

Impact of Virtual Reality Training on Balance among Subjects with Sarcopenia

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ABSTRACT

Introduction: Sarcopenia refers to the gradual decline in muscle mass and quality noted with advancing age. There is growing evidence linking sarcopenia to functional falls, disability, and decreased bone density in older adults. The prevalence of sarcopenia ranges from 3% to 24% have thus been reported in individuals older than 60 years. The study aimed to compare the effect of balance training using non-immersive virtual reality training among the subjects with sarcopenia.

Methodology: The present study was an experimental, comparative study conducted with 40 subjects. Group A includes 20 participants, and non-immersive virtual reality was given. Group B includes 20 participants, and resistance training was given. It was applied for 5 days a week for about 32 weeks of duration. Bio-impedance analyzer (BIA), Berg balance scale (BBS), 6 Minute Walk Test (6MWT), and SARC-F scores of the patients in both groups before the treatment and after the end of the treatment were recorded.

Results: The results showed that Group A had significantly higher BBS scores than Group B (33.4 vs. 24.0, $p < 0.001$). The mean difference in BBS was 9.4 points in favour of Group A. 6MWT distance was 43.5 meters greater in Group A (652.5 vs. 609.0, $p = 0.001$). SARC-F scores showed no significant difference between groups (5.9 vs. 6.1, $p = 0.59$). Group A showed significantly better outcomes than Group B for BBS and 6MWT ($p \leq 0.01$). SARC-F showed no significant between-group difference.

Conclusion: In this study, it was shown that non-immersive VR (Group A) is more effective for sarcopenia in improving balance and functional performance.

Keywords: Sarcopenia, non-immersive VR, Balance training, Bio-impedance analyser, 6 MWT

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Introduction

The term sarcopenia, first coined by Rosenberg in 1988 (Greek, sarx for flesh and penia for loss), refers

to the reduction of both muscular mass and strength, and of function, with aging. ⁽¹⁾ The aging process is characterized by systemic changes that cause an

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individual to suffer a progressive inability to adapt to the environment in which he or she lives. Consequently, this increases an individual's vulnerability to the onset of disease. ^(2,3) Epidemiological data from the USA shows 49% of men and 72% of women suffer from Sarcopenia, which is associated with increased morbidity, mortality, disability, and reduced resistance to metabolic stress. Sarcopenia is highly prevalent among elderly people, with estimates of prevalence up to 29% in Western countries. Worldwide, however, about 30% of people aged between 70 and 79 years old and 50% of people over 80 years old do not meet basic WHO guidelines for physical activity in older age ^(4,5) Virtual reality (VR) is a trending, widely accessible, contemporary technology of increasing utility to biomedical and health applications. It ranges from non-immersive to fully immersive, depending on the degree to which the user is isolated from the physical surroundings. ^(6,7,8) There are two types of interaction with virtual environments: immersive and non-immersive. To enable human interaction with the environment, non-immersive virtual reality uses traditional input devices like a mouse or joystick. Immersion virtual reality, on the other hand, uses body-connected interfaces, such as motion sensors, gloves, and head-mounted displays, to improve ecological validity and realism by allowing users to perform comparable motor activities through direct physical motions. ^(9,10) The application of virtual reality has a positive impact on the management of prevalent geriatric conditions, as it has been reported by numerous studies that strength training will benefit all adults, regardless of their functional level, based on a self-report survey of nearly 10,000 adults aged 60 years and older. ^{11,12} Accurate measurement of skeletal muscle mass is essential for diagnosing sarcopenia and monitoring treatment efficacy, with standardized body composition methods recommended for clinical use ¹³. In addition, physical performance tests are routinely employed to quantify functionality. Among these, the six-minute walk test (6MWT) has been extensively validated as a practical, well-tolerated measure that reflects activities of daily living. These strength training programs have shown improvement in the quality of life of the elderly patients. In addition, physical performance tests are routinely employed to quantify functionality. ¹⁴ Among these, the six-minute walk test (6MWT) has been extensively validated as a practical, well-tolerated measure that reflects activities of daily living. ^{15,16} Importantly, even

non-immersive systems—such as those operated via joystick or mouse—are highly acceptable to older adults, underscoring the feasibility of virtual interventions in this population. ¹⁷ On the existing evidence, the present study aims to compare the effect of balance training using non-immersive virtual reality training among the subjects with sarcopenia.

Materials and Methods

The present study is an experimental comparative study conducted at JK Physio & Rehab clinic and Ideal Physiotherapy Centre. A total of 40 participants diagnosed with sarcopenia were recruited who fulfilled the inclusion criteria using random sampling. The inclusion criteria for the patients in the present study were age between 60 and 80 years, the value of SARC-F screening tool should be greater than 4 ($SAR-F > 4$ points), the muscle mass of the patient should be calculated using bioimpedance analysis and the values should be less than $7.0\text{kg}/\text{m}^2$ for male and $5.0\text{kg}/\text{m}^2$, Hand grip strength of the patient should be less than 26kg for males and 18kg for females. The exclusion criteria for the present study were patients with any neurological disorders, such as stroke, vertigo, or Parkinson's disease, pathological diseases such as malignancy or referred pain, psychological disorders such as depression and anxiety, and orthopedic surgery causing pain or functional limitations. All 40 participants were divided into two groups: Group A (n=20) and Group B (n=20) patients. Subjects who were found suitable for participation in the study were required to sign a consent form.

Procedure

On the first visit, a complete pre-assessment of the patient was done. Pre-participation, the patient had completed a bio-impedance analyzer (BIA) device that measures body composition by analyzing skeletal mass. The Berg Balance Scale (BBS) is used to assess the elderly person's balance and risk of falling. 6(MWT) is a valuable tool for evaluating functional mobility, endurance, and physical performance. ^{18 19} Group A patients were trained with non-immersive virtual reality, and Group B patients were trained with resistance training. Both groups underwent training 5 days per week for a total of 32 weeks. The subjects were functionally independent and injury-free in the upper and lower extremities for at least 6 months before the study. The questionnaire and clinical examination were done with the exact same protocol after the treatment period. Each session began with a warm-up to prepare the patient and ended with cool-down stretches for recovery. Warm up exercises

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include head rotation, arm circles, knee lifts, hip circles, and ankle rotation. Cool-down exercises include biceps stretch, triceps stretch, quadriceps, hamstrings, and calf stretch.

Group A (Non-immersive virtual reality)

The participants will undertake the intervention in a non-immersive virtual reality intervention (with a series of games on a web platform). The training uses a Rymo rehabilitation machine in a non-immersive virtual reality (VR) environment (using a computer screen).²¹

FLOPPY BIRD EXERCISE

Upper limb strengthening: Patient is asked to pull or push the handlebars to move the bird forward and backward. And to adjust the movement to clear obstacles in the game. A weight cuff of 2kg was added for the resistance.

Lower limb strengthening: Patient was asked to pedal or extend the feet to move the bird upward. To keep the bird in the air and navigate through gaps. A weight cuff of 2kg was tied around the ankle for resistance. Repetition: 2 sets, 5 minutes of exercise, 1 minute of rest time.

TRAFFIC CAR EXERCISE

Upper limb strengthening: The patient was asked to push or bend the handlebars to steer left or right to avoid hitting other cars, to change lanes, and to follow the road with a 2kg weight cuff on the wrist.

Lower limb strengthening: The patient was asked to pedal or to extend the leg to control the car speed, maintain a constant speed while avoiding barriers. Repetition: 2 sets, 5 minutes of exercise, 1 minute of rest time.

HAIR HOCKEY EXERCISE

Upper limb strengthening: The patient was asked to push/pull the Rymo handles to move the paddle from left to right, along with a 2kg weight cuff for resistance. The main task is to hit the puck and prevent the opponent from scoring.

Lower limb strengthening: The patient was asked to pedal or to extend the leg to speed control the power of the paddle, along with a 2kg weight cuff for resistance. The main task was to pedal faster to hit the puck harder or slower for mild shots. Repetition: 2 sets, 5 minutes of exercise, 1 minute of rest time.

PINEAPPLE GAME EXERCISE

Upper limb strengthening: the patient was asked to push/ pull the handlebars to reach the pineapple, along with a resistance of a 2kg weight cuff on the wrist. The task was to collect high-falling pineapples and to prevent them from falling.

Lower limb strengthening: The patient was asked to pedal from right to left to move the pineapple into the basket. The task was to position the patient and to make them collect the pineapple, which was dropped down with a 2 kg weight cuff on the ankle. Repetition: 2 sets, 5 minutes of exercise, 1 minute of rest time.

Balance exercise:

The subject will be made to sit in the Mend Balance platform and asked to perform forward and backward sway if there is going to be an alteration in balance. A virtual diagram will represent the changes noted there. It will be given for 3 sets per week. Progression will be performed with single-limb support. Group B RESISTANCE TRAINING

Tandem standing: Repetition: 2 sets = 30 sec hold, 10 reps, 1 minute of rest after.

Biceps curl: Repetition: 2 sets = 10 reps, 1 minute of rest after each set.

Tricep curl: Repetition: 2 sets = 10 reps, 1 minute of rest after each set.

Supine gluteal bridges: Repetition: 2 sets = 10-second hold, 10 reps, 1 minute of rest after each set.

Straight leg raise: . Repetition: 2 sets = 10-second hold, 10 reps, 1 minute of rest after each set.

Wall push-up: Repetition: 2 sets = 10 reps, 1 minute of rest after each set.

Cable bicep curl: . Repetition: 2 sets = 10 reps, 1 minute of rest after each set.

Tricep pull-down: Repetition: 2 sets = 10 reps, 1 minute of rest after each set.

Leg extension: Repetition: 2 sets = 10 reps, 1 minute of rest after each set.

Results

Demographic data and characteristics

In the present study, the mean age of participants was similar between Group A (68.4 ± 6.2 years) and Group B (69.1 ± 5.8 years). Sex distribution was comparable, with 9 males and 11 females in Group A, and 10 males and 10 females in Group B. BMI values were nearly identical between groups (22.3 vs. 22.7 kg/m²). The duration of sarcopenia was similar in both groups (approximately 14 months). Prevalence of diabetes (30% vs. 25%) and hypertension (40% vs. 35%) did not differ significantly. Baseline BBS, and 6MWT, showed no significant differences between groups. The p-values for all baseline characteristics were >0.05 , confirming successful randomization. Both groups were comparable at the start of the study, allowing for a valid post-intervention comparison. [**Table 1**]

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Characteristic	Group A (VR) (n=20)	Group B (resistance training) (n=20)	Mean (SD)	Mean (SD)	p-value			
Age (years)	68.4 ± 6.2	69.1 ± 5.8	BBS	19.0	24.0	0.725	(2.8, 1)	
Sex (Male/Female)	9 / 11	10 / 10	(score)	± 4.5	± 5.0	0.75	(7.2)	
BMI (kg/m ²)	22.3 ± 2.1	22.7 ± 2.4	6MWT	375.2	609.5	0.001	(202.1, 265.5)	
Sarcopenia duration (months)	14.2 ± 4.5	13.8 ± 5.1	(meters)	± 58.1	± 63.6	0.79		
Diabetes (n, %)	6 (30%)	5 (25%)				0.72		
Hypertension (n, %)	8 (40%)	7 (35%)				0.74		
Baseline BBS (score)	18.5 ± 4.2	19.0 ± 4.5	Comparison between group A and B (post-test)					
Baseline 6MWT (meters)	380.5 ± 55.3	375.2 ± 58.1	Independent t-test analysis concluded that Group A showed significantly better outcomes than Group B					

Table 1: Baseline Demographic and Clinical Characteristics of Participants

Group A (Non-immersive) – pre-test and post-test comparison

In group A, the paired t – test showed significant improvement from pre-test to post-test. BBS scores improved significantly from 18.5 to 33.4, with a mean increase of 14.9 points. 6MWT distance increased by 272 meters, from 380.5 to 652.5 meters. All p-values were <0.001, indicating highly significant improvements. The 95% confidence intervals did not cross zero, confirming the reliability of improvements. Non-immersive VR training produced substantial gains in all outcome measures. [Table 2]

Outcome Measure	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	Mean Difference (Mean ± SD)	95% CI	p-value*	Cohen's d
BBS (score)	18.5 ± 4.2	33.4 ± 5.4	14.9 ± 4.5	(12.1, 17.7)	<0.001	1.78
6MWT (meters)	380.5 ± 55.3	652.5 ± 73.4	272.0 ± 58.1	(238.5, 305.5)	<0.001	1.78

Table 2: Within-Group Comparison (Pre-test vs. Post-test) – Group A (Non-Immersion VR) Group B (Resistance training) – pre- test and post-test comparison

In group B, the paired t-test showed significant improvement in all outcomes (p < 0.01), but the magnitude of improvement was smaller than that of group A. BBS scores improved from 19.0 to 24.0, with a mean increase of 5.0 points. 6MWT distance increased by 233.8 meters (from 375.2 to 609.0 meters). All p-values were ≤0.002, indicating significant improvements. The magnitude of improvement was smaller compared to Group A for all outcomes. Immersive training is effective but yields fewer gains than resistance training. [Table 3]

Outcome	Pre-test (Mean)	Post-test (Mean)	Mean Difference	95% CI	p-value*
BBS (score)	19.0 ± 4.5	24.0 ± 5.0	5.0 ± 4.5	(2.8, 7.2)	<0.001
6MWT (meters)	375.2 ± 58.1	609.5 ± 63.6	233.8 ± 58.1	(202.1, 265.5)	<0.001

Outcome Measure	Group A (Non-Immersion VR) Post-test	Group B (Resistance training) Post-test	Mean Difference (A - B)	95% CI	p-value*	Cohen's d
BBS (score)	33.4 ± 5.4	24.0 ± 5.1	9.4 ± 4.5	(6.0, 12.8)	<0.001	1.78
6MWT (meters)	652.5 ± 73.4	609.0 ± 63.6	43.5 ± 63.6	(8.2, 78.8)	0.001	0.63

Table 4: Between-Group Comparison (Post-test Only) Effect size comparison (Cohen's d)

For BBS, Group A showed a very large effect size (d=3.55) compared to Group B (d=1.11). The between-group effect size for BBS was large (d=1.78), strongly favoring VR. For 6MWT, both groups showed very large within-group effects (d=4.92 and 4.02). The between-group effect for 6MWT was moderate (d=0.63), still favoring VR. Non-immersive VR training consistently produced

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larger effect sizes across all muscle segments. [Table 5]

Outcome Measure	Cohen's d (within-group) Group A	Cohen's d (within-group) Group B	Cohen's d (between-group post-test)
BBS	3.55 (Large)	1.11 (Large)	1.78 (Large)
6MWT	4.92 (Large)	4.02 (Large)	0.63 (Moderate)

Table 5: Effect Size Comparison

(Cohen's d)

Discussion

This study was conducted to evaluate the impact of VR-based training in subjects with sarcopenia, to improve muscle mass and balance. This study is designed comparatively at the end of the study according to scores obtained from BBS, 6MWT, and bio impedance analyzer.^{21,22} It's the most commonly used scale to observe the patient's muscle mass, endurance, balance, and risk of falls. Therefore, it was taken as an outcome measure. There is a significant difference between Group A, in which non-immersive VR was performed, and Group B, in which resistance training was performed. VR (virtual reality) creates an artificial environment with the possibility of patient interaction. This kind of experience leads to the development of cognitive and motor abilities, which usually positively affect the emotional state of the patient, increasing collaboration and compliance.^(23,24) Some recent studies have suggested that rehabilitation treatment intervention might be useful and effective in treating motion and cognitive.⁽²⁵⁾ Joo-hee Park et al. conducted a systematic review that analyzed 25 studies with a total of 937 participants to examine the effectiveness of VR balance exercise for older adults. The finding revealed that VR balance exercise effectively improved the participants' balance and gait.⁽²⁷⁾ In the present study, on analyzing between Group A and Group B, Group A showed significantly better outcomes than Group B for BBS, 6MWT, and all skeletal muscle segments ($p \leq 0.01$). The difference between Group A and Group B Group A had significantly higher BBS scores than Group B (33.4 vs. 24.0, $p < 0.001$). The mean difference in BBS was 9.4 points in favour of Group A. 6MWT distance was 43.5 meters greater in Group A (652.5 vs. 609.0, $p = 0.001$). Cohen's d values ranged from 0.63 to 1.78, indicating moderate to large effect sizes. Non-immersive VR was superior to resistance training for balance, endurance. The

results indicate that the non-immersive virtual reality resulted in significantly better subjective and objective outcomes in sarcopenia patients. Of the 10 studies included in the review, only Negrini et al. used NIVR in both treatment groups, with 10 sessions in the control group and 15 in the experimental group. These authors found a significant difference in balance and fall rates between groups but no significant difference in the Tunetli test.⁽²⁸⁾ The study conducted by Holden systematically reviewed the literature on intervention using VRT for balance and motor skills specifically for neurological disorders in individuals over 45 years of age. The author notes that for body balance, the three studies reported significant performance improvement.⁽²⁹⁾ Although there are certain limitations in the study, such as a small sample size, including subjects in the age group between 60 and 80 years of age, were considered for the study, the results cannot be generalized to individuals of a specific age. Subjects with sarcopenia who had systemic diseases like diabetes or high blood pressure have taken a longer duration to complete the protocol.

CONCLUSION

The present study showed that non-immersive virtual reality was found to be effective in improving physical performance, balance, and quality of life in the elderly. According to the statistical analysis, both groups (Group A and Group B) have significant improvement in the mean values. On comparing both groups, Group A has significant results in the mean value. Hence, it is concluded that non-immersive VR for 5 days a week had beneficial effects regarding self-reported clinical outcomes of endurance, balance, and fall risk. The virtual reality was a safe and efficacious outcome measure of sarcopenia.

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