ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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The Effects of Virtual Reality Exergaming on Pain, Functionality and Acromiohumeral Distance in Shoulder Impingement Syndrome Patients: A Randomized Controlled Study

Sanal Gerçeklik Egzersizlerinin Omuz Sıkışma Sendromlu Hastalarda Ağrı, Fonksiyonellik ve Akromiohumeral Aralık Üzerine Etkisi: Tek Kör Randomize Kontrollü Bir Çalışma

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ABSTRACT Objective: The aim of this study was to evaluate the effectiveness of virtual reality exergaming on pain, functionality, and acromiohumeral distance in patients with shoulder impingement syndrome and compare this therapy with conventional exercise therapies. **Material and Methods:** This prospective randomized study included 34 patients with shoulder impingement syndrome. The patients were randomized into virtual reality exergaming (n:17, mean age: 19.7±0.7) or conventional exercise (n:17, mean age: 20±0.7) groups 3 times per week for 6 weeks. Pre-treatment and post-treatment evaluations were performed. The outcome parameters were the severity of shoulder pain (resting, activity, and night pain), shoulder range of motion, shoulder pain, and disability index. Acromiohumeral distance was measured by ultrasound. **Results:** Statistically significant improvements in pre-treatment and post-treatment pain parameters, range of motion, shoulder pain, and disability index ($p<0.05$) were observed, and acromiohumeral distance increased ($p<0.05$) in both groups. No statistically significant difference between groups was observed. **Conclusion:** Virtual reality exergaming is an effective method in shoulder impingement syndrome therapy. However, it did not provide additional benefits in terms of improvements in pain, joint range of motion, functionality, or ultrasonographic parameters compared with conventional exercise therapy.

Keywords: Shoulder impingement syndrome; exercise therapy; ultrasonography; virtual reality

ÖZET Amaç: Bu çalışmada amacımız omuz sıkışma sendromlu hastalarda sanal gerçeklik egzersiz tedavisinin ağrı, fonksiyonellik ve akromiohumeral aralık üzerine etkinliğini değerlendirmek ve bu tedaviyi konvansiyonel egzersiz tedavisi ile karşılaştırmaktı. **Gereç ve Yöntemler:** Prospektif, randomize çalışmamızda omuz sıkışma sendromu tanılı 34 hasta vardı. Hastalar 6 hafta boyunca, haftada 3 kez tedavi almak üzere sanal gerçeklik egzersiz grubu (n:17, ortalama yaş: 19,7±0,7) ve konvansiyonel egzersiz grubu (n:17, ortalama yaş: 20±0,7) olarak iki gruba randomize edildi. Değerlendirmeler tedavinin başlangıcında ve sonunda yapıldı. Sonuç parametreleri omuz ağrısının şiddeti (istirahat, aktivite ve gece ağrısı), omuz hareket açıklığı, omuz ağrısı ve disabilite indeksi idi. Akromiohumeral mesafe ultrasonografi ile ölçüldü. **Bulgular:** Her iki grupta da tedavi öncesi ve tedavi sonrası ağrı, eklem hareket açıklığı, omuz ağrısı ve dizabilite indeksi parametrelerinde istatistiksel olarak anlamlı düzelme görüldü ($p<0,05$) ve akromiohumeral aralıkda ($p<0,05$) anlamlı bir artış tespit edildi. Gruplararası kıyaslama yapıldığında ise istatistiksel olarak bir farklılık görülmedi. **Sonuç:** Sanal gerçeklik egzersiz tedavisi, omuz impingement sendromu tedavisinde etkili bir egzersiz yöntemi olmakla birlikte konvansiyonel egzersiz tedavisine kıyasla ağrı, eklem hareket açıklığı, fonksiyonellik ve ultrasonografik parametreler üzerine bir üstünlüğünün olmadığı görülmüştür.

Anahtar Kelimeler: Omuz sıkışma sendromu; egzersiz tedavisi; ultrasonografi; sanal gerçeklik

Shoulder impingement syndrome (SIS) is one of the most frequent causes of shoulder pain, and it arises as a result of compression of the supraspinatus tendon, subacromial bursa, and bicipital tendon between the humerus and coracoacromial arch.[1-2] Pain and functional limitations developing as a result of edema and inflammation have a significant impact on the quality of life of patients.[3-4] In addition to conser-

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vative and surgical options for therapy, it is considered that exercise is the primary conservative therapeutic approach for SIS.[5-6] The major concern related to exercise therapy in patients with musculoskeletal system defects is inadequate patient compliance and motivation. However, it was shown that exercise compliance and the motivation of patients increased when using virtual reality therapy in the area of rehabilitation.[7] To date, most studies have focused on the effects of virtual reality exergaming (VRE) on balance in neurological diseases, such as stroke, multiple sclerosis, and Parkinson's disease.[8-10] However, there have been few studies that evaluated the effectiveness of VRE in the treatment of different shoulder pathologies.[7,11] Ultrasound is becoming increasingly important in the diagnosis, differential diagnosis, and treatment of musculoskeletal pathologies.[12] Various parameters, such as subacromial structures, supraspinatus tendon pathologies, and acromiohumeral distance, expected to narrow compared with the healthy population can be evaluated by ultrasound in SIS patients.[13] In this study, we aimed to evaluate for the first time the effect of VRE treatment on pain, functionality parameters, and acromiohumeral distance, which is an important parameter in SIS pathogenesis. Our findings provide new insight and make a key contribution to the field.

MATERIAL AND METHODS

PARTICIPANTS

Forty voluntary patients who applied to the clinic at our hospital complaining of shoulder pain were diagnosed with SIS and separated into two groups: a VRE group and a conventional exercise (CE) group. Three patients in each group could not complete the treatment protocol due to personal reasons. Therefore, 34 patients completed our study.

The inclusion criteria were as follows: 1) SIS physical examination tests were positive (Hawkins and Neer test), 2) Positive magnetic resonance imaging findings (subacromial bursitis, supraspinatus tendinitis), and 3) Patients between ages 18 and 45.

The exclusion criteria were as follows: 1) Patients who received physical therapy for the shoulder region within the past three months, 2) a history of injections or surgery to the shoulder joint, 3) clinical conditions accompanied by neuromotor or sensory dysfunction, 4) a history of malignancy, 5) pregnancies, 6) presence of full-thickness rotator cuff tears or adhesive capsulitis, and 7) systemic diseases, such as chronic liver or kidney failure.

The study was approved by the ethics committee of Kafkas University Faculty of Medicine (number: 80576354-050-99/16- date: 30.4.2019). Informed consent forms were obtained from all patients. The study was conducted in accordance with the principles of the Helsinki Declaration. The details of including and excluding subjects through to final data analysis were provided as a flowchart in Figure 1.

DESIGN

This prospective randomized trial was conducted between May 2019 and October 2019 at our state hospital. The list randomization method was used. All participants were assessed by the same physiotherapist (B.Ç.) who was blinded to the group allocation at baseline and the sixth week after completing the exercise. We measured pain and function with a visual analog scale (VAS), range of motion, and the shoulder pain and disability index (SPADI). For acromiohumeral distance, the participants were sent to a physician (F.B.) who was blinded to the group allocation.

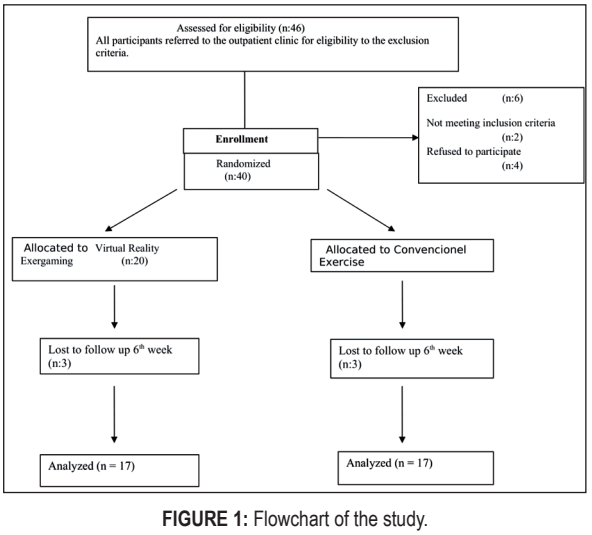

FIGURE 1: Flowchart of the study.

INTERVENTION

Group 1: Throughout the 6 weeks of VRE treatment, shoulder exercises were performed with the Nintendo Wii (Nintendo, Kyoto, Japan) for 45 minutes 3 days per week. The VRE program for the shoulder included warm-up, exercise training, and cool-down periods. Warm-up and cool-down programs included active stretching exercises for the posterior capsule, inferior capsule, anterior capsule, and pectoral muscles. The exercise training program included a boxing match, bowling game, and tennis game accompanied by the avatar. The boxing match included 3 sets that were 3 minutes long. Particularly, a punching exercise was performed during the boxing match game. There were 1 minute rest periods between each set. The bowling game included 10 sets with 2 shots in each. Particularly, a shoulder elevation exercise was performed in the full-can position during the bowling game. The tennis game included 5 sets with 5 services in each set, including forehand and backhand shots. During the first week, the participants were instructed to play each game for one set without any resistance. By determining theraband resistance available from week 2 progressions in boxing, bowling, and tennis games were sustained. Theraband resistance was increased gradually (Figure 2).[11]

Group 2: CE treatment was administered for 6 weeks, with three 45 minute sessions per day. The CE program for the shoulder included warm-up, exercise training, and cool-down periods. A triphasic exercise program was administered to the patients. Before starting the exercise program, the patients were instructed not to perform the movements exceeding 90° overhead. The exercise program was initiated using a Codman pendulum, passive joint motion range (with a 1-m stick), and a posterior capsule stretching exercise. Shoulder wheel, finger ladder, and shoulder strengthening exercises with theraband resistance were added to the exercise programs for patients with full or near total range of motion and pain relief. Then, the progression of the exercise program was achieved according to the patient's tolerance towards the anterior capsule, the inferior capsule and the stretches to the pectoral muscles, the shoulder strengthening exercises in the proprioceptive neuromuscular facilitation pattern and the bilateral shoulder elevation exercises.

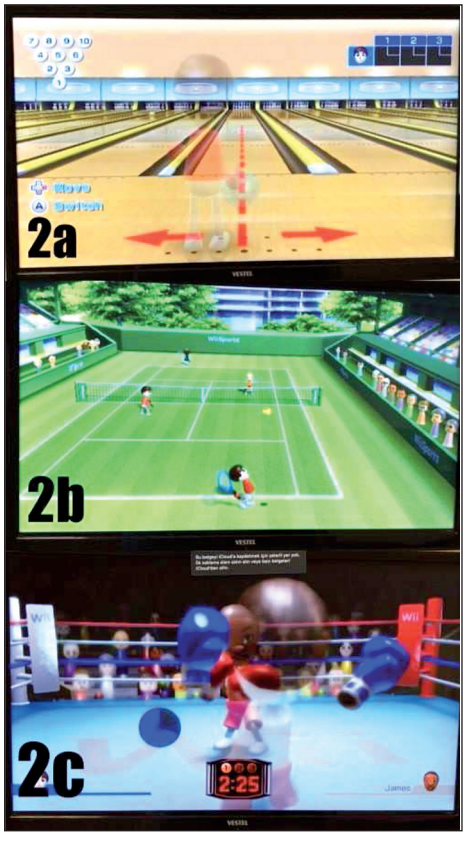

FIGURE 2: Virtual reality exergaming (**a.** Bowling game, **b.** Tennis game, **c.** Boxing match)

The exercise program was administered twice a week under supervision; however, the patients were advised to exercise in the patient room in hospital on the other days, with 20 repetitions of each exercise. The patients were followed up via telephone to ensure that they were adhering to their exercise programs.[14]

MEASUREMENTS

Pre-treatment and post-treatment evaluations of all patients were conducted.

Pain level: The severity of shoulder pain (resting, activity, and night pain) was evaluated using VAS. A VAS score of 0 represented no pain, whereas a score of 10 indicated the most severe pain.[15]

Functional status: To evaluate capability loss and daily life activities, the SPADI questionnaire was used. SPADI has 3 sub-parameters, including total, pain, and activity limitations. On the pain sub-scale, there are 5 questions related to shoulder pain during

daily life activities, and on the disability sub-scale, 8 questions related to challenges in performing daily life activities are included. Answers were rated by the subjects between 0 and 10. Ratings of all responses were added and divided by the number of questions in that sub-parameter. The total SPADI score was determined as the average of the 2 sub-parameter scores. A high score indicates increased pain and deteriorated shoulder functions.[16]

Joint range of motion measurements: Flexion, abduction, internal rotation, and external rotation were measured using a goniometer (Saehan Goniometer-plastic).[17] Measurements were repeated 3 times, and their average was recorded.

Acromiohumeral distance: Ultrasound was performed using a 7.5-mHz linear probe in the B mode (Shimadzu-Japan). The acromiohumeral distance was defined as the linear distance between the superior aspect of the humeral head and the inferior aspect of the acromion.[2,18] Measurements were repeated 3 times, and their average was recorded. Ultrasound measurements were made by F.B with an ultrasound device in the outpatient room.

STATISTICAL ANALYSIS

Median (minimum-maximum), frequency, and ratio values were used in the descriptive statistics of the data. The Kolmogorov-Smirnov test was used to determine whether the variables were normally distributed. Nonparametric tests were used. The Mann-Whitney U test was used for the analysis of quantitative independent data. The Wilcoxon test was used for dependent quantitative data analysis. The chi-square test was used to examine the relationship among independent categorical variables. SPSS 22.0 software was used for the analysis. p values<0.05 were considered statistically significant.

RESULTS

The demographic parameters of both groups are presented in Table 1. The mean age was 19.7±0.7 years in the VRE group and 20±0.7 years in the CE group. The duration of the disease was 4.8±1.4 months in Group 1 and 4.9±1.3 months in Group 2 (Table 1). There was no pre-treatment difference between groups in terms of VAS-resting, VAS-night, shoulder abduction, flexion, internal rotation, external rotation, SPADI, or acromiohumeral distance values. A statistically significant post-treatment improvement in all of these parameters (p<0.05) was observed in both groups. There was no statistically significant difference between the groups (p>0.05) (Table 2).

DISCUSSION

In our study, we investigated the effects of VRE and a CE program on pain, functionality, and acromiohumeral distance in patients with SIS. We observed that VRE did not provide an advantage over CE therapy. The effectiveness of exercise therapy for SIS treatment was shown previously in the literature.[19] However, there was no consensus on the most effective treatment or how much time should be given.[20]

TABLE 1: Sociodemographic characteristics of the patients.

	Virtual Reality Exergaming Group (n:17)		Conventional Exercise Group (n:17)		
Parameters	**Median**	**Min-max**	**Median**	**Min-max**	**p**
Age (year)	20	20-22	20	20-22	0.380
Gender					
Male	76.5%(13)		76.5%(13)		
Female	23.5% (4)		23.5%(4)		
BMI (kg/m^2)	22.9	19.3-28.4	25.2	20.1-36	0.218
Patient side					
Right	64.7%(11)		41.2%(7)		
Left	35.3%(6)		58.8%(10)		
Pain duration (month)	6.0	3-6	6,0	3-6	0.895

BMI: Body mass index.

TABLE 2: Visual analog scale, range of motion, functionality and acromiohumeral distance pressure at pre-posttreatment visit.

	Virtual Reality Exergaming Group		Conventional Exercise Group		
Parameters	**Median**	**Min-max**	**Median**	**Min-max**	**p**
VAS Activity					
Baseline	7.0	6-10	7.0	4-8	0.260m
6th week	3.0	3-5	3.0	1-4	0.195m
p	**p<0.001**		**p<0.001**		
VAS Resting					
Baseline	7.0	6-10	7.0	6-8	0.928m
6th week	3.0	3-5	3.0	1-4	0.414m
p	**p<0.001**		**p<0.001**		
VAS Night					
Baseline	8.0	6-10	8.0	6-10	0.490
6th week	3.0	2-5	3.0	2-4	0.235
p	**p<0.001**		**p<0.001**		
Abduction					
Baseline	151.0	105-180	150.0	90-180	0.475
6th week	180.0	155-180	180.0	145-180	0.767
p	**p<0.005**		**p<0.001**		
Flexion					
Baseline	160.0	112-180	143.0	90-180	0.052
6th week	180.0	160-180	168.0	150-180	0.060
p	**p<0.001**		**P<0.001**		
Internal rotation					
Baseline	26.0	18-60	30.0	18-55	0.972
6th week	68.0	45-70	64.0	42-70	0.083
p	**p<0.001**		**p<0.001**		
External rotation					
Baseline	35.4	20-88	31.4	20-65	0.732
6th week	73.2	60-90	75.5	60-80	0.755
p	**p<0.001**		**p<0.001**		
SPADI					
Baseline	66.0	40-83	67.0	46-93	0.796
6th week	29.0	5-43	32.0	5-48	0.133
p	**p<0.001**		**p<0.001**		
AHD					
Baseline	10.4	8.87-12.33	10.5	9.27-12.6	0.285
6th week	11.2	0.6-12.56	11.2	10.5-13.5	0.638
p	**p<0.001**		**p<0.001**		

VAS: Visual analog scale, SPADI: Shoulder pain and disability index, AHD: Acromiohumeral distance.

The aim of exercise therapy is to strengthen the rotator cuff and depress the humerus head during shoulder elevation to reduce compression and afterward suppression of inflammation and pain and promote restoration of joint range of motion.[21-23] Because of the advances in modern technology and the integration of these developments into our daily lives, VRE programs are considered to be more acceptable and applicable in the areas of physiotherapy and rehabilitation.[24,25] Thus, studies examining the effectiveness

of VRE in patients diagnosed with SIS have been performed.[11,26] Pekyavaş et al. determined that pain, joint range of motion, and functionality parameters in the VRE group were superior compared with home exercise programs for patients diagnosed with SIS.[11] Rizzo et al. rehabilitated SIS patients using the Nintendo Wii system and compared their treatment with a CE group, which were treated in a hospital.[26] A statistical superiority was observed compared with the control group in the parameters of pain, joint range of motion, and functionality, and it was suggested that studies including a wider range of participants should be conducted. In contrast, no difference was observed between VRE and CE groups in terms of pain and functionality parameters in our study. One of the reasons that VRE is considered to be superior compared with home exercise programs is because VRE programs are more attractive and more desirable based on the contribution of technology used in every area today.[11] In addition, VRE programs have more visual and sensual feedbacks, which improves the efficiency of exercise. In our study, CE therapy was used in hospitalized patients. In previous studies, CE therapy was performed as a home exercise program or at an outpatient physical therapy unit.[11,26] We can consider that our treatment results are not superior to each other due to this point. However, the possibility that the adaptability of the group receiving home treatment to the recommended exercise treatment is not followed objectively may have an impact on the results.

Although pain is decreased and functionality is increased with exercise therapy, the regression of tendinitis in the supraspinatus muscle is provided, the thickness of the tendon may be decreased, and acromiohumeral distance can be increased.[27,28] Thus, in the literature, it was observed by ultrasound measurements that supraspinatus tendon thickness increased in patients diagnosed with SIS compared with the population and acromiohumeral distance decreased.[18] Kaya et al. compared kinesio taping and manual therapy in SIS patients and evaluated supraspinatus tendon thickness by ultrasound, and no decrease in supraspinatus tendon thickness was observed after treatment.[29] In our study, supraspinatus tendon thickness was not measured as the ultrasound device we used could not provide a clear vision of tendon structures. We only evaluated acromiohumeral distance by using ultrasound. In both groups, an increase in acromiohumeral distance was found in accordance with our predictions after treatment, but no difference was observed between the groups.

CONCLUSION

Unlike previous studies, we obtained similar results in the parameters of pain, functionality, and acromiohumeral distance between VRE and CE groups. Limitations of our study were the low number of patients, our study was performed with a young patient group, our follow-up time was not long enough to show chronic results, and supraspinatus tendon thickness was not evaluated. On the other hand, exercises applied to groups are not exactly the same. It may have prevented us from objectively assessing the impact of virtual reality exercises. Studies conducted with larger patient groups, longer follow-up periods, and in which supraspinatus tendon thickness is evaluated should be conducted in the future.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Fatih Bagcier, Sevilay Çüçen Batıbay;* ***Design:*** *Fatih Bagcier;* ***Control/Supervision:*** *Sevilay Çüçen Batıbay;* ***Data Collection and/or Processing:*** *Fatih Bagcier;* ***Analysis and/or Interpretation:*** *Sevilay Çüçen Batıbay;* ***Literature Review:*** *Fatih Bagcier, Sevilay Çüçen Batıbay;* ***Writing the Article:*** *Fatih Bagcier, Sevilay Çüçen Batıbay;* ***Critical Review:*** *Sevilay Çüçen Batıbay;* ***References and Fundings:*** *Fatih Bagcier;* ***Materials:*** *Fatih Bagcier.*

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