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RESEARCH ARTICLE

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The efficacy of exergaming in patients with knee osteoarthritis: A randomized controlled clinical trial

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Abstract

Background: Exergaming, one of the most recognized virtual rehabilitation tools, has been shown to be useful for promoting physical activity and enhancing postural stability for neurologic conditions. However, studies with exergaming programs for patients with knee osteoarthritis (OA) are limited.

Aims: We aimed to investigate the effects of exergaming given by visual and auditory stimulated assisted joint training device in addition to the conventional physiotherapy program on pain intensity, range of motion (ROM), functional status, kinesiophobia, proprioceptive acuity, muscle strength, and postural stability in patients with knee OA.

Study Design: Randomized controlled clinical trial.

Methods: Sixty patients (47 female, 13 male) with knee osteoarthritis aged 40–65 years (57.36 ± 7.26) who were at stage of two to three according to the Kellegren Lawrence radiological evaluation were included in the study. The patients were randomly divided into two groups as study group (conventional physiotherapy + exergaming) and control group (conventional physiotherapy). Electrotherapy and exercise program were applied to both of the groups along 5 days a week for 6 weeks but exergaming only applied to study group. ROM, pain intensity, proprioceptive acuity, kinesiophobia, muscle strength, and postural stability of the patients were evaluated at the beginning and end of the treatment.

Results: In the intra-group analyses of all the assessments of the patients, there was a significant difference in the positive direction in both groups, except for the postural stability values. In the intra-group analyses of postural stability, there was a significant increase only in the study group. In comparison between the groups, proprioceptive acuity, ROM, functional status, and postural stability scores were significantly increased in the study group according to the control group; pain and kinesiophobia decreased significantly.

Conclusion: In this study, the exergaming accompanied with conventional physiotherapy programs resulted more positive improvements on pain, ROM, postural stability, kinesiophobia, proprioceptive acuity, and functional status in patients with knee OA compared to the conventional physiotherapy program alone.

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KEYWORDS
arthritis, musculoskeletal, physiotherapy

1 | INTRODUCTION

Knee osteoarthritis (OA) is a common joint disease worldwide and is the leading cause of pain and disability in the elderly. The Osteoarthritis Research Society International published consensus recommendations from experts based on evidence to treat knee OA, which also includes exercise programs. Land-based exercises are recommended for OA patients to relieve symptoms and to improve functionality in activities of daily living (Bannuru et al., 2019). Exercise programs can be a repetitive and boring task causing many patients to face problems such as lack of motivation to maintain treatment so finding strategies to increase motivation can be beneficial (Sílvia et al., 2021). In order to increase compliance with exercise programs and increase motivation, digital applications have been developed that allow exercises to be performed with video games. Exergaming is a term coined for the combination of exercise and gaming. It uses non- to semi-immersive virtual reality(VR)-based intervention that can be administered through any computer game or VR where the participant can interact with virtual objects through physical movement. The most used motion capture in consoles for exergaming in the researches are Nintendo Wii, Xbox, PlayStation. For example, Nintendo Wii is composed of a balance board with a video game console and its related software. While the person is standing on the balance board, person tries to play the game (such as boxing, baseball) on the screen opposite (Soares et al., 2021). It is reported that moderate-to-vigorous intensity physical activities can be performed with exergaming programs that include many different physical activities (e.g., kicking, throwing). For example, Kinect is an exergaming tool which enables three dimensional (3D) images of objects and access to skeletal tracking data. Thanks to Kinect, individuals can perform many physical activities by imitating the movements of the avatar figure they see on the screen, and they do not need to wear any equipment (Mousavi Hondori & Khademi, 2014). Exergaming contributes to motor learning as it provides audio-visual feedback and repetitive tasks. Due to its contribution to motor learning, exergaming studies are frequently encountered in neurological diseases (Cold pack, stroke, Parkinson) in both children and adults. Due to its contribution to motor learning, exergaming studies are frequently encountered in neurological diseases in both children and adults (Bonnechère et al., 2016). Studies in which exergaming is generally used after surgery in orthopedic diseases are reported. It has been reported that catastrophing of pain in the acute period after arthroplasty surgeries may lead to kinesiophobia. For these reasons, the effects of exergaming after surgery on kinesiophobia have been more studied (Filardo et al., 2016). Exergaming studies are limited in patients with knee OA who have not undergone surgery. Kinesiophobia, in other words, the fear of movement, is seen as a pain avoidance behavior in chronic painful conditions. Therefore, we think that the effects of exergaming on kinesiophobia should be investigated in knee OA.

Although exergaming studies in patients with knee OA are limited, the effects on muscle strength were not addressed in the studies. Taking all this into account, we aimed to investigate the effects of exergaming on muscle strength of knee, range of motion (ROM), pain, proprioceptive acuity, kinesiophobia, postural stability, and functional status in patients with knee OA.

The hypotheses of the research are:

H0: *The Exergaming has no effects on muscle strength of knee, ROM, pain, proprioceptive acuity, kinesiophobia, postural stability, and functional status in patients with knee OA.*

H1: *The Exergaming is an effective method to improve on muscle strength of knee, ROM, pain, proprioceptive acuity, kinesiophobia, postural stability, and functional status in patients with knee OA.*

2 | METHODS

This study was designed as a randomized controlled trial with outpatients applying to the Physical Therapy and Rehabilitation polyclinic of a medical center in Istanbul. The ethical approval was obtained from Non-Invasive Research Ethics Committee of Marmara University in Turkey. Prior to the study and all procedures were conducted according to the Declaration of Helsinki.

2.1 | Participants

Sixty volunteer participants with knee OA aged 40–65 years who were at stage of two to three according to the Kellgren Lawrence radiological evaluation were included in the study. Patients with a history of surgery at knee, hip, ankle, or/and foot, systemic anti-inflammatory joint disease, any condition which was contraindicated for electrical stimulation and/or exercise, previous physiotherapy on the same knee in the last 6 months and a history of corticosteroid injection in last 3 months were excluded.

2.2 | Sample size and randomization method

Our sample size was calculated based on assuming the power of the study to be 80%, type 1 (α) error of 0.05 and effect size = 0.68 (Wi & Kang, 2012). A sample calculation was made based on the balance scores in the study of Wi and Kang After calculating this we required a minimum of 30 patients in each of groups. Out of 70 patients

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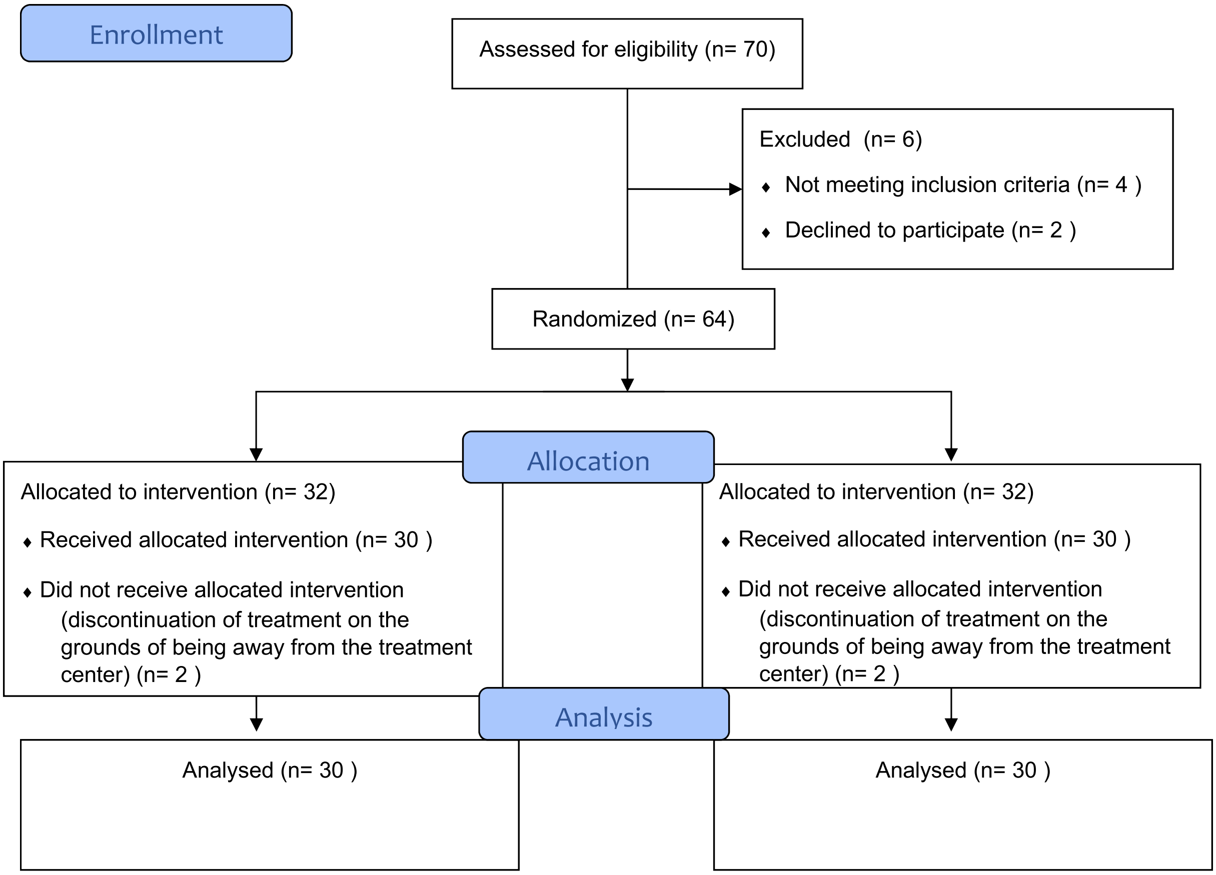

FIGURE 1 Consort flow diagram

assessed for eligibility, 60 patients met the inclusion criteria (Figure 1: Consort Flow diagram). Patients were divided into two groups using block randomization method. Patients were randomly allocated into two blocks of 30 patients in each group using a random number generation technique by computer. All assessments were done by researcher who were not in the study.

2.3 | Procedure

Written consent for participation and intervention procedure was obtained from all the participants. While a conventional physiotherapy program consisting of electrotherapy and exercise program was applied to both groups (study and control groups) 5 days a week for 6 weeks, an exergaming was added to the study group for 6 weeks, 5 days a week. At the beginning of the treatment and at the end of the sixth week, ROM, pain, kinesiophobia, proprioceptive acuity, postural stability, muscle strength, and functional status were evaluated.

Conventional physiotherapy consists of electrotherapy and exercise programs. Hotpack or coldpack, therapeutic ultrasound (US) and conventional transcutaneus electrical nerve stimulation were applied as electrotherapy program. Firstly, the participants were evaluated for the presence of edema. Patients who have edema have been treated with cold pack and others have been treated with hot pack. Exercise program consists of isometric strengthening of the quadriceps muscle, terminal knee extension, leg press exercise with elastic band (Thera-Band®), and hamstring stretching. Muscle strength of the patients was evaluated and then strengthening exercises were performed by selecting appropriate elastic band for patients according to muscle strength as 10 repetitions and 3 sets.

Exergaming program was implemented with a joint education device which is called MarVAJED® (Marmara Visual Auditory Joint Education Device). It was developed by Marmara University, Department of Physiotherapy and Rehabilitation, Istanbul, Turkey. MarVAJED® is a system that evaluates the ROM of the joints, analyzes the sensation of joint position, provides auditory and visual biofeedback support to increase joint control, and the same time allows exercises to be controlled. This device analyzes the joint motion with the help of small sensors. The obtained data transfers to your mobile phone, to the tablet or to your personal computer. It stores the data by downloading it to the central server via internet for storage (Aydoğdu et al., 2017). In this study, the patients performed the exercises with MarVAJED® system. At first, the sensors of MarVAJED® were placed under and above the knee joint and then it was calibrated. The content of the game programs included in the MarVAJED system and how to perform these games with the exercises were explained to the participants. We used games called "Crazy Wings (Figure 2) and Blasting Ball" included in the MarVAJED®. There was a bird figure in Crazy Wings game and

FIGURE 2 Crazy Wings ("Crazy Wings" is a video game which is in MarVAJED system)

represented knee joint of participants. When the bird figure moved upwards during knee flexion, it moved downward in knee extension, there were some obstacles on the way of the bird. The subjects were asked to follow the bird figure visually and to pass through the obstacles by flexing or extending their knees when they encountered obstacles. In the blasting ball game, the ball was swelling while knee was flexing, and was exploded when degree of knee flexion was reached peak value. In this game, the aim was to increase degree of knee flexion. Squat exercises (Figure 3) were performed with "Crazy Wings" and leg press exercises with elastic band were trained during "Blasting ball" game (Figure 4). Upper and lower limits of knee flexion were determined as 10°–60° for squat exercises. The exergaming program lasted 20 min for each session.

FIGURE 3 Squat exercises with Crazy Wings game

2.4 | Physical measurements

The active ROM (flexion, extension) was assessed by using a universal goniometer with participants lying in supine. The fully extended knee was considered as the zero position (Steultjens et al., 2000). Measurements were repeated three times and the average value was used in the statistical analysis.

Concentric and isometric muscle strengths of knee extensors and flexors were evaluated via Biodex System Pro 4 Isokinetic Dynamometer (Biodex Medical Systems, Inc.). The subjects were seated in such a position that knee and hip were at 90° flexion, and shoulders, ankle, and pelvis were fixed to the machine. Before testing, 5-min warming program was performed by using treadmill. Isokinetic test was performed with five repetitions at 120°/s and 240°/s angular velocities. Tests were performed in a standardized order and all subjects have received identical instructions and encouragements. Isometric knee extension and flexion were measured in 90° flexion position. Each test was performed three times with maximal contraction for 5- and 10-s rest between trials. For each test, peak torque (Nm) and peak torque normalized to body mass (Nm/kg) were used for analysis (Baert et al., 2013).

We used Visual Analog Scale (VAS) to evaluate knee pain during rest, night, and activity. The VAS consists of a 10 cm straight line which presents a continuum of intensity and has verbal anchors at opposite ends representing "no pain" at the bottom and "pain as bad as it can be" at the top. The participants were asked to mark the representing point of their pain levels. The values were recorded in cm (Gaston-Johansson & Gustafsson, 1990).

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FIGURE 4 Leg press exercises with Blasting Ball game ("Blasting ball game" is a video game which is in MarVAJED system)

TABLE 1 Demographic details of each group

	Virtual group (n = 30) Median (IQR 25/75)	Control group (n = 30) Median (IQR 25/75)	Significance level (p)
Gender (female/male)	24/6	23/7	0.754[a]
Age (years)	59.5 (55/64)	57 (51/65)	0.350[a]
Body-mass index (kg/m^2)	30.3 (24.96/33.16)	32.14 (31.8/32.42)	0.670[a]
Marial status			
Single	1	3	0.612[a]
Married	29	27	
Education level			
Primary school	16	10	0.306[a]
High school	12	15	
Undergraduate	2	5	
Work			
Yes	2	2	0.207[a]
No	23	17	
Retired	5	11	
Comorbidity			
Yes	20	23	0.162[a]
No	10	7	
Smoking			
Yes	3	2	0.956[a]
No	27	28	

Note: IQR 25/75, interquartile range 25/75.

[a]Mann–Whitney *U* test.

$p < 0.05$.

Proprioceptive acuity relies on joint position sense. Knee joint position sense was assessed with goniometer. The subjects were asked to lie down in prone position and were instructed to bend the knee slowly while a researcher held a goniometer away from the leg, with the arms in line with the reflective markers at the hip and ankle, and the axis over the lateral femoral epicondyle. When a target angle of 0°–30° of knee flexion was attained, the subject was instructed to stop and to hold the position for 5 s. They were then instructed to straighten the knee and return to the erect standing position. After an additional 7 s, the subject was instructed to reproduce the angle with their eyes closed. Subjects indicated when they felt they had attained the target angle. The tester then instructed the subject to return to the starting position. The same protocol was performed in 60°. The measurements were repeated three times and average values were recorded (Hopper et al., 2003).

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PEDALO® Sensamove Balance System was used to evaluate postural stability of subjects. This system is used to provide information about the balance control mechanisms of the body as well as to increase balance performance. It has a balance board in which consists of sensors to record and process data about balance performance to a computer. The subjects were asked to stand on the balance board for 30 s without their hands support. The balance score was recorded by the system in percent (https://www.pedalo.de/media/pdf/69/67/cd/Pedalo-catalog_2019-2020_EN.pdf, Accessed June 15, 2018).

2.5 | Questionnaires

Kinesiophobia (fear of movement) was assessed with TAMPA Scale for Kinesiophobia (TSK). TSK is a 17-item measure that assesses kinesiophobia. Each item is evaluated on a four-point Likert scale with scoring alternatives ranging from "strongly disagree" to "strongly agree." Total scores range from 17 to 68, with higher scores reflecting greater kinesiophobia. Turkish validity and reliability of TSK was carried out (Acar et al., 2016).

We assessed functional status of participants with "Western Ontario and McMaster Universities Arthritis" (WOMAC LK 3.1). It assess patient-relevant symptoms such as pain, stiffness, and physical function in patients with hip or knee OA. It has 24 questions in three subscales (pain, stiffness, physical functions). It is available in Likert, VAS, and numeric rating scale formats. In Likert version, each item is scored 0–4 on a Likert scale (0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = extreme). In order to normalize the WOMAC Osteoarthritis index on 0–10 scales, as recommended in the user guide, the following correction factors are used where S = sum of raw scores of items in dimension: pain score range: 0–20, normalization = ($S \times 0.50$); stiffness score range: 0–8, normalization = ($S \times 1.25$); and physical function score range: 0–68, normalization = ($S \times 0.147$). Total score is calculated sum values of three subscales (Tüzün et al., 2005).

TABLE 2 Comparison of pretest and posttest values of pain and functional status within and among groups

	Study group (n = 30) Median (IQR 25/75)	Within-group analysis p Value	Control group (n = 30) Median (IQR 25/75)	Within-group analysis p Value	Among group analysis of change p Value
VAS rest (mm)					
Pretest value	32.2 (20.75/40)	**0.001**[a]	36.6 (30–40)	**0.001**[a]	**0.048**[b]
Posttest value	10 (0/12.5)		20 (10/20)		
VAS activity (mm)					
Pretest value	74.2 (60/80)	**0.001**[a]	65.2 (50/70)	**0.001**[a]	**0.001**[b]
Posttest value	30 (30/40)		40 (30/40)		
VAS night (mm)					
Pretest value	43 (27.5/40)	**0.001**[a]	44 (20/50)	**0.001**[a]	**0.002**[b]
Posttest value	10 (0/20)		20 (10/30)		
WOMAC score (pain)					
Pretest value	6 (5.37/7.12)	**0.001**[a]	4.5 (4.3/6)	**0.001**[a]	**0.001**[b]
Posttest value	2.25 (1.5/3)		3 (2.5/4)		
WOMAC score (stiffness)					
Pretest value	7.5 (6/7.5)	**0.001**[a]	5.2 (4.9/7.5)	**0.001**[a]	**0.001**[b]
Posttest value	2.5 (2.18/3.75)		2.5 (0.98/5)		
WOMAC score (physical function)					
Pretest value	6.74 (6.4/7.2)	**0.001**[a]	5.2 (5.7/6.4)	**0.001**[a]	**0.001**[b]
Posttest value	2.35 (2/3.38)		3.23 (2.45/3.18)		
WOMAC total score					
Pretest value	19.7 (18.2/21)	**0.001**[a]	15.1 (9.3/18)	**0.001**[a]	**0.001**[b]
Posttest value	7.59 (4.95/9.4)		9.9 (6.4/11.5)		

Note: Δ: the amount of change between before and after treatment, IQR 25/75, interquartile range 25/75.
[a]Wilcoxon signed rank test.
[b]Mann–Whitney U test.
$p < 0.05$.

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2.6 | Statistical analysis

Statistical package for the social sciences version 22.0 statistical program was used to analyze the data of the study. "One Kolmogrov Smirnov" test and "Histogram analysis" were performed to evaluate the suitability of the data for normal distribution. It was found that the data of the study was not suitable for normal distribution. For this reason, nonparametric tests were performed. "Wilcoxon test" was used to analyze the pre- and post-treatment values of the groups, and "Mann–Whitney U″ test was used to analyze the difference values before and after treatment. In the statistical program, 95% confidence interval and significance level was taken as $p < 0.05$.

3 | RESULTS

Out of 70 patients assessed for eligibility, 60 patients met the inclusion criteria. Thirteen (22%) of participants were male and 47 (78%) of participants were female. According to pre-treatment analysis, there were no significant changes in sociodemographic characteristics (Table 1).

According to the results of intragroup analysis, there was a significant decrease in VAS, TAMPA, WOMAC, and joint position error values in both the study and control groups after treatment, while a significant increase was observed in ROM, isometric, and isokinetic scores (Tables 2–5). There was a significant increase in the postural stability scores only in the study group (Table 3).

Regarding to intergroup analysis, exergaming with conventional physiotherapy was found superior compared to conventional physiotherapy alone for improving pain, kinesiophobia, joint position sense, postural stability, ROM, and functional status (Tables 2 and 3); however, isometric and isokinetic scores were similar between groups (Tables 4 and 5).

In the study group, we see that the pain decreased more and balance, functional status, and proprioception improved more than the control group. ROM and muscle strength increased in both groups, but no significant difference was found between the groups.

At the end of the treatment, participants in the intervention group were questioned whether they were satisfied with their exergaming experience or not. Three options were presented to the patients. These are: "I am not satisfied," "I am undecided," "I am very satisfied." 60% of the participants stated that they were

TABLE 3 Comparison of pretest and posttest values of range of motion, proprioceptive acuity, postural stability, and kinesiophobia within and among groups

	Study group (n = 30) Median (IQR 25/75)	Within-group analysis p Value	Control group (n = 30) Median (IQR 25/75)	Within-group analysis p Value	Among group analysis of change p Value
Pedalo balance score (%)					
Pretest value	57 (50.2/62.2)	**0.001**[a]	70 (60/78.5)	**0.110**[a]	**0.001**[b]
Posttest value	75 (65/80)		72.5 (63.7/80)		
Knee flexion ROM (°)					
Pretest value	100 (95/110.5)	**0.001**[a]	110 (100/120)	**0.001**[a]	**0.015**[b]
Posttest value	115.5 (110/120)		111.5 (104.7/120)		
Knee extension ROM (°)					
Pretest value	176 (177/179)	**0.001**[a]	176 (176/179)	**0.001**[a]	**0.001**[b]
Posttest value	179 (178.7/180)		179 (178/180)		
Knee proprioception at 30°					
Pretest value	6.25 (5.75/8)	**0.001**[a]	7 (6/8)	**0.001**[a]	**0.001**[b]
Posttest value	3.5 (3/4)		6 (5/7)		
Knee proprioception at 60°					
Pretest value	8 (6/10)	**0.001**[a]	9 (7.3/10)	**0.001**[a]	**0.001**[b]
Posttest value	4 (3/5)		8 (6/9)		
TAMPA (score)					
Pretest value	46.5 (42.7/50)	**0.001**[a]	48 (45/49.25)	**0.001**[a]	**0.001**[b]
Posttest value	39 (36.7/40)		45.5 (41/48)		

Note: Δ: the amount of change between before and after treatment, IQR 25/75, interquartile range 25/75.

[a]Wilcoxon signed rank test.

[b]Mann–Whitney U test.

$p < 0.05$.

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TABLE 4 Comparison of pretest and posttest values of isokinetic muscle strength within and among groups

	Study group (n = 30) Median (IQR 25/75)	Within-group analysis p value	Control group (n = 30) Median (IQR 25/75)	Within-group analysis p value	Among group analysis of change p value
PT of KF at 120° (Nm)					
Pretest value	16.5 (11.3/20.8)	**0.001**[a]	14 (10.9/19.4)	**0.001**[a]	0.642[b]
Posttest value	28 (20.9/36.12)		25.5 (14.3/32.5)		
PT/BW of KF at 120° (Nm)					
Pretest value	23.5 (14/30)	**0.001**[a]	20 (12/26)	**0.001**[a]	0.210[b]
Posttest value	36.9 (26.4/47)		30.8 (24.3/40.5)		
PT of KE at 120° (Nm)					
Pretest value	20.4 (16.9/29)	**0.001**[a]	19.9 (12.5/27.5)	**0.001**[a]	0.115[b]
Posttest value	40.6 (31.8/47.9)		34.7 (26.3/44.7)		
PT/BW of KE at 120° (Nm)					
Pretest value	27.9 (21.6/39.2)	**0.001**[a]	25.6 (17.7/35.8)	**0.001**[a]	0.063[b]
Posttest value	52.5 (43.7/66.2)		40.2 (30.6/60)		
PT of KF at 240° (Nm)					
Pretest value	12 (10.2/15.6)	**0.001**[a]	12.1 (8.5/16.6)	**0.001**[a]	0.267[b]
Posttest value	28.14 (20/36.12)		27.9 (19/35.15)		
PT/BW of KF at 240° (Nm)					
Pretest value	16.4 (12.4/23.5)	**0.001**[a]	15.8 (10/21.4)	**0.001**[a]	0.109[b]
Posttest value	26 (21.3/31.4)		22.12 (19/28.2)		
PT of KE at 240° (Nm)					
Pretest value	11.9 (10.6/18)	**0.001**[a]	14.8 (11.2/20.5)	**0.001**[a]	0.084[b]
Posttest value	28 (19.9/33.9)		25.4 (18.3/30)		
PT/BW of KE at 240° (Nm)					
Pretest value	16.4 (13/24.8)	**0.001**[a]	20.3 (13.4/26.4)	**0.001**[a]	0.092[b]
Posttest value	36.8 (26.3/44.2)		31.7 (22.5/39)		

Note: IQR 25/75, interquartile range 25/75.

Abbreviations: KE, knee extension; KF, knee flexion; PT/BW, peak torque/body weight.

[a]Wilcoxon signed rank test.

[b]Mann–Whitney U test.

$p < 0.05$.

very satisfied, 10% were undecided, and 30% stated that they were not satisfied because they had difficulty using technological applications.

4 | DISCUSSION

The present study is the first randomized controlled trial investigating the effects of exergaming on the muscle strength in patients with knee OA. The effects of exergaming on muscle strength in individuals with different health statuses were examined (Viana et al., 2021) but were not examined in patients with knee OA. In a review it was declared that Exergaming may improve upper and lower limb muscle strength in individuals with different heath statuses compared to usual care interventions, but not muscle strength in middle age/older adults after accounting for random error (Lin et al., 2020). In the present study, the muscle strength results of the control group and the exergaming group were found to be similar. It is stated that exergames require body weight bearing exercises; they might be a useful tool for increasing muscle strength (Wiemeyer et al., 2015). In this study, body weight was used as resistance in squat exercises. But the focus was not on resistance exercises. The lack of difference between the two groups may be due to this. In a meta analysis, it is emphasized that in exergaming programs muscle strength cannot be increased unless resistance exercises are focused on (Viana et al., 2021). And also, poor adherence is recognized as a universal problem in all types of eHealth interventions in older people especially when users have limited experience of using such

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TABLE 5 Comparison of pretest and posttest values of isometric muscle strength within and among groups

	Study group (n = 30) Median (IQR 25/75)	Within-group analysis p value	Control group (n = 30) Median (IQR 25/75)	Within-group analysis p value	Among group analysis of change p value
PT of isometric KF (Nm)					
Pretest value	25.6 (24.2/32)	**0.001**[a]	25.15 (20/30.5)	**0.001**[a]	0.525[b]
Posttest value	40.3 (37.8/42.7)		39.8 (24.5/40.2)		
PT/BW of isometric KF (Nm)					
Pretest value	36.4 (28.3/40.2)	**0.001**[a]	33.75 (23.6/42)	**0.001**[a]	0.255[b]
Posttest value	53.5 (46.8/57.3)		49 (30.7/52.6)		
PT of isometric KE (Nm)					
Pretest value	58.5 (43.5/70.2)	**0.001**[a]	54.6 (43.6/66.5)	**0.001**[a]	0.090[b]
Posttest value	86.4 (70.15/100)		79.5 (63.1/92)		
PT/BW of isometric KE (Nm)					
Pretest value	76.4 (58.8/99)	**0.001**[a]	72.9 (54/88.45)	**0.001**[a]	0.380[b]
Posttest value	111.9 (92.5/130)		103 (88.2/120.6)		

Note: IQR 25/75, interquartile range 25/75.

Abbreviations: KE, knee extension; KF, knee flexion; PT/BW, peak torque/body weight.

[a]Wilcoxon signed rank test.

[b]Mann–Whitney U test.

$p < 0.05$.

applications (Carter et al., 2018). In this study, 30% of participants stated that they had difficulty using technological applications. We are of the opinion that more research should be done to increase awareness in adapting to technological applications in elderly people.

Exergaming has several advantages compared to conventional exercises. It can motivate people to practice through an attractive and interactive way and train both motor and cognitive skills (Oesch et al., 2017). Besides these effects, it has been shown that exergaming can also have positive effects on pain. Ditchburn et al. found that exergaming could be effective in low back pain (Ditchburn et al., 2020). However, there is not any research in the literature investigating the effectiveness of exergaming on knee pain. In this study, we found a significant reduction in knee pain in the exergaming group. There are some current hypotheses in the literature to explain the impact of exergaming on pain. Exergaming decreases the level of the sensation of pain in the brain by using the auditory, visual, and proprioceptive senses and thus provides less perception of pain (Jameson et al., 2011). In this study, individuals performed exercise applications by focusing on the game programs of MarVAJED system. In this way, it is thought that their minds went away from the sensation of pain and pain was less perceived by them.

In the literature, the range of knee joint flexion motion was found to be 137.80° in the 45–69 age range (Soucie et al., 2011). Based on these values, it was found that the ROM values of the participants in this study were low. Dal Jae and colleagues have found that exercises with video games have a positive effect on ROM of knee (Dal Jae Im et al., 2015). According to the data of this study, exergaming was found to be effective on the ROM of patients with knee OA.

Exergaming has been shown to improve the feeling of knee proprioception in geriatric individuals (Sadeghi et al., 2017). The data of this study recorded on proprioception also support the view that exergaming improves proprioception. Lai et al. showed that squat exercises improve the sense of knee joint proprioception positively (Lai et al., 2018). In the present study, squat exercises were implemented to improve muscle strength. Exercise programs which increase muscle strength may also facilitate the neural pathways involved in proprioception, central processing, and the acquisition of motor skills (Hurley et al., 1998). The increase in muscle strength and the decrease in the pain intensity of the patients in present study at the end of the treatment may have developed the feeling of knee proprioception. Proprioceptive acuity and precise neuromuscular control are vital for postural stability (Hurley et al., 1998). In present study it was found that postural stability of participants have improved. Based on these results, it is possible to say that exergaming improves balance due to the positive effects on proprioception and muscle strength. And also in present study it was used a virtual figure on the screen of the MarVAJED system and patients have easily followed the figure by visual and auditory stimuli. Young et al. have expressed that visual and auditory stimuli may improve the postural stability (Young et al., 2011).

In this study, it was found that the improvement in the functional status of the exergaming group was higher than the control group at the end of the treatment. In this study, researchers are in opinion that the functional status improves with the increase in muscle strength and postural stability scores. Santos et al. showed that functional status could be improved with an increase muscle strength and postural stability in knee OA patients (Santos et al., 2011).

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There is an opinion in the literature that muscle weakness, proprioception, and balance disorders in knee OA patients may cause kinesiophobia (Hart et al., 2015). It is suggested that exercise with video games can reduce the fear of pain and encourage individuals to act more and thus may reduce kinesiophobia (Yelvar et al., 2017). The data of this study also supports the fact that exergaming may reduce kinesiophobia.

Besides to the strengths of this study, there are some limitations. A total of two evaluations were made at the beginning and the end of the 6-week treatment period. The long-term effects of the study were not investigated. Therefore, in the future studies, we believe that it is necessary to investigate the long-term effects of exergaming on patients with knee OA.

5 | IMPLICATIONS ON PHYSIOTHERAPY PRACTICE

According to the data of this study, we conclude that exergaming accompanied with conventional physiotherapy programs resulted more positive improvements on pain, ROM, postural stability, kinesiophobia, proprioceptive acuity, and functional status in patients with knee OA compared to the conventional physiotherapy program alone.

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ETHICS STATEMENT

The ethical approval was obtained from Non-Invasive Research Ethics Committee of Marmara University (Protocol number: 09.2017.096).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Data collection, data analysis and interpretation, drafting the article, approving of the final version: Emel Mete. Conception and design of the work, data interpretation and approval of the final version: Zubeyir Sari.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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