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Effects of virtual reality game-based exercises on pain, functional mobility, and balance in patients with knee osteoarthritis: A randomized controlled study

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Abstract
Objectives: The purpose of this study is to investigate the effects of virtual reality game-based exercises on pain, functional mobility, and balance in knee osteoarthritis patients.
Materials and Methods: Fifty patients (5 males and 45 females) having idiopathic knee osteoarthritis were included and divided into two groups as the control and study. For each patient, the knee which had the higher visual analog scale (VAS) value was evaluated. The same knee's active flexion and extension range of motion values were recorded. The Western Ontario and McMaster Universities Arthritis Index (WOMAC) total score and Community Balance and Mobility Scale (CB&M) score were also recorded for each patient. In the control group, patients received conventional physiotherapy and knee OA exercises, whereas the study group received game-based exercises in addition to the treatment applied in the control group. Both groups received 15 sessions of treatment for three weeks, then the same measurements which were performed at the beginning of the study were repeated for each patient.
Results: At the end of the treatments, significant differences was found between two groups for VAS, WOMAC total and CB&M scores ($p<0.05$), whereas there were no significant differences for the active flexion and extension range of motion values ($p>0.05$).
Conclusions: Adding virtual reality game-based exercises to the treatment program in knee osteoarthritis may produce more beneficial results for patients.

Keywords: exercise, knee, osteoarthritis, pain, virtual reality

Introduction
Osteoarthritis (OA), also known as degenerative arthritis, is a chronic joint disease. OA causes degradation of the joint cartilage over time, and it is seen most frequently in knee joints [1, 2] Knee OA leads to pain, stiffness, reduced muscle strength, and joint instability, and the long-term effects of the disease can reduce person's functional mobility. These activity limitations may result in cardiovascular disease, low quality of life, and loss of physical function [1, 3].
Exercise is an indispensable aspect of conservative OA treatment, and it is generally recommended by clinical guidelines regardless of a patient's age, joint involvement, radiographic disease severity, pain intensity, functional levels, or comorbidities [1, 2] In recent years, virtual reality (VR) applications have begun to be used to support conservative exercise treatments [4].
Virtual reality has been defined as the use of interactive simulations generated by computer hardware and software to provide users with an opportunity to participate in environments that resemble the real world [5]. Exercises performed by using VR games allow patients to interact with a virtual environment while performing certain motions [6]. Thus, a rehabilitation program wherein patients imitate body movements with the help of games may be more entertaining [7].
In the literature, some research has been done on the use of VR game-based exercise programs [4, 8-14]. and it has been found that such applications can be useful for both physical and mental improvement [10, 15, 16]. increasing motivation [4]. and leading to increased dynamic balance in elderly patients [12-14]. However, studies supporting the idea that VR game-based exercise provides similar or better improvements in physical function in knee OA patients are limited [17-20]. Therefore, the purpose of this study was to investigate the effects of VR game-based exercises on knee pain, functional mobility, and balance in knee OA patients.

Materials and Methods
This study was planned as a prospective randomized-control study. The participants in the sample consisted of patients who visited the clinic of the Department of Physical Medicine and Rehabilitation in Bülent Ecevit University Health Application and Research Hospital in Zonguldak, Turkey between April 1, 2016 and April 1, 2017 with complaints of knee pain. Ethical approval was obtained from the Clinical Studies Ethics Board of Bülent Ecevit University, protocol number 2016-44-24/02.
Patients included in the study were identified as having idiopathic knee OA according to the American College of Rheumatology's (ACR) criteria [21]; had a stage two or higher advanced knee OA diagnosis according to the Kellgren-Lawrence (K-L) classification[22]; and had physical, cognitive, and sociocultural capacities that enabled them to participate in physiotherapy, exercise, and game-based exercise programs.
The exclusion criteria included the following: cardiovascular and systemic diseases preventing exercise; acute inflammatory pathology in the knee joint; a central or peripheral neurological disease that would lead to loss of lower extremity muscle strength, sensation, balance, and

proprioception; prosthetic joints; a history of major lower extremity surgery; a history of physical therapy in the past six months; severe psychiatric diseases; and advanced peripheral vascular disorders. In addition to these factors, patients who could not sufficiently adapt to the VR game-based exercises or did not agree to participate were also excluded. Based on the inclusion and exclusion criteria, a total of 50 patients (5 males and 45 females) between the ages of 40 and 70 were included in the study. Informed voluntary consent was obtained from each patient before the study. All patients attended their treatment regularly, and none of them were excluded from the study (Fig.1).

Patient Assessment

For each patient, information on age, gender, weight, height, and disease duration was recorded at the beginning of the study. After this, the knee that had the higher visual analog scale (VAS) value was chosen to be evaluated. The same knee's K-L score, active flexion range of motion (AFRM) and active extension range of motion (AERM) values were recorded. In addition, the Western Ontario and McMaster Universities Arthritis Index (WOMAC) total score and Community Balance and Mobility Scale (CB&M) score were also recorded for each patient.

Formation of Groups

The 50 patients included in the study were randomly divided into two equal groups (n=25) as control and study group. Randomization was performed by using a website (www.randomizer.org).

All patients in the control group received treatment including conventional physiotherapy and knee OA exercises consisted of 15 sessions for three weeks (five days per a week). In the conventional physiotherapy, superficial heat, 30 minutes of conventional transcutaneous electrical nerve stimulation (TENS), and ultrasound (1.5 w/cm^2, 5 minutes) were applied to the relevant knee. For conventional exercises, the patients performed knee range of motion exercises and stretches (quadricep and hamstring self-stretch); knee muscle strengthening (isometric quadricep strengthening, knee active flexion and extension exercises with resistance); and balance exercises (on a balance board and a trampoline under supervision of the physiotherapist).

In the study group, all patients received a VR game-based exercise program in addition to the treatment protocol applied in the control group. The game-based exercise program was done under the supervision of the same doctor (S.Y.D.) by using a game console (Microsoft Xbox One Kinect, Microsoft Corp., Washington, USA) for 30 minutes per a day, and each patient received a total of 15 sessions over three weeks. The game-based exercise was carried out in a quiet, private room with adequate space. After connecting the game console to a 40-inch television (40T5300, Samsung Corp., Seoul, South Korea), the motion sensor was positioned at a fixed point to allow the patient to easily perform the movements. At the beginning of the game, the patients were positioned standing up in front of the motion sensor while their avatar images were created on television screen. Afterwards, the exercise game was started; the patients were asked to perform the movements shown by the trainer in the game and at the same time check whether or not they could make the same movements by following their avatars. The game-based exercise program consisted of two different games: Ultimate Lower Body Training (subsection of the game of Fitness, 10 Minute Solution) and Kinect Dance. In Ultimate Lower Body Training, the patients performed two sets each of leg circles, side steps, side lunges, single leg squats, single leg hops, lunge claps, squat leg extensions, cross squat jacks, squat walking, rear lunges with kicks, isometric lunges, lunges, directional squats, and leg stretches in 20 minutes. After this, the patients played Kinect Dance and performed dance movements for 10 minutes. The patients were instructed to perform every movement only to the extent they could tolerate, and no adverse effects were reported during or after the games.

The conventional knee exercises in both groups were performed with the same physiotherapist. When the treatments were completed, the measurements and assessments that had been performed at the beginning of the study were repeated for each patient by the same doctor, and the data were recorded.

Statistical Analysis

The statistical analysis of the study was conducted using the SPSS 19 (SPSS Inc., Chicago, IL, USA) program. In the analysis of the results obtained from the two groups, a Mann-Whitney U test, an independent-sample t-test, and a paired-samples t-test were used. The analysis results were assessed in a 95% confidence interval, and results with a *p* value smaller than 0.05 were considered statistically significant.

Results

The distribution of gender, mean values of age, body mass index (BMI) and duration of disease, and the distribution of K-L radiological stage were shown in Table 1. There was no significant difference between two groups in terms of any factor stated above (p>0.05).

Table 1: Basic demographic data of study participants

Characteristic		Study Group (n=25)	Control Group (n=25)
Gender	Male	1	4
	Female	24	21
Age (years)		57.72 (± 5,82)	59.32 (± 6,71)
BMI (kg/m^2)		36.88 (± 6,45)	34.36 (± 5,67)
Duration of disease (months)		71.84 (± 53,41)	84 (± 51,84)
K-L Stage (n/%)	Stage 2	9 (36)	5 (20)
	Stage 3	10 (40)	12 (48)
	Stage 4	6 (24)	8 (32)

Assessment Results Before and After Treatment

All data regarding the pre-treatment and post-treatment VAS, AFRM, AERM, and WOMAC total score and the CB&M score results of the patients in both groups are shown in Table 2.

The VAS, AFRM, AERM, and WOMAC total score and the CB&M score mean values between the groups were found to be close before the treatment, and no significant differences were found between the groups for each parameter ($p > 0.05$). A statistically significant difference was found in all parameters according to the intra-group comparison of the pre- and post-treatment results in both groups ($p < 0.05$). In the intergroup comparison of the results obtained for each parameter after the treatments were applied in both groups, it was found that the differences

between the VAS values, WOMAC total and the CB&M scores were statistically significant, whereas there were no significant differences between groups in the AFRM and AERM ($p < 0.05$).

Table 2: Distribution of the mean values of VAS, AFRM, AERM, and total WOMAC scores and CB&M scores before and after the treatment in the control and experiment groups. * means the statistically significant differences for intra-group comparisons of the results of before and after treatment ($p < 0.05$). ** means the statistically significant differences for inter-group comparisons of the results of after treatment ($p < 0.05$). (CON = Control Group, EXP = Experiment Group).

	Group	Before Treatment Mean ± Std.Dev	After Treatment Mean ± Std.Dev	*p*
VAS (0-10)	CON	7,32 ± 2,05	4,72 ± 2,24 **	0.000*
	EXP	7,32 ± 1,86	2,80 ± 1,73	0.000*
AFRM (0-140)	CON	109,6 ± 10,19	112,40 ± 8,05	0.042*
	EXP	109,20 ± 10,96	115,40 ± 11,07	0.000*
AERM (140-0)	CON	-7,60 ± 6,63	-5,80 ± 6,40	0.007*
	EXP	-7,40 ± 7,51	-3,20 ± 4,53	0.000*
WOMAC Total Score (0-96)	CON	53,24 ± 14.02	38,08 ± 12,51 **	0.000*
	EXP	50,04 ± 14.67	16,48 ± 11,34	0.000*
CB&M Score (0-96)	CON	35,68 ± 19,11	41,84 ± 17,10 **	0.000*
	EXP	40,92 ± 14,09	51,36 ± 12,53	0.000*

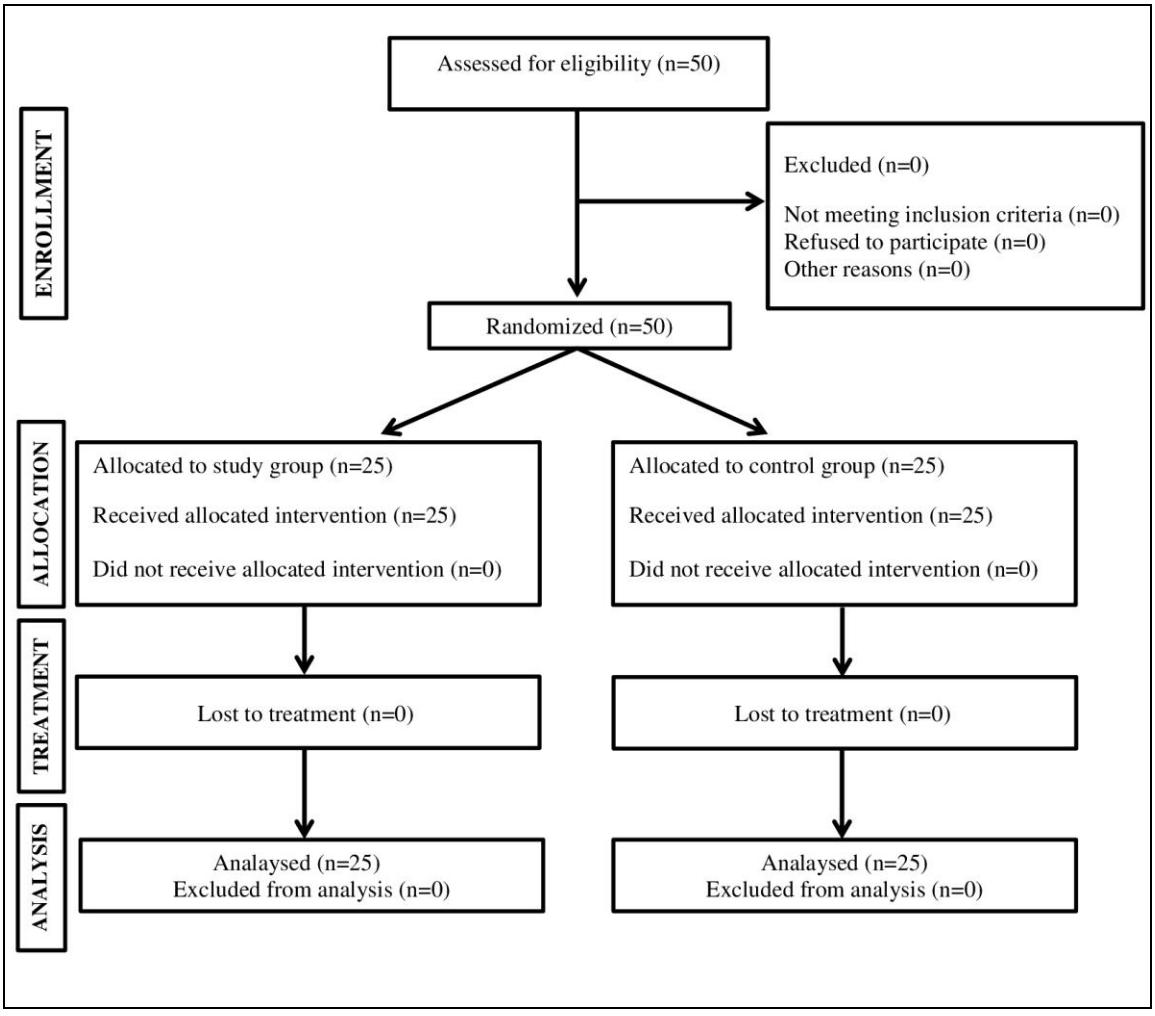

Fig 1: Participants allocation and randomization

Discussion

The results of this randomized controlled study indicated that VR game- based exercises had beneficial effects on VAS value, WOMAC and the CB&M scores on knee OA patients, but no similar results was found for AFRM and AERM values.

Knee OA is a disease that affects the knee joint and leads to physical disorders such as pain, disrupted proprioception, and reduced balance.[1] Exercise is recommended as the first-step treatment for patients who have painful knee OA; however, while its effectiveness has been supported by studies and strong evidence from international guidelines, is used less often than expected in clinical practice [23]. It has been reported that, in the occurrence of this situation, factors such as individuals' motivation levels, health and exercise attitudes, OA knowledge and personal experiences, doctors' encouragement and exercise partners can be effective.[24] In addition, misconceptions that exercise may be harmful to the OA joint and that no benefits are obtained from exercise in more severe radiographic knee OA cases reduce patients'

participation in exercise [23]. Moreover, conventional exercise programs are often considered boring by patients, as the same movements are repeated for a long time, and treatment may be left incomplete because of this [25].

Because of the disadvantages emphasized above, VR systems have started to be utilized in the field of physical therapy and rehabilitation, as they are more entertaining than conventional methods, encourage patients to practice multiple and regular repetitions, optimize motor learning by providing simultaneous feedback, and allow for the performance of tasks that are dangerous in the real world [5, 9, 10].

Studies evaluating the use of VR systems in physical therapy and rehabilitation have investigated these systems' effects on mobility [9], lower extremity muscle strength [11], cognition, physical activity [10], and balance control [12, 13]. Sadeghi et al. [26]. found that an exercise program prepared by a game console provided an increase in knee proprioception in individuals over the age of 65. However, despite reports on an increase in knee proprioception and the other positive effects mentioned above, there are limited data in the literature on the use and effectiveness of VR systems for knee OA patients [17-20]. Keeping this situation in mind, in the current study, the effects of VR-game-based exercise programs on pain, functional mobility, and balance in knee OA patients were examined.

This study results showed that after treatment, VAS values significantly decreased in the study group compared to the control group. Landmark et al. [27]. in a study in which the relationship between exercise and pain was evaluated, emphasized that exercising led to a significant reduction in pain. This may explain the finding in our study that the reduction in pain levels was significantly higher in the study group than the control group, as using the VR system increased the patients' motivation, thereby also increasing their compliance with the exercise program [10] A similar result was reported in a study [19] in which 60 OA patients were evaluated, and authors claimed that VR training could improve pain.

Until now, various clinical tests have been used to measure dynamic balance and mobility in knee OA patients. CB&M is one of these tests; it consists of 13 different tasks, such as bending over, turning, looking while walking, standing on one leg, and going down stairs. Higher scores in this test indicate better balance and mobility [28, 29] The CB&M scale has been reported to be valid and reliable for use in individuals with knee OA [29] Thus, in the present study, CB&M was preferred to evaluate the patients' balance and mobility. An important result was that CB&M scores in the study group was significantly higher than in the control group when the treatments were completed ($p < 0.05$). One reason for this may be that the visual feedback provided by the VR systems increased patients' balance control awareness, as was also found in a study by Szturm et al. [13] In addition to increased balance, the same authors reported that increased mobility was also obtained in patients through the dynamic, task-focused exercise approaches of these systems, which engage the entire body. Another study [17]. conducted on women over 65 with knee OA reported that VR games achieved positive results on balance. Although it was not as high as in the study group, the improvement in CB&M scores in the control group was thought to be due to the balance-enhancing effects of muscle strengthening and the balance exercises applied within the conventional exercise program.

In the present study, the total WOMAC scores in the study group had decreased significantly compared to those of the control group at the end of the treatment ($p < 0.05$). This result shows that the program done with the VR system provided a significant increase in physical function compared to the conventional exercise program. Factors such as pain, reduction in muscle strength, and degradation in joint stabilization reduce the physical capacities of patients. In addition, deterioration occurring in the proprioception of individuals is another significant factor in reduced physical function [30]. By eliminating these factors, knee OA patients may more effectively perform daily life activities, such as climbing stairs and walking [19]. We are of the opinion that the noticeable decrease in the VAS values and the noticeable increase in the CB&M values in the study and control groups after treatment may have been effective in reducing the total WOMAC scores. The reason there was a significant difference in the WOMAC total scores between the groups may be that the reduction in the VAS value was higher in the study group, as was the increase in the CB&M score. Furthermore, the lower WOMAC scores of the study group may have been affected by the more entertaining nature of the exercise performed with VR, as well as the other advantages it provided, such as multiple repetitions, motivation, and ease of implementation [5, 10] In a study [20] which was published recently, active video games were compared with therapeutic exercises on 80 knee patients. According to the results of that study, significant decrease was detected in WOMAC score with active video games compared to therapeutic exercises.

In this study, there was an increase in the AFRM and AERM values in both the study and control groups over the course of the treatment. There was no significant difference in the intergroup comparison of the results in the AFRM and AERM values. In a different study where a VR system was utilized for the purpose of the rehabilitation of total knee replacement patients [31], it was found that the system did not create a significant difference between the study and control groups in terms of flexion or extension joint movement ranges. In the present study, the reason there were no significant differences between the study and control groups in AFRM and AERM values may be that the initial values in both groups were already high, which may have created a ceiling effect. Virtual reality based exercise programs might not always be superior to conventional treatments [31, 32]. The reasons for this may be explained by a variety of study methods, such as usage of different VR programs, samples that are examined, and evaluation criteria [33]. Although this study's results were promising with regard to the effectiveness of VR systems for knee OA patients, it also had some limitations. One of these limitations was the sample size: the present study included 50 patients in the analysis. While this number may seem low, it is close to the sample sizes in similar studies [17-20]. The other limitation is that our study reported the short-term results, and it is not possible to say what the long-term effects might be.

Conclusion

In conclusion, VR game-based exercises may be an effective contributing factor in terms of treatment in knee OA patients by positively affecting motivation and increasing treatment compliance as well as proprioception.

Thus, in this study, it was determined that game-based exercise programs performed in a virtual reality environment significantly contributed to conventional treatment in knee OA. On the other hand, further studies examining the long-term effectiveness of VR systems in the treatment of knee OA patients that have larger sample sizes are needed.

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Conflict of Interest
All authors declared that there was no conflict of interest. Authors received no personal funding from any commercial corporation or organization.

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