.) | 4.72 (2.36–7.1) | 7.1 (2.36–7.1) | 4.72 (2.36–7.1) | 7.1 (2.36–7.1) | 2.36 (2.36–7.1) | 4.72 (2.36–7.1) | 2.36 (2.36–4.72) | 2.36 (2.36–7.7) | | |
| ***z* ($p_0$)** | 2.714* (0.007*) | | 2.887* (0.004*) | | 3.355* (0.001*) | | 2.636* (0.008*) | | | |
| **Mean difference** (mean ± SD) | **0.96 ± 1.18** | | **1.07 ± 1.21** | | **1.90 ± 1.46** | | **1.09 ± 1.52** | | 5.47 | 0.14 |
| **Percentage of change (%)** (mean ± SD) | **30.59 ± 40.75** | | **25.17 ± 30.50** | | **65.21 ± 61.08** | | **43.83 ± 62.96** | | 5.656 | 0.13 |

*1-RM* 1 repetition maximum, *kg* kilograms, *SD* standard deviation, *H* Kruskal–Wallis test, *Z* Wilcoxon signed-rank test

*p*: *p* value for comparing between the studied groups

$p_0$: *p* value for comparing between before and after

* Statistically significant at $p \leq 0.05$

**Table 4** Comparison between the different studied groups according to WOMAC

| WOMAC | Group 1 ($n=20$) | | Group 2 ($n=20$) | | Group 3 ($n=20$) | | Group 4 ($n=20$) | | *H* | *P* |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | | |
| **Pain** Median (min–max) | 9 (4–15) | 4 (1–6) | 10.5 (4–15) | 4 (0–6) | 12 (5–17) | 5 (1–13) | 14 (10–16) | 6.5 (3–12) | | |
| ***z* ($p_0$)** | **3.929*** (<0.001*)** | | **3.929*** (<0.001*)** | | **3.927*** (<0.001*)** | | **3.931*** (<0.001*)** | | | |
| Mean difference | 6.15 ± 2.35 | | 6.85 ± 2.87 | | 6.55 ± 2.67 | | 6.15 ± 2.39 | | 1.059 | 0.787 |
| Percentage of change | 63.32 ± 12.71 | | 64.75 ± 13.39 | | 57.71 ± 16.93 | | 45.74 ± 17.2 | | **13.361*** | **0.004*** |
| Sig. bet. groups | $p_1$ = 1.000, $p_2$ = 1.000, $\mathbf{p_3 = 0.002}$*, $p_4$ = 0.185, $\mathbf{p_5 = 0.001}$*, $p_6$ = 0.061 | | | | | | | | | |
| **Stiffness** Median (min–max) | 4 (2–7) | 2 (0–4) | 5 (1–6) | 2 (0–3) | 5 (1–7) | 2 (0–5) | 6 (2–8) | 2 (1–5) | | |
| ***z* ($p_0$)** | **3.963* (<0.001*)** | | **4.025* (<0.001*)** | | **3.660* (<0.001*)** | | **3.955* (<0.001*)** | | | |
| Mean difference | 2.55 ± 1.19 | | 2.90 ± 0.85 | | 2.70 ± 1.53 | | 3.05 ± 1.10 | | 3.429 | 0.33 |
| Percentage of change | 60.23 ± 14.87 | | 64.75 ± 12.45 | | 53.10 ± 28.35 | | 54.21 ± 16.76 | | 3.272 | 0.352 |
| **Physical function** Median (min–max) | 23 (14–48) | 11 (3–18) | 29 (16–46) | 12 (2–25) | 32.5 (14–48) | 16 (8–34) | 37 (24–57) | 19 (7–40) | | |
| ***z* ($p_0$)** | **3.925* (<0.001*)** | | **3.924* (<0.001*)** | | **3.925* (<0.001*)** | | **3.924* (<0.001*)** | | | |
| Mean difference | 16.15 ± 9.04 | | 15.9 ± 5.63 | | 14.5 ± 5.22 | | 15 ± 5.91 | | 0.619 | 0.892 |
| Percentage of change | 57.79 ± 13.29 | | 55.17 ± 13.92 | | 46.04 ± 13.04 | | 42.41 ± 16.41 | | **14.064*** | **0.003*** |
| Sig. bet. groups | $p_1$ = 0.483, $\mathbf{p_2 = 0.017}$*, $\mathbf{p_3 = 0.001}$*, $p_4$ = 0.090, $\mathbf{p_5 = 0.008}$*, $p_6$ = 0.344 | | | | | | | | | |
| **Total score** (mean ± SD) | 40.8 ± 12.94 | 15.95 ± 5.63 | 43.7 ± 9.73 | 18.05 ± 6.41 | 48.45 ± 13.7 | 24.7 ± 11 | 55.35 ± 8.9 | 31.15 ± 11.7 | | |
| ***t* ($p_0$)** | **9.270* (<0.001*)** | | **13.428* (<0.001*)** | | **13.678* (<0.001*)** | | **12.375* (<0.001*)** | | | |
| Mean difference | 24.85 ± 11.99 | | 25.65 ± 8.54 | | 23.75 ± 7.77 | | 24.20 ± 8.75 | | 0.765 | 0.858 |
| Percentage of change | 24.85 ± 11.99 | | 25.65 ± 8.54 | | 23.75 ± 7.77 | | 24.20 ± 8.75 | | **13.586*** | **0.004*** |
| Sig. bet. groups | $p_1$ = 0.688, $\mathbf{p_2 = 0.025}$*, $\mathbf{p_3 = 0.002}$*, $p_4$ = 0.067, $\mathbf{p_5 = 0.006}$*, $p_6$ = 0.348 | | | | | | | | | |

Pairwise comparison between each 2 groups was done using post hoc test (Dunn's for multiple comparisons test)

*H* Kruskal–Wallis test, *t* paired *t* test, *Z* Wilcoxon signed-rank test

*p*: *p* value for comparing between the studied groups

$p_0$: *p* value for comparing between before and after

$p_1$: *p* value for comparing between group 1 and group 2

$p_2$: *p* value for comparing between group 1 and group 3

$p_3$: *p* value for comparing between group 1 and group 4

$p_4$: *p* value for comparing between group 2 and group 3

$p_5$: *p* value for comparing between group 2 and group 4

$p_6$: *p* value for comparing between group 3 and group 4

* Statistically significant at $p \leq 0.05$

**Table 5** Comparison between the different studied groups according to timed up and go test and six meter walk time

| Timed up and go test (Mean ± SD) | Group 1 ($n=20$) | | Group 2 ($n=20$) | | Group 3 ($n=20$) | | Group 4 ($n=20$) | | H | p |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | | |
| **Total score (sec)** | 12.1 ± 1.36 | 9.89 ± 0.78 | 11.91 ± 1.5 | 9.98 ± 0.98 | 12.9 ± 1.88 | 10.53 ± 1.5 | 14.7 ± 2.35 | 12.3 ± 1.97 | | |
| t ($p_0$) | **9.302* (< 0.001*)** | | **10.164* (< 0.001*)** | | **7.816* (< 0.001*)** | | **9.299* (< 0.001*)** | | | |
| Mean difference | 2.22 ± 1.06 | | 1.93 ± 0.85 | | 2.39 ± 1.36 | | 2.45 ± 1.18 | | 1.425 | 0.700 |
| Percentage of change | 17.78 ± 6.84 | | 15.75 ± 6.17 | | 17.94 ± 7.93 | | 16.41 ± 6.69 | | 0.213 | 0.975 |
| **Stand up (sec)** | 1.10 ± 0.21 | 0.82 ± 0.15 | 1.12 ± 0.26 | 0.88 ± 0.16 | 1.28 ± 0.35 | 0.91 ± 0.21 | 1.33 ± 0.30 | 1.08 ± 0.28 | | |
| t ($p_0$) | **5.715* (< 0.001*)** | | **5.670* (< 0.001*)** | | **5.895* (< 0.001*)** | | **3.603* (0.002*)** | | | |
| Mean difference | 0.28 ± 0.22 | | 0.25 ± 0.19 | | 0.38 ± 0.28 | | 0.25 ± 0.31 | | 2.277 | 0.517 |
| Percentage of change | 23.69 ± 15.74 | | 19.49 ± 13.94 | | 26.22 ± 18.32 | | 16.87 ± 21.35 | | 1.883 | 0.597 |
| **Walk 1 (sec)** | 3.79 ± 0.57 | 3.18 ± 0.29 | 3.73 ± 0.59 | 3.18 ± 0.32 | 3.89 ± 0.63 | 3.19 ± 0.49 | 4.60 ± 1.0 | 3.93 ± 0.78 | | |
| t ($p_0$) | **5.395* (< 0.001*)** | | **5.627* (< 0.001*)** | | **5.246* (< 0.001*)** | | **5.418* (< 0.001*)** | | | |
| Mean difference | 0.61 ± 0.51 | | 0.55 ± 0.44 | | 0.7 ± 0.59 | | 0.68 ± 0.56 | | 0.649 | 0.885 |
| Percentage of change | 15.07 ± 9.72 | | 13.68 ± 9.25 | | 16.79 ± 12.18 | | 13.73 ± 10.05 | | 0.457 | 0.928 |
| **Turn (sec)** | 1.41 ± 0.35 | 1.19 ± 0.25 | 1.50 ± 0.29 | 1.16 ± 0.26 | 1.65 ± 0.32 | 1.29 ± 0.33 | 1.76 ± 0.42 | 1.40 ± 0.3 | | |
| t ($p_0$) | **3.535* (0.002*)** | | **9.121* (< 0.001*)** | | **4.460* (< 0.001*)** | | **5.401* (< 0.001*)** | | | |
| Mean difference | 0.22 ± 0.28 | | 0.34 ± 0.17 | | 0.37 ± 0.37 | | 0.36 ± 0.3 | | 3.350 | 0.341 |
| Percentage of change | 13.03 ± 20.44 | | 22.62 ± 10.17 | | 20.79 ± 19.42 | | 18.43 ± 16.65 | | 3.110 | 0.375 |
| **Walk 2 (sec)** | 3.73 ± 0.51 | 3.07 ± 0.36 | 3.69 ± 0.47 | 3.20 ± 0.33 | 3.85 ± 0.59 | 3.34 ± 0.55 | 4.68 ± 1.01 | 3.90 ± 0.7 | | |
| t ($p_0$) | **6.990* (< 0.001*)** | | **6.861* (< 0.001*)** | | **5.852* (< 0.001*)** | | **6.597* (< 0.001*)** | | | |
| Mean difference | 0.66 ± 0.42 | | 0.49 ± 0.32 | | 0.51 ± 0.39 | | 0.78 ± 0.53 | | 5.839 | 0.120 |
| Percentage of change | 16.97 ± 9.62 | | 12.73 ± 7.73 | | 12.89 ± 8.65 | | 15.74 ± 8.8 | | 3.675 | 0.299 |
| **Sit down (sec)** | 2.08 ± 0.54 | 1.63 ± 0.4 | 1.87 ± 0.38 | 1.57 ± 0.3 | 2.25 ± 0.44 | 1.81 ± 0.4 | 2.34 ± 0.5 | 1.96 ± 0.5 | | |
| t ($p_0$) | **4.321* (< 0.001*)** | | **4.629* (< 0.001*)** | | **4.311* (< 0.001*)** | | **5.473* (< 0.001*)** | | | |
| Mean difference | 0.45 ± 0.46 | | 0.31 ± 0.29 | | 0.45 ± 0.46 | | 0.38 ± 0.31 | | 0.752 | 0.861 |
| Percentage of change | 19.06 ± 16.29 | | 14.86 ± 14.14 | | 18.34 ± 17.51 | | 15.38 ± 11.86 | | 0.759 | 0.859 |
| | **Before** | **After** | **Before** | **After** | **Before** | **After** | **Before** | **After** | **F** | **P** |
| **6m walk time (sec)** | 7.47 ± 1.09 | 6.25 ± 0.59 | 7.42 ± 0.96 | 6.38 ± 0.56 | 7.73 ± 1.17 | 6.53 ± 1.0 | 9.28 ± 1.96 | 7.83 ± 1.44 | | |
| t ($p_0$) | 6.254* (< 0.001*) | | 7.615* (< 0.001*) | | 5.866* (< 0.001*) | | 6.516* (< 0.001*) | | | |
| Mean difference | **1.23 ± 0.88** | | **1.04 ± 0.61** | | **1.20 ± 0.91** | | **1.46 ± 1.0** | | 0.786 | 0.506 |

**Table 5** (continued)

| Timed up and go test (Mean ± SD) | Group 1 ($n=20$) | Group 2 ($n=20$) | Group 3 ($n=20$) | Group 4 ($n=20$) | H | *p* |
|---|---|---|---|---|---|---|
| Percentage of change | **19.69 ± 13.42** | **16.15 ± 9.27** | **19.30 ± 15.93** | **18.54 ± 11.93** | 0.305 | 0.822 |

*H* H for Kruskal Wallis test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Dunn's for multiple comparisons test)p: *p* value for comparing between the studied groups

*F* F for ANOVA test

*t* Paired t-test

*SD* Standard deviation

*Sec* Seconds

*6 m* six meter

*p p* value for comparing between the studied groups

$p_0$ *p* value for comparing between before and after exercise program

* Statistically significant at $p \leq 0.05$

**Table 6** Comparison between the different studied groups according to MSEBT

| MSEBT (Mean ± SD) | Group 1 ($n=20$) | | Group 2 ($n=20$) | | Group 3 ($n=20$) | | Group 4 ($n=20$) | | H | p |
|---|---|---|---|---|---|---|---|---|---|---|
| | Before | After | Before | After | Before | After | Before | After | | |
| **Anterior** | 65.74 ± 7.91 | 76.02 ± 10.14 | 68.91 ± 9.52 | 75.70 ± 8 | 65.91 ± 8.89 | 72.25 ± 8.58 | 69.1 ± 6.75 | 73.4 ± 5.81 | | |
| **t ($p_0$)** | **7.779*** **(< 0.001*)** | | **4.894*** **(< 0.001*)** | | **4.322*** **(< 0.001*)** | | **3.253*** **(0.004*)** | | | |
| **Mean difference** | 10.28 ± 5.91 | | 6.79 ± 6.2 | | 6.34 ± 6.54 | | 4.31 ± 5.92 | | **8.023*** | **0.046*** |
| **Sig. bet. Groups** | $p_1 = 0.086$, $p_2 = 0.069$, $\mathbf{p_3 = 0.005^*}$, $p_4 = 0.916$, $p_5 = 0.287$ $p_6 = 0.337$ | | | | | | | | | |
| **Percentage of change** | **15.73 ± 8.99** | | **10.72 ± 10.47** | | **10.30 ± 10.54** | | **6.75 ± 8.89** | | **8.831*** | **0.032*** |
| **Sig. bet. Groups** | $p_1 = 0.059$, $p_2 = 0.081$, $\mathbf{p_3 = 0.003^*}$, $p_4 = 0.886$, $p_5 = 0.299$ $p_6 = 0.238$ | | | | | | | | | |
| **Posteromedial** | 79.24 ± 10.08 | 95.69 ± 7.9 | 79.09 ± 9.51 | 94.95 ± 7.84 | 75.67 ± 8.51 | 90.61 ± 9.13 | 77.52 ± 11.51 | 85.52 ± 11.74 | | |
| **t ($p_0$)** | **10.937*** **(< 0.001*)** | | **13.456*** **(< 0.001*)** | | **8.768*** **(< 0.001*)** | | **4.870*** **(< 0.001*)** | | | |
| **Mean difference** | 16.45 ± 6.72 | | 15.86 ± 5.27 | | 14.95 ± 7.62 | | 8.01 ± 7.35 | | **15.748*** | **0.001*** |
| **Sig. bet. Groups** | $p_1 = 0.809$, $p_2 = 0.600$, $\mathbf{p_3 = 0.001^*}$, $p_4 = 0.778$, $\mathbf{p_5 = 0.001^* p_6 = 0.003^*}$ | | | | | | | | | |
| **Percentage of change** | 21.79 ± 10.83 | | 20.82 ± 8.81 | | 20.35 ± 11.01 | | 10.87 ± 10.26 | | **13.382*** | **0.004*** |
| **Sig. bet. Groups** | $p_1 = 0.884$, $p_2 = 0.809$, $\mathbf{p_3 = 0.002^*}$, $p_4 = 0.924$, $\mathbf{p_5 = 0.003^*}$, $\mathbf{p_6 = 0.004^*}$ | | | | | | | | | |
| **Posterolateral** | 75.65 ± 7.16 | 91.99 ± 9.24 | 72.85 ± 6.25 | 88.32 ± 8.11 | 73.81 ± 7.56 | 89.44 ± 7.50 | 68.17 ± 8.87 | 80.12 ± 9.93 | | |
| **t ($p_0$)** | **9.008*** **(< 0.001*)** | | **10.651*** **(< 0.001*)** | | **9.066*** **(< 0.001*)** | | **6.937*** **(< 0.001*)** | | | |
| **Mean difference** | 16.34 ± 8.11 | | 15.47 ± 6.50 | | 15.63 ± 7.71 | | 11.95 ± 7.70 | | 4.775 | 0.189 |
| **Percentage of change** | 22.10 ± 11.88 | | 21.55 ± 9.99 | | 21.89 ± 12.03 | | 18.19 ± 12.70 | | 2.661 | 0.447 |

*t* Paired t-test

*H* H for Kruskal Wallis test, Pairwise comparison bet. each 2 groups was done using Post Hoc Test (Dunn's for multiple comparisons test)p: *p* value for comparing between the studied groups

p: *p* value for comparing between the studied groups, $p_0$: *p* value for comparing between before and after

$p_1$: *p* value for comparing between Group 1 and Group 2, $p_2$: *p* value for comparing between Group 1 and Group 3

$p_3$: p value for comparing between Group 1 and Group 4, $p_4$: *p* value for comparing between Group 2 and Group 3

$p_5$: *p* value for comparing between Group 2 and Group 4, $p_6$: *p* value for comparing between Group 3 and Group 4

*: Statistically significant at $p \leq 0.05$

the combined balance and strengthening exercise program and their effects on KOA symptoms and functional outcomes was studied.

There was a statistically significant difference in age and BMI between the 4 studied groups, where group 4 patients were the eldest and had the highest BMI. This was unavoidable as this study was a non-randomized interventional study where the enrolled KOA patients were divided into four groups according to the KL grading scale.

The highest frequency of falls during walking and descending stairs was among G4 patients (75%) as compared to the other groups. Moreover, G4 had more frequent fallers (60% of patients). Furthermore, the lowest statistical frequency of insecurity during walking was encountered in G1 (65%) compared to other groups (95–100%). This is consistent with other studies that showed higher stability and less falls in patients with mild KOA comparable to normal healthy individuals [25]. Several factors could explain the sense of insecurity in patients with KOA including pain, muscle weakness, impaired proprioception, and knee joint laxity [26, 27]. Pain could interfere with the spinal reflex pathway, which in turn interferes with sensory and motor signals via synaptic inhibition [28]. Q-muscle weakness is a common finding in most KOA patients, where arthrogenic muscle inhibition (AMI) is accused as a contributor to this weakness [29]. AMI is a phenomenon of inadequate knee extension caused by reflex Q-muscle inhibition, involving spinal and supraspinal centers, which in turn leads to muscle dysfunction and weakness [30]. The Q-muscle weakness interferes with proper shock absorption and appropriate transfer of force across the joint decreasing the ability to control joint movements [26, 31]. Furthermore, impaired proprioception leads to abnormal loading of the knee joint through disruption of the afferent component of neuromuscular reflex. This results in inadequate timely and effective motor responses in postural control and incoordination of the muscles around the joint [32, 33]. Knee joint laxity may delay neuromuscular responses as larger joint excursions are needed to activate the mechanoreceptors [12].

#### Outcome measures

Several positive effects have been observed due to different types of exercise; resistance exercises increase the Q-muscle sensorimotor sensitivity, functional activity-oriented exercise programs enhance motor learning, and weight-bearing exercises increase intra-articular pressure, thereby stimulating Ruffini nerve endings in the capsule and ligaments. These could improve the ability of the nervous system to fully activate the muscle, thus increasing its strength [34].

In this study, there was a statistically significant improvement in Q-muscle strength in all the studied groups following exercise, with no statistically significant difference between groups as regards 1-RM percentage of change. However, one could notice that the 1-RM percentage of change was lower in patients with milder KOA (groups 1 and 2; 30.59% and 25.17%, respectively) than in those with more severe KOA (groups 3 and 4; 65.21% and 43.83%, respectively). This observation highlights the relation between the grade of KOA, muscle power, and exercise gain. In this regard, patients with milder KOA had a better initial muscle power in contrast to patients with more severe KOA, which explains the gain difference observed. A similar finding was reported by Pazit et al.[23] who reported improvement in muscle power following exercise regardless of the exercise implemented.

Physical function (assessed by WOMAC, TUC, and 6-m walk time) and pain (assessed by WOMAC) showed a significant improvement in all the studied groups at the end of the exercise program. This is in accordance with literature reviews and individual prospective studies, and they proposed that muscle activation and strengthening by exercise result in mechanoreceptor stimulation which could reduce pain and improve physical function [34–36]. Exercise also generates endogenous analgesia through muscle contractions by activating the endogenous opioid system. This improves the reported pain and function [9, 37]. Moreover, other studies found that balance exercise increases coordination between muscle groups and improves muscle response to sensorial information. This, in turn, improves the physical function of patients [17, 36].

In this study, patients with milder KOA (groups 1 and 2) had a higher improvement in the percentage of change of physical function and total WOMAC scores compared to those with more severe KOA (groups 3 and 4). This could be explained by the adverse effects of severe KOA on muscle coordination, marked inflammatory changes of the joint tissue, and the extensive cartilage loss that is irreversible by any exercise program. Moreover, patients with more severe KOA had the worst clinical findings at enrollment.

The 4 groups showed a statistically significant shorter 6-m walking time at the end of the exercise program, with no statistically significant difference between the groups. The effect of exercise training in increasing the Q-muscle strength and improving its neural control could explain the improvement in 6-m walking time. Moreover, the decreased pain and disability due to strengthening exercises could also contribute to the improvement of the walking speed [38, 39].

All the studied groups showed a statistically significant improvement in dynamic balance after exercise. This

was represented by an increase in the reach distance in all three tested directions of the MSEBT after exercise. The MSEBT balance challenge setup entails the necessary competent stiffness reaction acting at the knee joint and is fulfilled by efficient Q-hamstring co-contraction [17, 40]. Although the MSEBT is more widely used in assessing dynamic postural control and to help predict athletes at risk for injuries to lower limbs, in recent years, the original SEBT reliability and longitudinal validity have been proven in KOA [41].

The improvement in MSEBT reach distance may implicitly reflect improved co-contraction of muscles acting at the knee. This improved co-contraction is assumed to be an outcome of the employed exercise program. Increased muscle strength after exercise could play a role in increasing reach distance in each direction. It has been found that improvement of the vastus medialis muscle strength increases reach distance in the anterior direction [40, 42]. The vastus lateralis is highly activated during the posteromedial direction due to the varus force created at the knee. Thus, improvement of its strength may increase reach distance in the posteromedial direction. The bicep femoris, tibialis anterior, and medial hamstring are activated more in the posterior direction; therefore, improvement in their strength improves reach in the posterior-based directions [40].

Several authors reported similar results in which patients with KOA showed a significant improvement in dynamic balance after exercise [17, 42–44], whether they have used combined hydrotherapy and land-based exercises [43] or combined strengthening and balance exercises [17, 44].

The results showed that group 1 patients exhibited a significantly higher percentage of change in A and PM directions compared to group 4, while groups 2 and 3 showed a significantly higher percentage of change only in PM compared to group 4. This could signify that patients with milder KOA attain a higher benefit from exercise compared to more severe KOA. The observed higher benefit achieved from exercise in the milder grades of KOA can be explained by variation in muscle activation patterns with increased severity of KOA. This activation variation with increased structural severity could be explained by variation in systematic delays in temporal responses and raised demand for the overall active stiffness, especially during mid-stance in grade 4 KOA [45]. In addition, patients with severe KOA have more degenerative histological changes including severe synovitis and extensive cartilage surface loss, which in turn negatively affect proprioception [12, 32, 33] that may not be re-established by rehabilitation and training. Moreover, patients with grade 4 KOA had the worst fall history at the enrollment.

Although KOA patients in this study were non-randomized categorization into four groups (20 patients each) based on the KL grading scale, this led to a discrepancy in the demographic, anthropometric, and clinical data between the 4 groups. This discrepancy affected the overall outcome of the study, where patients with mild-moderate KOA showed more significant improvements across all the outcome measures.

This study had several limitations. First, a longer duration of follow-up to assess the long-term effects of the program may give important information. Secondly, the relatively high dropout rate was attributed to the COVID-19 pandemic and other socioeconomic reasons. Thirdly, a control group could have supported the findings of this study.

## Conclusion

Combined balance and strengthening exercise programs may improve pain, physical function, and dynamic balance in patients with KOA regardless of the grading of KOA. Patients with mild-moderate forms of KOA may show better improvement in pain, physical function, and some directions of dynamic balance compared to patients with severe KOA. However, patients with more severe KOA may still benefit from exercise programs as they showed comparable improvement in the same aspects of the disease.

### Abbreviations

| | |
|---|---|
| A | Anterior |
| AMI | Arthrogenic muscle inhibition |
| BMI | Body mass index |
| FE | Fisher's exact |
| G | Grade |
| KL | Kellgren and Lawrence |
| KOA | Knee osteoarthritis |
| MC | Monte Carlo |
| MSEBT | Modified Star Excursion Balance Test |
| OA | Osteoarthritis |
| PL | Posterolateral |
| PM | Posteromedial |
| Q | Quadriceps |
| RM | Repetition maximum |
| TUG | Timed up and go |
| WOMAC | Western Ontario and McMaster University Osteoarthritis Index |
| $X^2$ | Chi-square test |

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### Authors' contributions

All authors have read and approved the manuscript, and all authors have contributed significantly and are in agreement with the content of the manuscript. MA contributed to the idea, study design, and writing and editing of the manuscript. ST contributed to the idea, study design, and editing of the manuscript. YA contributed to the idea, handled the categorization of patients into different groups according to KOA severity, and wrote and edited the manuscript. SM contributed to the idea, study design collection, clinical

assessment of the patients, and carrying out balance and exercise programs; analyzed and interpreted the patient data; and wrote and edited the manuscript. All authors read and approved the final manuscript.

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**Availability of data and materials**
Not applicable.

## Declarations

**Ethics approval and consent to participate**
All participants were informed about the nature of the study, and written informed consent was taken from all of them. The Ethical Committee, Faculty of Medicine, Alexandria University, approved the study, serial number: 0105852. The research was prospectively registered in ClinicalTrials.gov: NCT04227860 on the 9th of January 2020. The research was conducted in accordance with the Declaration of the World Medical Association of Helsinki.

**Consent for publication**
Not applicable.

**Competing interests**
The authors declare that they have no competing interests.

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