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Efficacy of Recovery Tech Virtual Reality Rehabilitation System for Shoulder Impingement Syndrome

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***Abstract*—**The most common cause of shoulder pain occurs when rotator cuff tendons become trapped under the bony area in the shoulder. This pilot study was performed to evaluate the feasibility of Virtual Reality based rehabilitation of shoulder impingement syndrome in athletes. Three consecutive patients with subacromial impingement syndrome were enrolled. The participants were rehabilitated for 5 times a week for 4 weeks, 20 sessions in total (with duration of each session being 60 minutes). In addition to the conventional rehabilitation program, a 10-minute game-based virtual reality exercise was administered. Primary outcome measures were range of motion evaluated with goniometer, pain sensation, disability intensity using 'The Disabilities of the Arm, Shoulder and Hand Questionnaire', muscle strength using 'dynamometer'; pain threshold with 'algometer' and level of satisfaction. There were significant improvements in the range of motion, pain sensation, disability, pain threshold and muscle strength compared to basis ($P < 0.05$). There were no major adverse effects. This study showed the usefulness of VR therapy as an adjunct to conventional physiotherapy in improving function in patients with shoulder impingement syndrome.

***Keywords*—**Shoulder impingement syndrome, VR therapy, feasibility, rehabilitation.

I. Introduction

THE shoulder is the most movable joint in the body. However, it is an unstable joint because of the range of motion allowed. This instability increases the likelihood of joint injury, often leading to a degenerative process in which tissues break down and no longer function well. Painful shoulder is the most common condition visited in sport injury clinics [1], [2]. Scapular dyskinesis is a potential impairment to optimum shoulder function which should be diagnosed and managed appropriately [3], [4]. Subacromial impingement syndrome is developed due to contraction of the anatomical structures passing through the subacromial fossa and is affected by scapular motion and position [5], [6]. Upper limb dysfunction in patients with subacromial impingement syndrome decreases the quality of life and leads to functional disability [7]-[9]. Most investigations showed no significant difference in the outcomes between patients randomized to surgical decompression or conservative treatment [1]. However, some studies reported better results after surgery, especially in the long term [10].

Recovery of restricted daily life tasks (such as personal care, dressing, and eating) is one of the main aims in physiotherapy and rehabilitation in subacromial impingement syndrome. Currently, conventional physiotherapy and rehabilitation methods are the most common used techniques [10]-[12]. Accordingly, the main purpose of this method was to reduce pain and improve range of motion and muscle strength. With developing technology, various virtual reality applications have been merged into physiotherapy and rehabilitation programs. These virtual reality applications are used to motivate patients. In addition, the diversity of virtual reality applications is increasing gradually to enhance the participation rate. Hence in this study the effectiveness of game-based virtual reality was assessed in patients with subacromial impingement syndrome.

II. Material and Methods

This was a pilot case series. Three consecutive patients with subacromial impingement syndrome in past 12 months admitted to a sport injury clinic in 2020 were enrolled. The exclusion criteria were any visual or auditory problems, neurological, orthopedic or rheumatic problems that may restrict shoulder motion or cause pain, physical disability or uncontrolled chronic systemic disease, major trauma, treatment for shoulder problems within the last 6 months and history of epilepsy.

An ethical approval was obtained from the ethics committee of Tehran University of Medical Sciences. All participants gave their informed consent prior to the first session. A single physician was involved in the treatment protocol at baseline, and at fourth week of treatment.

We designed and developed exclusive Virtual Reality game-based rehabilitation product with different stages based on upper extremity rehabilitation to increase the range of motion in the shoulder joint. The basis of the game instruction is to grab the balls of different colors that are showed on the monitor, hold them and throw them into the baskets of the same color at the bottom of the screen. The difficulty of the game increases as the stages goes on and the patient is rewarded after every successful movement. Following factors make our Virtual Reality game-based product unique:

A- Our game-based product can be adjusted by the physiotherapist according to the patient assessment.
B- Range of Motion (ROM) assessment in shoulder joints and elbows is displayed and recorded (real-time) on the screen and can be monitored at any time.
C- By comparing pre-assessment and post-assessment of the

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patient's ROM we can judge our rehabilitation efficiency.

D- The time in which patient spends at each stage of grabbing, holding, and dropping the balls is recorded and used as a measure of Muscular Function & Fatiguability.

Primary outcome measures were as follows: shoulder ROM was assessed using a 'goniometer', the pain level was measured with 'Visual Analogue Scale (VAS)', the degree of disability was evaluated using 'The Disabilities of the Arm, Shoulder and Hand (DASH) Questionnaire', an algometer was utilized to measure pain threshold and satisfaction with treatment evaluated using a Likert scale. Participants underwent rehabilitation 5 times a week for 4 weeks with a total of 20 sessions (60 minutes for each session). They received conventional physiotherapy and rehabilitation treatment together with game-based virtual reality exercises. In addition to the conventional physiotherapy and rehabilitation program, a 10-minute game-based virtual reality exercise was scheduled. The game-based virtual reality device named Balls & Clock (Version 2) was used for the rehabilitation program.

Data analysis was performed using SPSS software [Statistical Procedures for Social Sciences; Chicago, Illinois, USA] version 26. Chi-Square, Fisher exact, Independent-Sample-T, Mann-Whitney, and Kolmogorov-Smirnov tests were used where appropriate. P value less than 0.05 was considered as statistically significant.

III. Result

Three patients with shoulder impingement syndrome were recruited. Demographics and medical history of participants are listed in Table I.

TABLE I
BASELINE CHARACTERISTICS OF THE PARTICIPANTS

Participant	1	2	3
Age (year)	59	49	50
Gender	Female	Female	Male
Education	Primary school, no degree	Bachelor's degree	High School diploma
BMI (kg/m^2)	29	32	28
Pain duration (month)	2	6	5
Affected limb	Right	Bilateral	
Medical history	No	Diabetes mellitus	No
Smoking	No	No	No
Trauma history	No	No	No

All three patients completed a total of 20 game-based virtual reality exercise sessions. Figs. 1-3 show the scores of VAS, DASH, pain tolerance threshold and ROM of each shoulder joint movements including flexion, extension, abduction, adduction, internal rotation and external rotation before and after the intervention. Comparison of VAS, DASH and pain thresholds before and after the treatment showed a significant decrease in shoulder pain and disability and a significant increase in patients' pain tolerance threshold.

There was also a significant change in shoulder ROM in the form of increased flexion, extension, abduction and external rotation. Despite an increase in ROM of shoulder adduction after treatment, this change was not statistically significant (Table II). In terms of treatment satisfaction based on a 5-point scale, one patient was completely satisfied with the treatment (score 5), the second expressed good satisfaction (score 4) and the third one complete satisfaction (score 5).

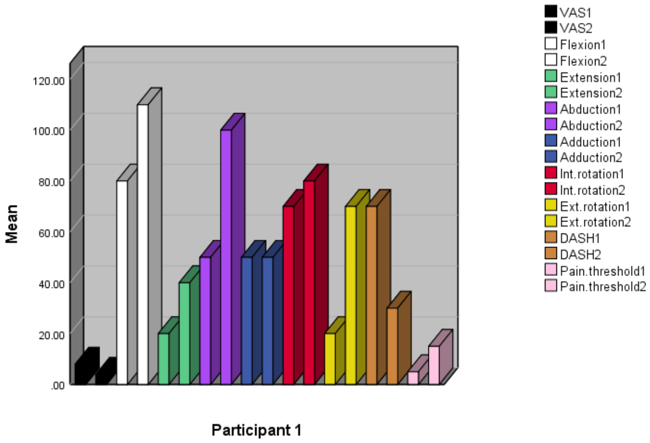

Fig. 1 VAS, DASH, pain threshold and ROM in participant 1 before and after the intervention

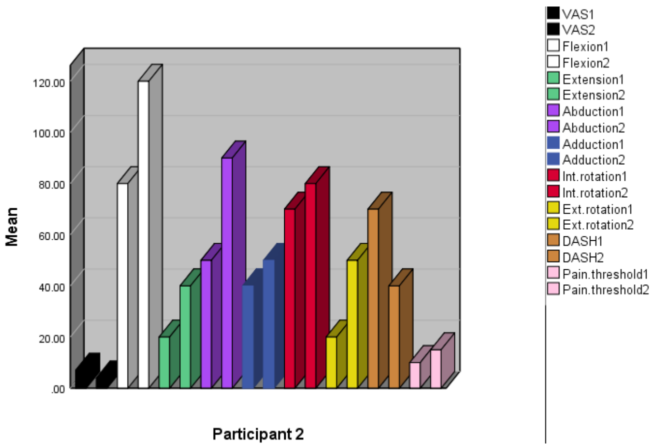

Fig. 2 VAS, DASH, pain threshold and ROM in participant 2 before and after the intervention

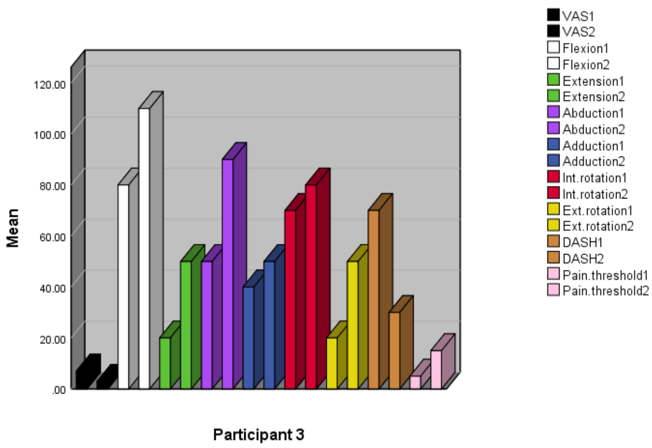

Fig. 3 VAS, DASH, pain threshold and ROM in participant 3 before and after the intervention

TABLE II
COMPARISON OF VAS, DASH, PAIN THRESHOLD AND ROM BEFORE AND AFTER THE TREATMENT

	Before the treatment	After the treatment	P value
VAS	7.33 ± 0.57	3.66 ± 0.57	0.008
DASH	70.00	33.33 ± 5.77	0.008
Pain threshold	6.66 ± 2.88	15.00	0.038
Flexion	80.00	113.33 ± 5.77	0.010
Extension	20.00	43.33 ± 5.77	0.020
Abduction	50.00	93.33 ± 5.77	0.006
Adduction	43.33 ± 5.77	50.00	0.184
Internal rotation	70.00	80.00	-
External rotation	20.00	56.66 ± 11.54	0.032

IV. DISCUSSION

Research on the effects of VR to improve the results of rehabilitation therapies has shown positive effects of exercise therapy in virtual environments. Numerous studies have shown some levels of evidence for the effectiveness of VR in improving patients' functional ability, ROM, physical disability, and muscle strength [13]-[26]. Some articles have reported positive results in the management of pain, including nonspecific chronic low back pain, chronic neck pain, subacromial occlusion syndrome, general and asymptomatic pain, fibromyalgia, knee surgery, ankylosing spondylitis, and osteoarthritis [14], [17], [18], [20], [22], [23], [26]-[29]. In addition, various studies have been focused on some of the benefits of VR rehabilitation, such as patient's satisfaction, quality of life, perception, commitment and enjoyment [14], [17], [20]-[24], [28], [29].

The results of this pilot study showed that VR-assisted exercise therapy in selected patients with shoulder impingement syndrome was associated with a significant improvement in subjective indices including pain intensity and joint disability and an increase in pain tolerance threshold and objective criteria, i.e. the ROM. The exact mechanism for reducing pain and disability with this method is not exactly known, however several theories have been proposed to explain this mechanism, which include the Gate Control Theory, activation of descending inhibitory pathways, production of endogenous opioids, mirror neuron activation, and beneficial neuroplasticity [30], [31], [33].

In a study by Pekyavas et al. [27] in Turkey in 2017, 30 patients with subacromial impingement syndrome (SAIS) were randomized into two groups as Home Exercise Program (EX Group) and Virtual Reality Exergaming Program (WII Group). Intensity of pain was significantly decreased in both groups with the treatment ($p < 0.05$). The WII Group had significantly better results for the Neer test, SRT and SAT than the EX-Group ($p < 0.05$) [27]. They concluded that virtual reality exergaming programs with these programs were more effective than home exercise programs at short term in subjects with SAIS which is consistent with our results.

Moreover, in a study by Hayashi et al. in Japan [32], 52 healthy students participated in a randomized cross-over controlled trial. One VR-based task aimed to passively use the imagery of driving a car as a distraction intervention (the driving group), whereas the other VR-based task aimed to use exercise imagery (running) to actively engage the participants in movement (the running group). The mechanical pressure pain thresholds of the quadriceps and forearm and the heat pain threshold of the hand were measured before, during, and after each VR task. The results showed that VR combined with exercise imagery had a greater effect on pressure pain thresholds, but not heat pain thresholds. Furthermore, in a pilot study by Chau et al. [33], the effects of therapeutic immersive VR on pain in upper limb complex regional pain syndrome (CRPS) were assessed. Four of six participants who completed the study reported subjective improvement of their pain and daily function. However, objective pain scales had limited correlation to reported subjective [33]. They concluded that immersive virtual reality might provide subjective analgesia and functional improvement in selected patients with upper limb CRPS, which is consistent with our results.

Despite the benefits of VR in improving pain and disability and effective rehabilitation of patients, some limitations have been suggested. For instance, Burdea cited a number of challenging issues for the widespread use of this method, such as expensive facilities, lack of infrastructure support, and insufficient experience of therapists or patients to use this technique, especially in the early development phase [34]. On the other hand, the home nature of VR technique and lack of need for patients to spend time to refer to rehabilitation centers, are some of its advantages over conventional techniques. As a result, it is possible to replace VR with expensive hospital care if it becomes cost-effective. In other words, reducing hardware and software expenses by redesigning virtual reality devices and expanding low-cost devices is essential to increase its widespread application. Accordingly, various articles have focused on low-cost virtual reality systems [35]-[38]. For example, Saini et al. [39] developed a low-cost framework based on the Kinect for home-based stroke rehabilitation. Moreover, Standen et al. developed a low-cost VR system for home-based rehabilitation for stroke patients [37].

Our pilot study had several limitations, including design, small number of participants, and lack of long-term follow-up. Additionally, due to the heterogeneity and limited number of patients, it is difficult to draw a definite conclusion and generalize the results to other patients with shoulder impingement syndrome.

V. CONCLUSION

Game-based virtual reality exercises could lead to pain relief along with functional improvement of shoulder joint in patients with impingement syndrome. Further studies are necessary with more participants and more elaborate methodology to measure other outcomes to confidently characterize the effects of virtual reality exercises.

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