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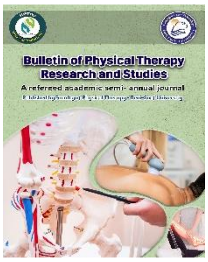

Does Weight Shifting Virtual Games Improve Knee Joint Position Sense After Reconstruction of The Anterior Cruciate Ligament in Young Male Adults? A Randomized Controlled Trial

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Running Title: **Virtual Reality Games Effects on Knee Joint Proprioception After ACL Reconstruction**

Abstract:

Background: Anterior cruciate ligament (ACL) is crucial for knee joint stability, but total failure can impair proprioception. Rehabilitation involves unique regimens, virtual reality VR games being a helpful aid.

Purpose: Examining how a Wii Fit rehabilitation program affects knee proprioception following ACL reconstruction.

Methods: Thirty patients were assigned randomly to Study group (A), and control group (B). For eight weeks, the study group received the Wii Fit training protocol three times a week, lasting forty minutes each, with a conventional exercise program tailored to the control group. The knee joint's position sense was measured in both groups, before and after activities using a Biodex isokinetic dynamometer.

Results: After treatment the joint position error JPE significantly improved for group A and group B. With significant decrease of JPE for the three angles of group A compared to group B ($P<0.01$).**:**

Conclusion: The results revealed that Playing weight shifting VR games on the Wii Fit for eight weeks, with a consistent exercise rehabilitation program, can significantly improve knee joint position sense.

Keywords: ACL, Knee joint, Virtual games, Proprioception, Joint position sense

Introduction

The knee's mechanical stability is a crucial function of the joint, primarily provided by the ligaments. The anterior cruciate ligament (ACL), for example, is involved in knee motion sensory feedback and participates in proprioception; hence, it plays an important role in neuromuscular stability. The ACL injury, which removes mechanoreceptors present in the joints, accounts for more than half of all ligament injuries, especially when its fibers break completely. (1)

ACL injury dramatically reduces knee proprioception, functional performance, and quadriceps femoris strength in the damaged knee joint.(2) The first line of treatment is ACL reconstruction (ACLR) surgery, which is becoming less intrusive and more anatomic as time goes on. There are also increasing attempts to match native ACL architecture with a better understanding of how the ACL functions in conjunction with other knee joint components. (3)

An effective pre- and post-operative rehabilitation program is crucial to the early restoration of full joint range of motion and the capacity to bear weight, both of which are vital for the success of the ACLR. (4)

The knee joint's functions will be restored, and static stability will be enhanced through the reinforcement of neuromuscular control. However, there is still no consensus on how long it takes to recuperate after commencing a rehabilitation program. Opinions differ from 5 to 12 months following ACLR. The recommendation is for a six-month follow-up following ACLR, based on the evidence from rehabilitation clinic studies. This does not prevent stability and function deficiencies from persisting following ACLR for up to two years. (5)

Even though ACL procedures have improved, and the rehabilitation process has advanced over the past ten years owing to new surgical techniques, clinical experience, and a greater knowledge of the need for rehabilitation, some patients still experience instability and give way. indicating that there is still a functional recovery to be achieved. (6)

Virtual reality (VR) as a tool for interactive game-based rehabilitation has been the subject of increasing research since the late 1990s, as seen by the sharp rise in publications in the last several years. (7)

Virtual reality therapy's cutting-edge technology is now so widely accessible that they can be used in addition of conventional therapy or routine care. VR therapies are regarded as technological interventions that alter the physical world's characteristics by generating perceptual qualities that give the subjects additional sensory feedback that directs their movement in a virtual setting. (8)

Considering evidence demonstrating that VR games, exercise+games, and active video game exercises can enhance balance, flexibility, and strength, these technologies are now frequently utilized in the rehabilitation of balance disorders. They are highly advantageous and foster a unique atmosphere of inspiration, fun, and enjoyment that improves adherence and inspires the subjects to carry out the rehabilitation program. (9)

Clinical studies are progressively showing that virtual reality games improve the function of the neurological system in individuals with spinal cord injuries, cerebral palsy, and other neurological disorders. (10) Aside from that, they create a motivating, engaging, and extremely useful tool for musculoskeletal patients' rehabilitation. (11)

A previous study looked at when to be immersed in an environment of VR that would affect the knee mechanics in ACLR patients. The findings imply that following ACLR, patients may be distracted from controlling motor activity consciously by a highly simulated VR environment. Current rehabilitation programs could benefit from using clinic-based technologies to address impaired mobility styles after ACLR. (12)

Following ACLR surgery, the absence of knee joint proprioception and the need for ongoing, consistent rehabilitation programs to return to normal levels are regarded as the two main issues. (1) Thus, the purpose of this study was to assess how well virtual reality exercise games affect knee proprioception following ACL reconstruction surgery.

Methods

The current study used a pre-test, post-test, randomized control trial design. Ethical approval granted from Jazan University's ethics council of scientific research (Rec-45/04/833), and each patient signed an informed consent form granting permission to participate, following the guidelines of declaration of Helsinki for human research conduction.

Participants

utilizing the G*Power program (Universität Mannheim, Mannheim, Germany) and presuming that the primary outcome variables have an effect size of 0.3 based on data from a related prior study (13), Given previous sample size calculations, we estimated that we would need 32 participants in total with 90% power (Type II error rate, 0.10) and alpha-level 0.05 (Type I error rate). The sample size was expanded by 15% in the case of dropouts, therefore 45 people who were assigned to have their eligibility for participation in the study evaluated was the appropriate minimum sample size for this investigation. Lastly, a 1:1 random assignment was made to place 36 patients in the study (A) or control (B) groups using flipping a coin technique. At last, thirty participants finish the study for various reasons indicated in Figure 1's consort flow chart.

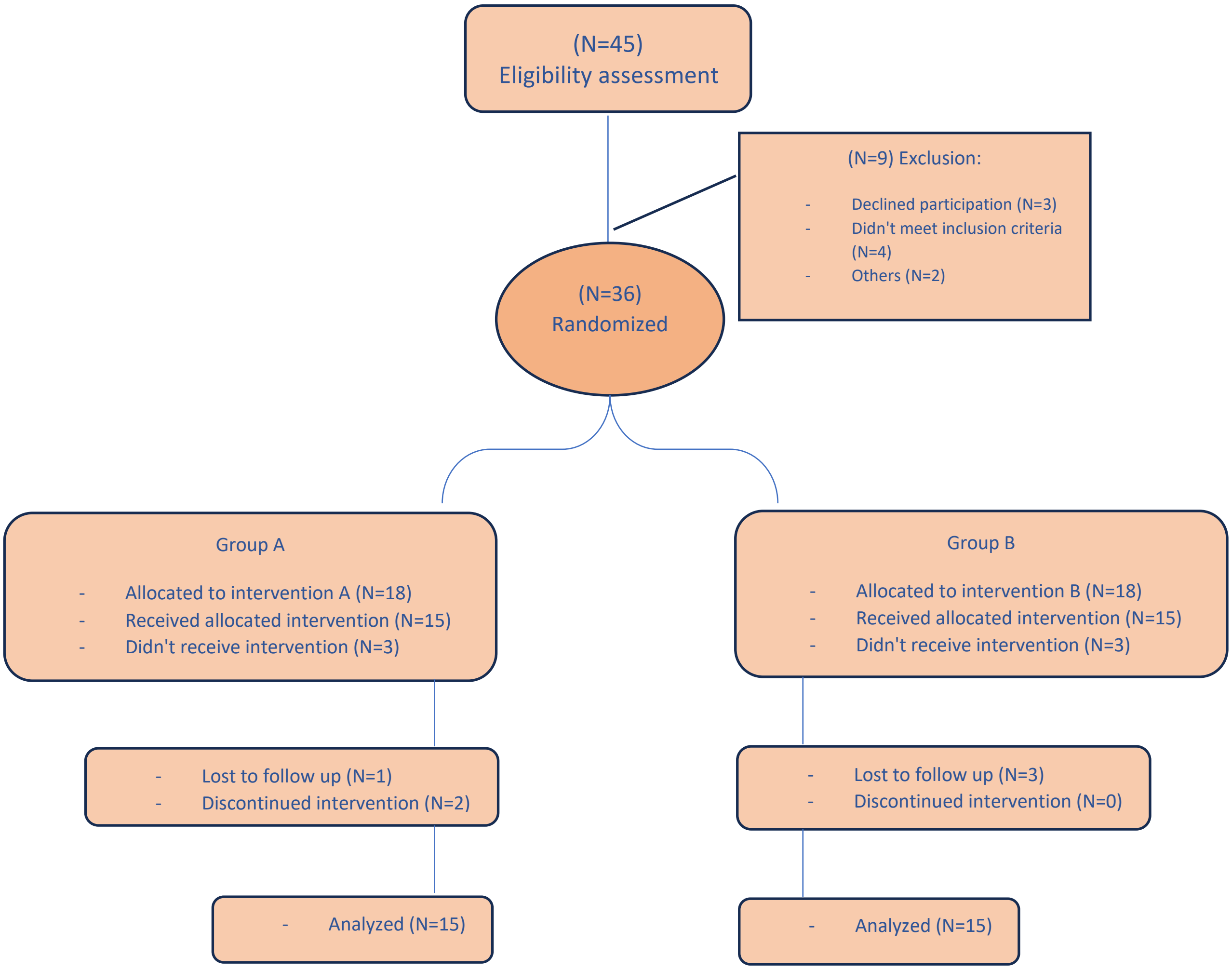

Figure 1. Consort flow chart of the participants with randomization.

All the patients were ACL-damaged patients after undergoing ACLR surgery, with a mean age of 25.47 ± 3.5 years and a mean body mass index (BMI) of 24.23 ± 0.7. They were recruited from the physical therapy section of the Alamal hospital for psychiatric health in Jazan, Saudi Arabia. Patients in the early postoperative phase (week 2 after surgery), (14) as well as those with a BMI of less than 25, and more than 20, were included. Those who had ACLR accompanied with any knee injury or operation, such as meniscectomy, and patients with any anomalies influencing knee joint alignment, such as genu valgus, genu Varus, or genu recurvatum, were excluded.

The patients were divided into two equal groups at random, **Group A** was the research group, and **Group B** was the control group. **Group A** was given the Wii fit program of virtual reality games for 8 weeks, 3 times a week for 40 minutes per once in addition to the standard schedule of regular exercise rehabilitation, 3 times a week for eight weeks according to Adams et al, 2012 exercise rehabilitation protocol (14) criteria nearly the same was given to **Group B**, only 3 days per week regular exercise rehabilitation program, for 8 weeks, as group A.

Instrumentation

For evaluation

A Universal Height and Weight Scale: This scale was used to calculate the patient's BMI. (15)

Biodex Isokinetic Dynamometer: This is an isokinetic dynamometer from the Biodex System "2." (Biodex, Inc, NY, USA). This item is a computerized system that securely provides data for assessments, especially in adult and child rehabilitation. (16) A computer (DELL) that is compatible with the dynamometer and is used to gather, display, and save data as well as define the protocol that controls the dynamometer's movements. The knee, ankle, and trunk are stabilized through various attachments and belts.

The data was recorded using charts and graphs, including movement duration, speed, work, torque, and power, with various rates, then printed for analysis. It has different muscle contraction moods (isokinetic, isometric, eccentric, and passive) with proprioception protocol for all the body joints. Besides that, three angular velocities were available for the system: slow (30–60 °/sec), moderate (60–90 °/sec), and fast (90–120 °/sec). (17) In this investigation, proprioception was measured from three angles using the Biodex system (30º,45º,60º) by measuring the average difference error of perception of each angle.

For treatment

The Wii Fit: (Nintendo Co. Ltd., Tokyo, Japan) was released in 2006 as a home-based active video game (AVG). Virtual reality games with a Balance Board are available for the Wii (Wii Fit). This could be used as a body weight scale or a board that responds to weight shifts. It was designed to work in tandem with the Wii system to create a mix of hard and entertaining activities that require body movement and weight shift. It motivates subjects and patients to improve their physical condition by displaying simulated animation on a screen in front of them that mimics the movement of the patients during the game. According to the research review, physicians and physical therapists can use the Wii Fit in their offices.(18)

In Wii Fit activities, players use the Wii remote control or adjust their weight to play games while standing on the Wii Fit balance board. The subjects stand over the Wii balancing board and begin playing by shifting their weights. They can also use the remote control to initiate activities. Reinterpreting the four components of self-efficacy performance mastery, verbal persuasion, physiological responses, and vicarious learning while applying the Social Cognitive Theory. The first component is performance mastery, which is the ability to accomplish a certain activity or ability. The second component is vicarious learning, it involves seeing others as they successfully execute skills. It gives the subjects confidence to do the job. To do that, group competitions using Wii Fit games would be practiced, and players would be encouraged throughout the activities. The third component is verbal persuasion, which results from reliable responses, effective direction, and the encouragement of endeavors. Moreover, the Wii system generates visual and aural feedback based on the subjects' performance. (19)

Yoga protocols, which can be static, or dynamic, single, or double leg supports, balance training protocols, which include anteroposterior and lateral weight shifting training, muscle strengthening protocols, which are performed in a dynamic manner for one or two limbs, and aerobics protocols, which include jogging, running, and stepping exercises, are all examples of exercises. (20)

The patients in group A were given Wii fit games that required them to shift their weight while playing for 40 minutes on three nonconsecutive days each week for eight weeks. (13)

Assessment Procedure

Knee proprioception assessment

Every individual involved in this research had their proprioception of the afflicted knee tested using the Biodex Isokinetic Dynamometer. Each participant was evaluated twice in two consecutive sessions at the same time of day, with an eight-week delay between assessments, which corresponded to the treatment period. All evaluations were conducted between 9 a.m. and 1 p.m. (21) The same examiner conducted all the tests. Testing took place in a clinical laboratory at Jazan University's Faculty of Applied Medical Sciences, Department of Physical Therapy.

Test Protocol: calibrating isokinetic dynamometer was done before testing session as the manufacturers' instructions and recommendations. All Using a belt across the hips and pelvis, people were securely secured in a comfortable sitting position on the Biodex machine chair, two belts across the chest and trunk. The distal leg of the tested side, just proximal to the malleoli, was connected to the dynamometer attachment that concerns the leg and thigh, which was secured to the chair with a belt, with the dynamometer's axis of rotation on the same line as the frontal axis of rotation of the tested knee, which is always become on the line of lateral femoral condyle. (21,22)

Before beginning the test session for each subject, calibration of the joint's position regarding the angel of its anatomical position should be done to correlate curve deficiencies to joint position.

The device arm was set to 0 and kept at a right angle, while the seat was also set to a right angle, and the back of the seat was inclined at a 70-to-85-degree angle. The knee proprioception of the affected operated leg was assessed at three target angles (30, 45, and 60) after the system was adjusted. To begin assessing proprioception, the examiner used the Biodex system's active testing mode, which is more functional than the passive testing mode. (22)

The participants were given instructions regarding how to finish the test. They were educated about the exam's goals, benefits, and method, and they were given three opportunities to practice the test before it was given to them. They were given instructions on how to sit, how to move the knee joint to flexion and extension, how to act with the angle of knee joint to memorize, the duration between test sequences, and how to halt the movement on the target angle by pushing the stop button.

The participants were told to stretch their legs from the beginning position (90◦) until the Biodex dynamometer arm stopped moving at the goal angles to collect data. The individual was asked to memorize the angles that the knee joint achieved when the movement halted for 10 seconds (sec.) at the goal angle. The subject then flexed his knee to reach (90◦), which was the starting position, and was then asked to extend his knee. When the subject sensed that the desired angle had been reached, he had to click the stop button. Before testing, the individual completed three consecutive trials to reach goal angles, each one alone (30, 45, and 60 degrees), followed by a 30-second rest period before beginning the next angle. The difference in inaccuracy between the target angle's locations and the angles positions which is called the joint position error JPE perceived by the subjects, then averaged. (13)

Treatment Procedure

All the exercise sessions took place at Alamal Hospital for Psychiatric Health's physical therapy department. According to **Adams et al. (2012)** criterion, (14) both groups (A) and (B) received a regular rehabilitative exercise routine that included strengthening, range of motion (ROM), and flexibility activities for three non-consecutive days. Group (A) had a ten-minute break (min.). Then began Wii fit workout by standing barefoot on the Wii fit board, hands on hips, and both eyes open. Before beginning the period of exercise and after hearing the directions of the tester, the subject was given a Wii Fit pretest to familiarize them with the board and weight transfer tasks. A 42-inch screen was used, which was placed 2 meters in front of the subject, with the center of the screen at eye level. (23)

Patients performed balance training While standing on the device accessory board, patients conducted balance training protocols such as anteroposterior and lateral weight shifting. The tester chose the games in difficulty order, starting with the easiest and progressing through harder and faster weight shifts to make the workout more challenging. In addition, several of the department's patients and therapists were watching the game to provide some inspiration and challenge. Participants in the study group participated in a 40-minute Wii fit games intervention session three times a week for eight weeks. (13)

Data Analysis

Unpaired t-test was conducted for comparison of subject characteristics between groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to ensure the homogeneity between groups. Mixed design MANOVA was performed to compare within and between groups effects on knee JPE. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics:

Table (1) showed the subject characteristics of group A and B. There was no significant difference between groups in age, weight, height, and BMI ($p > 0.05$).

Table 1. Comparison of subject characteristics between group A and B:

	Group A	Group B			
	Mean ±SD	**Mean ±SD**	**MD**	**t- value**	**p-value**
Age (years)	25.53 ± 3.74	25.4 ± 3.39	0.13	0.10	0.92
Weight (kg)	71.04 ± 6.04	71.22 ± 3.33	-0.18	-0.11	0.91
Height (cm)	171.47 ± 5.84	171.20 ± 4.46	0.27	0.14	0.88
BMI (kg/m²)	24.12 ± 0.75	24.33 ± 0.72	-0.21	-0.81	0.42

SD, Standard deviation; MD, mean difference; p-value, level of significance.

Effect of treatment on knee JPE:

There was a significant interaction of treatment and time ($F_{(3,26)}$ = 46.16, p = 0.001, η^2 = 0.84). There was a significant main effect of time ($F_{(3,26)}$ = 424.06, p = 0.001, η^2 = 0.98). There was a significant main effect of treatment (F (3,26) = 21.20, p = 0.001, η^2 = 0.71).

Within group comparison

There was a significant decrease in knee JPE at 30˚, 45˚ and at 60˚ of group A and group B post treatment compared with that pretreatment (p < 0.001), The percent of change of knee JPE at 30˚, 45˚ and at 60˚ of group A was 64.42, 62.65 and 65.51%% respectively and that of group B was 32.28, 31.79 and 32.28% respectively.

Between groups comparison:

There was no significant difference between groups pre-treatment (p > 0.05). There was a significant decrease in knee JPE at 30˚, 45˚ and at 60˚ of group A compared with that of group B post treatment (p < 0.01). (Table 2).

Table 2. Mean knee JPE at 30˚, 45˚ and 60˚ pre and post treatment of group A and B:

	Group A	Group B		
	Mean ± SD	**Mean ± SD**	**MD (95% CI)**	**P value**
JPE at 30˚				
Pretreatment	7.87 ± 0.73	7.93 ± 0.75	-0.06 (-0.62: 0.49)	0.81
Post treatment	2.80 ± 0.51	5.37 ± 0.54	-2.57 (-2.97: -2.18)	0.001
MD (95% CI)	5.07 (4.75: 5.37)	2.56 (2.24: 2.86)		
% of change	64.42	32.28		
	p = 0.001	***p = 0.001***		
JPE at 45˚				
Pretreatment	7.71 ± 0.96	7.55 ± 0.98	0.16 (-0.57: 0.88)	0.66
Post treatment	2.88 ± 0.61	5.15 ± 0.66	-2.27 (-2.74: -1.78)	0.001
MD (95% CI)	4.83 (4.38: 5.26)	2.4 (1.95: 2.84)		
% of change	62.65	31.79		
	p = 0.001	***p = 0.001***		
JPE at 60˚				
Pretreatment	7.48 ± 1.18	7.62 ± 0.97	-0.14 (-0.94: 0.68)	0.73
Post treatment	2.58 ± 0.64	5.16 ± 0.82	-2.58 (-3.13: -2.03)	0.001
MD (95% CI)	4.9 (4.48: 5.34)	2.46 (2.03: 2.89)		
% of change	65.51	32.28		
	p = 0.001	***p = 0.001***		

SD, Standard deviation; MD, Mean difference; CI, Confidence interval; p-value, Level of significance.

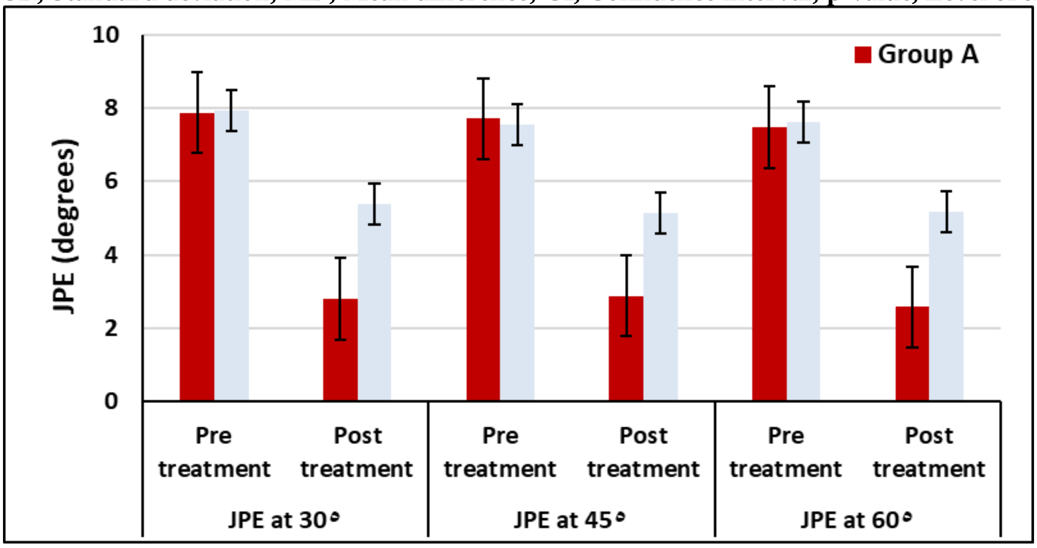

Figure 2. Mean knee JPE at 30, 45 and 60° pre and post treatment of group A and B

Discussion

The current study's findings showed that adding virtual reality games with Wii fit (Nintendo-Tokyo) exercises in the form of weight shifting to a rehabilitation program enhance knee joint position sense and reduce proprioception mean error in patients who undergone ACLR.

Stimulation of the proprioceptive receptors which occurred with VR weight shifting games led to continuous feedback to the receptors and decrease JPE within study group significantly. This result is consistent with the findings of **Mackinnon. (2018)**, who claimed that feedforward and feedback control systems, which provide information on the perception of the position and movement of distinct body parts, are the primary sources of proprioception. These systems support controlled, coordinated motions of the head, body, and upper and lower limbs, as well as the maintenance of proper posture.(24)

Furthermore, these findings corroborate the findings of **Aman et al. (2015)**, who suggested that proprioception therapy may be very beneficial, particularly in situations of neurological impairments such as dystonia, strokes, and cerebral palsy (CP). Additionally, in certain musculoskeletal conditions such as ankle instability, osteoarthritis (OA), and ACLR.(25)

Because the Wii Fit virtual reality games include moving one's weight and rearranging the head, trunk, and segments in space, they activate the Golgi tendon organs and the muscle spindle. A principle proposed by Park et al. (2014), which provides support for the earlier view of Sarlegna et al. (2009) who stated that, proprioception is expressed by muscle spindles and Golgi tendon organs, which provide position and movement information as part of the somatosensorial system. Additionally, they claimed that proprioception may convey the segment-to-segment coordination needed for complex movements. (26,27)

The results of this study showed that playing exergames using the Wii Fit protocol considerably reduced the mean error difference of joint position. Increased weight-shifting repetition and active joint-angle motions are features of the exergames that improve task performance. This may result in an increase in the sensitivity of mechanoreceptors and a stretching of the muscles surrounding the target knee joint, both of which increase the activation of muscle receptors.(28) Additionally, that would cause the muscle spindles' Ia afferents to become activated, increasing the knee joint's perception of position and reflex stabilization through an appropriate efferent response.(29)

According to **Cuppone et al. (2016)**, who conducted research on robot-assisted proprioceptive training. Movement perception is significantly impacted by sensory co-stimulation, because visual and tactile proprioceptive co-stimulation have been shown to be highly effective in inducing kinesthetic illusions of hand rotation. This suggests that the co-stimulation of visual and tactile elements in virtual reality games may also contribute to improvements in proprioceptive function.(30)

Additionally, researchs conducted by **Cho et al. (2014)** and **Lee et al. (2017)** revealed that playing VR games reduced the mean error differences of proprioception in the upper body of stroke patients. Additionally, they said that for those who needed to focus on proprioception and develop efficient movement, visual input was crucial.(31,32) The current study's results were consistent with those of **Abbruzzese et al. (2014)**, who studied the visual feedback VR games provide and how it can enhance proprioceptive stimulation, which in turn improves motor function skills. This enhancement happens normally during game sessions.(33)

A previous study by **Gschwind et al. (2015)** found that VR games played by older women using a custom-built Kinect had a nonsignificant effect on the proprioception of the knee joint during the Physiological Profile Assessment (PPA) conducted between these older women, which seemed to contradict the findings of the current study.(34) but as the current study focused on young guys, this might be a justification of the contradiction.

Conclusion

The results of this study showed that playing weight shifting virtual reality games on the Wii Fit (Nintendo/Tokyo) for 40 minutes three times a week for eight weeks, along with a consistent exercise rehabilitation program, can significantly improve knee joint position sense following ACL reconstruction surgery.

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