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Original Article

Virtual Reality Training on Bone Mineral Density in Post Thyroidectomy Patients, Randomized Controlled Trial

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Abstract

Purpose: This trial's primary goal was to evaluate the effects of virtual reality (VR) training on post-thyroidectomy patients' bone mineral density (BMD).

Materials and Methods: Sixty subjects with affected BMD post-thyroidectomy engaged in the experiment. At random, participants were split evenly into two groups. All participants within the experiment were treated with traditional osteoporotic care including calcium intake (vitamin D calcium chewable tablets containing 100 IU of Vit D, 200 IU/day) and were instructed for regular walking outdoors every day for 30 min, in addition the experimental group (VR group) received virtual reality training. The training program lasted for three months and consisted of three sessions a week of 50 minutes each. Hip and lumbar spine T score and BMD were calculated through Dual-energy X-ray absorptiometry (DEXA). Evaluation information was documented for all subjects before the experiment and at the 12th week of therapy.

Results: While BMD improved for all subjects ($p < 0.001$), the VR group showed the greatest statistical increase, as the VR group's BMD of the lumbar spine (ES = 0.95), BMD of the hip joint (ES = 1.19), T score of the lumbar spine (ES = 0.82), and T score of the hip joint (ES = 0.78) recorded higher results than the controlled group **when** the groups were compared after treatment ($p < 0.05$).

Conclusion: Adding VR training in rehabilitation program for post thyroidectomy osteoporotic cases have significant benefits in BMD.

Keywords: Virtual reality (VR); Thyroidectomy; Bone mineral density (BMD); Dual-energy X-ray absorptiometry (DEXA).

Introduction:

Low bone mass is indicative of osteoporosis, which is characterized as having a T-score (bone mineral density) 2.5 standard deviations lower than that of young adults as determined by Dual-energy X-ray absorptiometry (DEXA). It arises when the processes of bone production and resorption are out of balance **(1).** The musculoskeletal (muscular and skeletal) system of the body is impacted by osteoporosis, a condition that causes the inner structure of bones to deteriorate and become more brittle and prone to breaking. Since osteoporosis typically shows no symptoms until an osteoporotic fracture happens, it is known as a silent illness **(2).**

By promoting the activation of new remodeling cycles and boosting the activity of osteoplastic and osteoclastic in cortical and trabecular bone, thyroid hormone plays a significant role in bone turnover. Following radioiodine treatment and a total or partial thyroidectomy, calcitonin secretion is significantly decreased, which causes osteopenia by disrupting bone resorption. Osteoporosis was also caused by excessive endogenous thyroxin and overzealous thyroid replacement therapy after thyroidectomy. Whether administering thyroid-stimulating hormone (TSH) suppression therapy or T4 therapy, it was found that individuals who had a subtotal thyroidectomy had significantly less BMD. The impact of total thyroidectomy on bone health has been linked to a diminished BMD with higher risk of osteoporosis, especially after menopause. After a total thyroidectomy, Thyroxine treatment is typically necessary to preserve euthyroid level or subclinical hyperthyroid status in order to avoid the recurrence of thyroid tumor **(3-7).**

The Xbox KinectTM, a video gaming controller from Microsoft, detects a user's movement using an infrared camera and sensor. No particular controller or handheld device is required, unlike other gaming gadgets. The user receives instant visual and aural feedback while their movements are recorded in real time. Because they incorporate whole body movements in an engaging and enjoyable way, Microsoft Xbox KinectTM video games provide promising rehabilitation and treatment possibilities **(8).**

According to research, regular exercise can effectively prevent fragility fractures, and promoting physical activities is a controllable agent in lowering the incidence of fracture. Other positive benefits on musculoskeletal health include preserving muscles strength and exercising to manage falling, as well as increasing bone mass. Few studies have been done on thyroid tumor survivors using levothyroxine replacement, and the majority of earlier research demonstrating the positive influences of regular exercising on bone mass and health was done on older individuals **(9,10).**

The long-term risk of osteoporosis was considerably elevated by thyroidectomy. Changes in postoperative bone density should be tracked in women, younger patients, individuals with comorbid conditions, and those on long-term thyroxin medication. There is not enough data to determine whether Kinect-based VR training is beneficial in osteoporotic cases following thyroidectomy. Examining the effectiveness of exercise using VR training on lumbar spine and femoral neck BMD in post thyroidectomy patients was the goal of the current trial.

Materials and Methods:

Design and setting

The Faculty of Physical Therapy's Ethical Committee at Cairo University approved this randomized controlled experimental trial. Every participant was chosen from the National Cancer Institute's outpatient clinics in Cairo, Egypt. Informed consent signatures were obtained from all patients, and the intervention was administered at an outpatient rehabilitation facility. Every procedure was performed in compliance with the Declaration of Helsinki's ethical guidelines.

Participants

In this study, 60 women with a diagnosis of post-thyroidectomy OP took part. A specialist orthopedist made the diagnosis for each patient. Participants’ age within the experiment were between 40 and 60 years, with a normal cognitive ability, and be able to comprehend and cooperate with the training, patients who underwent total or partial thyroidectomy and received hormonal therapy (2-5 years post-surgery) and have had evaluations of lower BMD of their lumbar spine and femoral neck (T-score < −1.1 SD). The following were the exclusion criteria: (1) people with severe hearing or vision impairments; (2) people with neurological conditions that impair balance; (3) people with lower extremities injuries or surgical history; (4) people having intense cardiovascular and cardiopulmonary conditions; (5) people having any kind of hip or waist fractures.

All trial's individuals completed a consent form after being informed about the trial's goals, advantages, and procedures. The intervention was carried out under a physiotherapist's supervision. Participants were split evenly into two groups and assigned at random. All trial participants received standard anti-osteoporosis medication and were instructed for regular walking outdoor every day for 30 min, in addition the experimental group (VR group) received Virtual reality sports games 3 days a week for twelve weeks.

Assessment

Bone mineral density (BMD) assessment: Dual-energy X-ray absorptiometry (DEXA) is essential for osteoporosis clinical practice, as DEXA is considered the golden and objective technical method in determining BMD at the lumbar spine and proximal femur.(11,12) The BMD and T-score of the subject's femoral neck and lumbar vertebrae were calculated through DEXA (Hologic Discovery W series). All subjects were tested for BMD prior to the experiment, and 3 months post interventions.

Treatment procedures:

Before beginning the experiment, each participant received education about the intervention procedures. Calcium was regularly administered to all individuals within the experiment as the primary anti-osteoporotic medication (vitamin D calcium chewable tablets containing 100 IU of Vit D, 200 IU/day). The Xbox 360 Kinect console (Microsoft Inc., Redmond, WA, USA) was utilized for training in the experimental group (VR group). The participants received four different Xbox games (River Rush, 20000 Leaks, Rally Ball, and Reflex Ridge). An LG screen of fifty inches was used to display the games. The field of play was 16 x 12 m. The interactive training program lasted for 3 months and consisted of three sessions of 50 minutes each, including 5 minutes of warm-up exercises, 40 minutes of VR games rehabilitation, and 5 minutes of structured exercises.

Sample size and Randomization:

Using data on BMD from a pilot study that involved five individuals in each group, the G*POWER statistical software (version 3.1.9.2; Franz Faul, Universitat Kiel, Germany) was conducted for sample size calculation. The findings indicated that 60 individuals were demanded for this experiment. Using $\alpha = 0.05$, power = 80%, effect size = 0.74, and allocation ratio 1:1, calculations were performed. Randomly individuals were allocated either to VR group (n = 30) or controlled group (n = 30). A physical therapist who didn't participate in the procedures for gathering data conducted the randomization process. The GraphPad software© (1:1 basic randomization) was used to generate a unique computer-generated random code for each patient, which was then hidden in a sealed envelope. Prior to the treatment, the physiotherapist received the sealed envelopes. A physiotherapist who was not included in the allocation steps gathered the results before the experiment and throughout the 12th week of treatment.

Statistical analysis

For individuals' demographic data comparison across groups, an unpaired t-test was used. The distribution of surgical types and menopause was compared between groups using the chi-squared test. The Shapiro-Wilk test was used to verify that data was normally distributed. To check for group homogeneity, Levene's test for homogeneity of variances was used. To examine the effects on lumbar and hip BMD within and across groups, a mixed design MANOVA was used. For the ensuing multiple comparison, post-hoc analyses were conducted using the Bonferroni correction. For every statistical test, the significance level was set at $p < 0.05$. The statistical package for social studies (SPSS) version 25 for Windows (IBM SPSS, Chicago, IL, USA) was conducted for trial's statistical analyses.

Results:

Participants' characteristics:

Table 1 shows the individuals' demographic data of the study and control groups. No discernible difference between groups in age, sex, BMI, surgery duration, menopause and type of surgery distribution ($p > 0.05$). **Figure 1** shows a flow diagram for participants at every stage of the trial.

Effect of intervention on lumbar and hip BMD: Intervention and time had significant interaction. ($F = 81.08$, $p = 0.001$, $\eta^2 = 0.86$). The main effect of time was significant ($F = 289.49$, $p = 0.001$, $\eta^2 = 0.96$). The main effect of intervention was significant ($F = 4.38$, $p = 0.004$, $\eta^2 = 0.24$).

Intra- group comparisons: Both the VR and control groups' BMD in the hip joint and lumbar spine increased significantly after treatment as compared to pre intervention ($p > 0.05$). Moreover, the VR and control groups' lumbar spine and hip joint T scores significantly increased after treatment as compared to pre intervention ($p > 0.05$) **(Table 2).**

Inter- groups comparisons: Prior to therapy, there weren't discernible differences between the groups ($p > 0.05$). The VR group's BMD of the lumbar spine (ES = 0.95), BMD of the hip joint (ES = 1.19), T score of the lumbar spine (ES = 0.63), and T score of the hip joint (ES = 0.78) recorded higher statistical results than the other group when groups were compared following the intervention ($p < 0.05$) **(Table 2).**

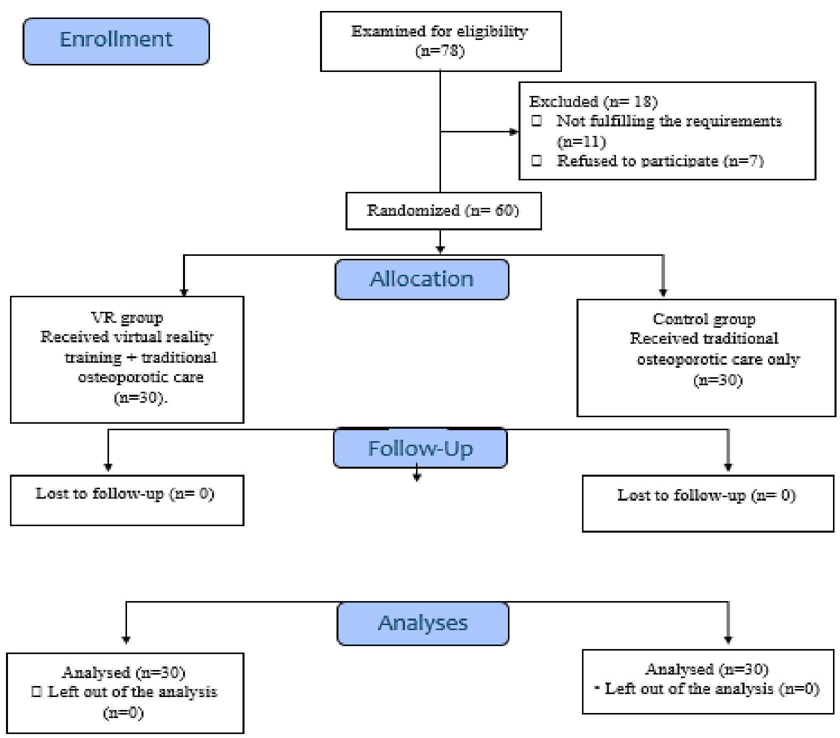

Figure1. CONSORT 2010 Flow Diagram

Table 1. Subject characteristics.

	VR group Mean ± SD	Control group Mean ± SD	MD	t- value	p-value
Age (years)	48.97 ± 5.71	48.90 ± 5.59	0.07	0.05	0.96
BMI (kg/m²)	25.57 ± 2.80	24.77 ± 3.39	0.8	1.01	0.32
Surgery duration (years)	3.57 ± 1.04	3.80 ± 0.95	-0.23	-0.92	0.36
Sex, n (%)					
Females	19 (63%)	21 (70%)		0.3	0.58
Males	11 (37%)	9 (30%)			
Menopause, n (%)					
Postmenopausal	9 (47%)	8 (38%)		$\chi2$ = 0.35	0.55
Premenopausal	10 (53%)	13 (62%)			
Type of surgery, n (%)					
Total	18 (60%)	17 (57%)		$\chi2$ = 0.07	0.79
Partial	**12 (40%)**	**13 (43%)**			

SD, standard deviation; MD, mean difference; $\chi2$, Chi squared value; p-value, level of significance

Table 2. Mean lumbar and hip BMD and T score prior to and following the intervention for the two groups:

BMD (g/cm2)	VR group Mean ±SD	Control group Mean ±SD	MD (95% CI)	P value	ES
Lumbar spine					
Pre treatment	0.88 ± 0.11	0.89 ± 0.09	-0.01 (-0.07: 0.04)	0.61	
Post treatment	1.01 ± 0.09	0.92 ± 0.10	0.09 (0.04: 0.14)	0.001	0.95
MD (95% CI)	-0.13 (-0.15: -0.12)	-0.03 (-0.04: -0.01)			
	p = 0.001	p = 0.001			
Hip joint					
Pre treatment	0.80 ± 0.08	0.81 ± 0.07	-0.01 (-0.04: 0.04)	0.88	
Post treatment	0.95 ± 0.11	0.83 ± 0.09	0.12 (0.06: 0.17)	0.001	1.19
MD (95% CI)	-0.15 (-0.16: -0.12)	-0.02 (-0.04: -0.002)			
	p = 0.001	p = 0.03			
T score					
Lumbar spine					
Pre treatment	-2.15 ± 0.74	-2.14 ± 0.72	-0.01 (-0.39: 0.36)	0.94	
Post treatment	-1.41 ± 0.74	-1.88 ± 0.76	0.47 (0.08: 0.86)	0.02	0.63
MD (95% CI)	-0.74 (-0.80: -0.67)	-0.26 (-0.32: -0.19)			
	p = 0.001	p = 0.001			
Hip joint					
Pre treatment	-2.10 ± 0.68	-2.22 ± 0.65	0.12 (-0.22: 0.47)	0.47	
Post treatment	-1.48 ± 0.70	-2.03 ± 0.71	0.55 (0.18: 0.91)	0.004	0.78
MD (95% CI)	-0.62 (-0.66: -0.58)	-0.19 (-0.24: -0.16)			
	p = 0.001	p = 0.001			

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

Discussion:

The purpose of the current trial was to assess how exercise using virtual reality training improved the BMD of the lumbar spine and femoral neck in post thyroidectomy cases as the outcome's measurements showed greater improvements in lumbar and hip T scores and BMD in the VR group compared to the controlled group ($p < 0.05$). According to the results, exercising using virtual reality training improved patients' BMD more than traditional care did.

The relationship between constant training and bone mass and health has been assessed in numerous earlier studies. In contrast to the gentle stretching exercise utilized in the control group for 15 minutes, a strengthening exercises program lasting half an hour, two times per week, was found to substantially improve BMD in a postmenopausal women's exercise-based randomized clinical study **(13).** According to exercise research conducted on older men, BMD rose in direct proportion to exercise intensity. **(14)**. **Kim et al 2023,** reported that individuals who frequently exercised before and after a surgical thyroidectomy had a significantly lower incidence of fracture than those who were sedentary, and suggested that maintenance of physical activities is essential for fractures prevention in thyroid tumor cases. Additionally, starting regular exercises should be advised for individuals who lead sedentary lives and have thyroidectomy **(9).** Another alternative study showed that after 12 months of training, the VR group's lumbar spine and femoral neck BMD rose dramatically. Nevertheless, following the 6-month training, the control group's lumbar spine and femoral neck BMD did not considerably improve **(15).** The 12-week virtual reality training trial examined BMD in postmenopausal women with osteoporosis, and reported a substantial increase in BMD and bone health with improved quality of life, **(16)** moreover, similar study with longer duration for 24 weeks showed improved BMD with decreased risk of fracture **(17).**

The study's outcomes come in agreement with the aforementioned studies, the possible explanation for these obvious outcomes were the impact of regular physical training on bone health and BMD as Increased physical activity has been found in studies to improve metabolism and raise the bone metabolic rate in older people. These mechanisms then increase bone formation and raise bone mineral density (BMD) by encouraging osteoblast proliferation and decreasing osteoclast numbers. Moreover, exosomes from skeletal muscle can stop bone loss. Increased exosome production during skeletal muscle contraction during exercise training alleviates osteoporosis symptoms **(18).**

The progress of the VR group in this study was anticipated and may be linked to a few key interactive video games (IVG) traits. IVGs allow bodily movements that are similar to those made in the real world, IVGs promote practice in a dynamic, safe, and realistic setting. IVG activities may contain essential components for effectively regaining motor skills, such as time management and specialized environmental experiences, which are difficult to achieve in the actual world; ongoing feedback and motivation boosted by the IVGs' vying nature; and modifications to the difficulty of reaching a certain level of execution. For instance, the willingness of the patient and the lack of satisfaction and success in such procedures may limit the ability to conduct practical tasks in a standard therapeutic environment. On the other hand, game-based exercise provides a variety of scenarios where participants are not at risk for errors, and the standards for achieving execution can be adjusted depending on the patient's ability **(19).**

Bone mineralization, calcium absorption, and cell activity can all be enhanced by creating a scientific aerobic exercise rehabilitation program and regularly measuring exercise volume and capability. To the author's knowledge, none of the previous studies have examined the impacts of VR training in Osteoporotic cases caused by thyroidectomy. Research is desperately needed to find novel ways to improve BMD levels and slow the progression of osteoporosis in Post thyroidectomy patients as VR technology is one of the techniques that can improve adherence by encouraging people to work out in a fun and interesting way.

This trial reported obvious improvement in BMD measured by objective DEXA modality, however there were some limitations in this trial as it was difficult to follow up after the trial, the long-term effects of treatment were not examined. Therefore, it is recommended that future trials analyze VR training with patients' follow-up. Also, absence of quality-of-life assessment is another limitation that should be considered in future trials. Additionally, awareness-building about the prevention, early detection, and prompt treatment of osteoporosis and osteopenia after thyroidectomy is crucial in order to lower the risk of fracture and associated costs. Therefore, Evaluations of early physical therapy interventions should be carried out to prevent decreased BMD after thyroidectomy.

Conclusion:

Focusing on VR training can be very beneficial in treating osteoporotic cases as a rehabilitation exercise program including VR training significantly improved bone health following thyroidectomy, which was evident in patients' BMD.

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Data Availability Statement: The datasets generated and analyzed during the current study can be made available from the corresponding author upon reasonable request and after obtaining necessary ethical approvals 6 months after publication.

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Conflicts of Interest: Regarding this research, no potential conflicts of interest were disclosed.

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