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Original Article

Virtual Reality Programs and Motor Imagery Training Reduce Plantar Pressure and Depression in Isolated Older Adults

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SUMMARY

Background: The purpose of this study was to measure the level of plantar pressure and depression in isolated older adults. We also proposed virtual reality program (VR) and motor imagery training (MIT) as interventions to prevent falls.
Methods: This study was conducted with 34 healthy older individuals admitted to a convalescent hospital. The participants were divided into three groups: virtual reality group (VRG), motor imagery training group (MIG), and control group (CG). The evaluation period was six weeks, after which an eight-week follow-up study was conducted. The Gaitview® AFA-50 system was used to measure the difference in the ratio between static plantar pressure and dynamic plantar pressure. The degree of depression was measured using the Geriatric Depression Scale.
Result: In the interaction between the group and period, there were significant differences in the left and right (L/R) static plantar pressure (p = .044), anterior and posterior (A/P) static plantar pressure (p = .000), L/R dynamic plantar pressure (p = .008), A/P dynamic plantar pressure (p = .031), and depression (p = .000). Unlike the VRG, there was no significant difference in the MIG in the comparison between the L/R static plantar pressure pre-test and post-test in time. However, compared to the post-test, follow-up showed significant results (d = -0.9, 95% CI, -1.8 to -0.1), confirming the positive effect (p < .05).
Conclusion: VR and MIT are effective in improving balance and depression in older individuals isolated from convalescent hospitals. Therefore, VR and MIT are recommended as alternatives to physical activity for isolated older individuals.

1. Introduction

Isolation measures are recommended to minimize the risk of COVID-19 infection, which can be fatal to older adults.[1] However, reduced physical activity due to social isolation of older adults may result in physical and mental frailty.[2] These facts raise concerns regarding an increase in falls as a negative result of isolation.[3]

The plantar pressure distribution, one of the evaluations of balance and gait, is proposed as an indicator to predict the risk of falls.[4] A decrease in plantar sensitivity in older adults occurs predominantly at the heel, shifting plantar pressure to the midfoot and forefoot as a strategy to maintain balance.[5] It is important to reduce plantar pressure as plantar stress causes persistent pain in the feet of older individuals and increases the risk of falling.[6]

Gait and balance training for isolated older adults should include psychological factors.[7] The relationship between depression and falls has a complex bidirectional mechanism, and depression is an independent risk factor for falls.[8]

Nintendo Wii, used in virtual reality programs (VR), is effective in improving balance and relieving depression in older adults.[9,10] Another study recommends motor image training (MIT) to improve balance and gait ability in older adults.[11] Motor imagery (MI) is an imagining concept without physical movement used to mentally simulate behavior.[12] MIT does not incur any cost and can enhance a subject's arousal and concentration and improve performance.[13]

However, despite these advantages, studies on plantar pressure and depression on the effects of VR and MIT in isolated older adults are insufficient. Therefore, we proposed VR and MIT as a method to prevent falls in older isolated individuals.

2. Materials and methods

2.1. Study design and participants

This study was conducted for eight weeks from January to February 2021. A total of 36 older adults aged 65 years or older who were admitted to a convalescence hospital were recruited. The final 34 individuals participated in the study (Figure 1). The sample size of the study subjects was determined using the G*power 3.1 program.[14] The calculation was made by considering an alpha level of 5%, effect size of 0.8, and power of 95%.[15,16] Subjects were extracted by random sampling. The sampling was conducted with a single-blind test. The subjects were provided with a sufficient explanation regarding the purpose and experimental method of this study prior to participating. They provided voluntary written consent.

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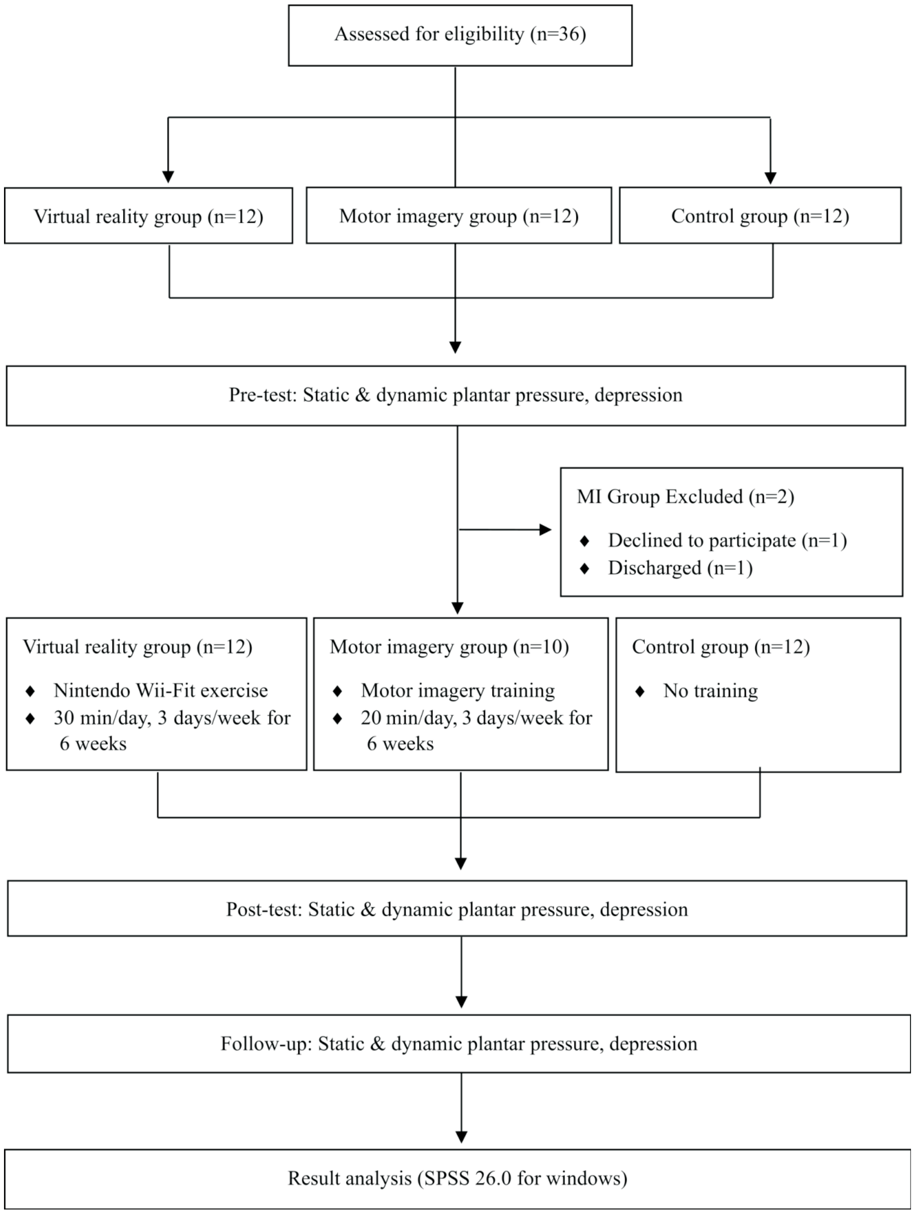

Figure 1. Flow diagram of the study design.

The diagnosis name and specific details at the time of hospitalization of the patients are as follows. The subjects of this study were those who were not hospitalized for gait-related rehabilitation treatment. (1) Patients who have completed chemotherapy after a cancer diagnosis by a specialist and have been hospitalized for treatment to prevent recurrence. Patients had no diagnosed cancer tissue on radiographic examination after six months (breast cancer, colorectal cancer, ovarian cancer, stomach cancer, uterine cancer); (2) patients hospitalized for medical treatment after aspiration pneumonia due to age related dysphagia.

The criteria for selecting the study subjects were as follows: (1) Korean mini-mental status examination (MMSE-K) score of 24 or higher; (2) vividness of movement imagery questionnaire (VMIQ) score of 2.26 or less; (3) no vestibular function, visual, or hearing impairments; (4) ability to ambulate independently; (5) absence of musculoskeletal lesions and no history of surgery within the last six months; (6) not taking drugs that affect balance; (7) not performing regular exercise that would affect the experiment in the last six months; (8) isolated for at least three months; and (9) no neurological disorders (stroke, dementia, or Parkinson's disease).

The virtual reality group (VRG) performed the training 30 minutes a day, three times per week for six weeks. The MIG performed the training 20 minutes a day, three times per week for six weeks. A follow-up investigation was conducted at week eight (two weeks later) to determine the effects of intergroup treatment interventions (Figure 1). The primary outcome was plantar pressure and the secondary outcome was depression. This study was approved by the Institutional Review Board (IRB) of Nambu University, Gwangju City, South Korea (NBU-IRB-1041478-2017-HR-016) and was conducted in accordance with the ethical standards of the Declaration of Helsinki (Clinical trials registration number: KCT0006053).

2.2. Training methods and measurement tools

The VR implemented a game program composed of Wii Fit, a Wii exclusive software released by Nintendo (Nintendo Inc., Japan). Wii Balance Board (WBB) and a Wii remote control were used. The VR was conducted using a 30-minute program with five minutes of warm-up stretching, 20 minutes of the exercise program, and five minutes of rest. The program consists of "balance ski", "table tilt", "jogging", and "rhythm step", which aimed at improving balance and gait. For consistency with the MIT recommended training time, the main training was set for 20 minutes.[17,18] The program was conducted under the supervision of qualified physical therapists with more than five years of experience.

For the MIT, a stroke MIT intervention of a previous study, which included both motor-sensory imagery training and visual imagery training, was modified and adopted for the older subjects in this study.[19] The subjects imagined the therapist's verbal instructions. A relaxation state of 150 s was included before and after the initiation of MIT. The primary training was performed for 15 min. A recommended training time of 20 min was adopted for optimal efficiency.[20]

VMIQ is a tool to evaluate the degree of motion imagination (r = .76).[21] VMIQ consists of 24 items. The most vivid imagination is scored as 1 point. In the case where an action cannot be imagined at all it is measured at five points. Those with an average VMIQ score of 2.26 or less were selected as subjects as they displayed a normal level of imagination.[22]

Plantar pressure was measured using a Gaitview AFA-50 system (AlFOOTs, Seoul, Republic of Korea). This system has proven its' reliability as a plantar pressure system in previous studies.[23] The measured value of the plantar pressure is provided by numerically determining the ratio of the left and right (L/R) and anterior and posterior (A/P). It becomes 50:50 with the balance of the foot located in the center. For the static plantar pressure measurement, the subjects were instructed to gaze at a marked point in front of them. Both feet were measured by holding them in a static position for 30 s (Figure 2). Dynamic plantar pressure measurements were the plantar pressure ratio of the left and right feet was measured by stepping and crossing the meter one foot at a time (Figure 3).

The standard Korean version of the 30-item Geriatric Depression Scale was used in this study (r = .94).[24] The scale is a self-report instrument that uses a "yes/no" format. The cut-off score was 17 points. The score ranged from 0 to 30, with a lower score indicating a lower degree of depression.

2.3. Data analysis

Data analysis of the results of this study was performed using SPSS (version 26.0) for Windows. The mean and standard deviation, which are descriptive statistics for each measured variable, were calculated. The general characteristics of the subjects were analyzed using one-way analysis of variance (ANOVA). Two-way repeated measures ANOVA was used to compare the changes according to the experimental period between the pre-test, post-test, and follow-up tests between each group. One-way ANOVA and one-way repeated ANOVA measures were used when the main effects of the group and the experimental period, respectively, were statistically significant. A post-test for statistically significant differences was performed using the Scheffe test, and the statistical significance level (α) was set at .05.

3. Results

3.1. General characteristics of the study subjects

The total number of subjects included in the study was 34. The VRG was comprised of 12 individuals, the MIG was comprised of ten individuals, and the CG was comprised of 12 individuals. No significant difference was found between the groups in homogeneity and normality tests (p > .05) (Table 1).

3.2. Static and dynamic plantar pressure ratios

The L/R (p = .044) and A/P (p = .000) static plantar pressure ratios showed a statistically significant difference in the interaction effect of time × group. A significant difference was observed in the main effect according to the experimental period (L/R, p = .001) (A/P, p = .000). In the L/R static plantar pressure, the VRG showed a significant difference in all variables according to the period (p < .05). However, the MIG showed a significant difference only in the comparison between the post-test and follow-up (d = -0.9, 95% CI, -1.8 to -0.1). The L/R (p = .008) and A/P (p = .031) dynamic plantar pressure ratios showed a statistically significant difference in the interaction effect of time × group.

A significant difference was observed in the main effect, within the experimental period (p = .000). There were significant differences in the VRG, except for the pre- and post-test (p = .304) of the L/R dynamic plantar pressure ratio (p < .05). The MIG was significantly different in the post-test and follow-up of the L/R static plantar pressure ratio, in the pre- and post-test, and in the post-test and follow-up of the A/P. The L/R dynamic plantar pressure ratio and the A/P were significantly different in the pre- and post-test, as well as in the post-test and follow-up (p < .05) (Table 2, Figure 4).

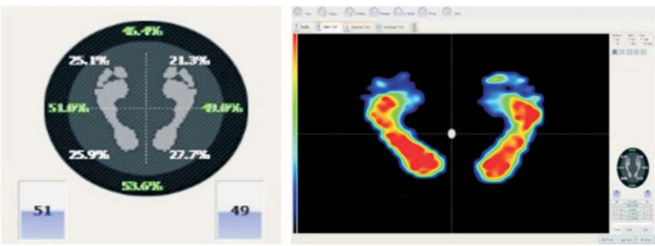

Figure 2. Static plantar pressure.

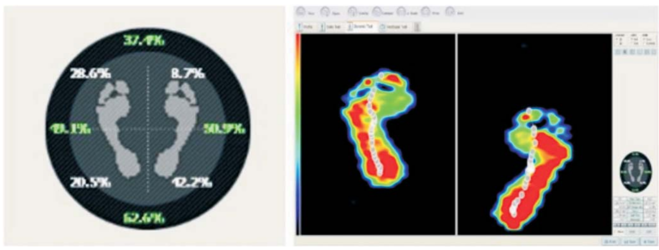

Figure 3. Dynamic plantar pressure.

Table 1
Characteristics of the participants (N = 34).

Groups	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	MMSE-K	VMIQ
VRG (n = 12)	75.75 ± 10.15	157.17 ± 9.48	58.67 ± 12.15	23.82 ± 5.23	26.17 ± 1.53	1.60 ± 0.33
MIG (n = 10)	83.10 ± 5.24	156.20 ± 10.49	54.70 ± 9.15	21.88 ± 2.73	25.60 ± 1.90	1.89 ± 0.31
CG (n = 12)	80.75 ± 6.03	157.33 ± 10.53	59.75 ± 9.98	24.90 ± 4.30	25.83 ± 1.59	1.76 ± 0.34
F	2.753	.039	.672	1.366	.325	2.207
p	.079	.962	.518	.270	.725	.127

* p <. 05; mean ± standard deviation; BMI, body mass index; MMSE-K, Korean Mini-Mental State Examination; VMIQ, Vividness of movement imagery questionnaire.

3.3. Depression

A statistically significant difference was found in the interaction effect of time × group (p = .000). Significant differences were also noted in the main effects between the groups and the experimental period (p = .000). As a result of verifying the effect by group, there were significant differences in the VRG and CG, MIG and CG in post-test ($p < .05$). Regarding the effects in time, the VRG was significantly different at all time points ($p < .05$). The MIG was significantly different in the pre- and post-test, as well as in the pre-test and follow-up ($p < .05$) (Table 2, Figure 4).

4. Discussion

This study was conducted to confirm that the application of VR and MIT reduce plantar pressure and depression and contribute to the prevention of falls in isolated older individuals.

This study resulted in a reduction in the ratio of L/R and A/P plantar pressures in both the VR and the MIT. In a previous study, the A/P static, Berg Balance Scale (BBS), as well as static and dynamic balance control scores using the WBB were significantly improved by applying the VR to older adults. These findings are consistent with the results of this study.[25,26] Based on a systematic review,[27] this study agrees that Wii is an effective virtual reality approach for balance training in older adults without cognitive or neurological disorders. MIT was suggested to be an alternative means of improving balance and gait in older adults without neurological problems.[28] BBS, center of pressure (COP)-based static balance, and the Timed Up and Go Test (TUG) improved when MIT was used.[29] It was applied based on the actual environment of older adults who had experienced a fall. That is, our results suggest that both trainings have a positive effect on balance and gait stability in older adults.

Another major result was that there was no significant difference in the L/R static plantar pressure in the pre- and post-test concerning the MIT time point. However, there was a significant difference between the post-test and follow-up. This indicates that the MIT requires a longer period of intervention. Therefore, although the VR is more effective than MIT according to the primary effect of time, the application of MIT as an alternative training for older adults who have difficulty with ambulation may be highly beneficial.[30]

In this study, compared to the CG's depression score, the primary effects and interactions of the two trainings were significantly different according to time and group. The CG, who had no intervention, showed a continuous increase in depression. A study in which the VR was applied to older adults with depression showed a decrease in depression in these patients.[25,31] It was thought that the training had positive results by providing recreation to the older adults. This is because VR not only increase physical activity in depressed individuals, but they are also useful for self-management of negative emotions.[32]

Moreover, a study that introduced meditation such as MIT as a psychological intervention in individuals who were isolated due to COVID-19 showed a positive effect by offsetting negative thoughts.[33]

Table 2
A comparison of static, dynamic plantar pressure (unit: %) and depression (unit: score) difference in proportions during the intervention on each group.

Variables	Group	Pre-test M ± SD	Post-test M ± SD	Follow-up M ± SD	Mean difference (95% CI) Effect size (d)			F(p)		
					Pre-test compared with post-test	Pre-test compared with follow-up	Post-test compared with follow-up	Group	Time	Group × Time
L/R static plantar pressure	VRG	4.1 ± 2.7	1.6 ± 1.4	3.1 ± 1.9	2.5 (1.2 to 3.7)[b] 1.15	1.0 (0.2 to 1.9)[b] 0.44	-1.5 (-2.2 to -0.7)[b] -0.87	.527 (.596)	9.806 (.001*)	2.612 (.044*)
	MIG	4.1 ± 4.0	2.4 ± 2.6	3.3 ± 3.2	1.7 (0.0 to 3.4) 0.49	0.7 (-0.2 to 1.5) 0.20	-0.9 (-1.8 to -0.1)[b] -0.33			
	CG	4.0 ± 3.8	4.1 ± 3.7	4.3 ± 3.8	-0.2 (-0.2 to -0.2) 0.00	-0.3 (-0.3 to -0.3) -0.08	-0.2 (-0.2 to -0.2) -0.04			
A/P static plantar pressure	VRG	9.0 ± 3.6	3.6 ± 3.4	6.2 ± 3.4	5.4 (3.4 to 7.4)[b] 1.55	2.9 (1.3 to 4.4)[b] 0.83	-2.5 (-4.3 to -0.8)[b] -0.74	.395 (.677)	25.650 (.000*)	7.533 (.000*)
	MIG	7.0 ± 5.4	4.1 ± 4.1	6.2 ± 3.7	2.9 (0.4 to 5.4)[b] 0.60	0.8 (-1.4 to 2.9) 0.17	-2.1 (-3.2 to -1.0)[b] -0.54			
	CG	7.5 ± 6.2	7.2 ± 5.8	7.6 ± 5.7	0.3 (-0.4 to 1.0) 0.05	-0.1 (-0.6 to 0.4) -0.01	-0.3 (-1.0 to 0.3) -0.06			
L/R dynamic plantar pressure	VRG	3.6 ± 2.4	1.4 ± 1.3	2.9 ± 1.8	2.2 (0.9 to 3.5) 1.12	0.8 (-0.8 to 2.4)[b] 0.37	-1.4 (-2.2 to -0.6)[b] -0.91	.043 (.958)	9.777 (.000*)	3.761 (.008*)
	MIG	3.4 ± 2.2	1.4 ± 1.3	2.8 ± 1.8	2.0 (0.6 to 3.3)[b] 1.07	0.6 (0.0 to 1.3) 0.31	-1.3 (-2.3 to -0.4)[b] -0.86			
	CG	2.5 ± 2.1	2.8 ± 1.8	2.9 ± 2.2	-0.3 (-1.5 to 0.8) -0.17	-0.5 (-1.5 to 0.5) -0.22	-0.1 (-1.2 to 0.9) -0.07			
A/P dynamic plantar pressure	VRG	9.5 ± 5.2	4.9 ± 2.9	6.8 ± 3.6	4.6 (1.7 to 7.4)[b] 1.08	2.7 (0.9 to 4.5)[b] 0.60	-1.9 (-3.4 to -0.3)[b] -0.58	1.075 (.354)	10.061 (.000*)	2.848 (.031*)
	MIG	7.3 ± 4.6	5.2 ± 3.5	6.5 ± 4.4	2.1 (0.3 to 4.0)[b] 0.52	0.8 (-0.2 to 1.8) 0.17	-1.4 (-2.6 to -0.1)[b] -0.34			
	CG	8.7 ± 4.8	8.5 ± 4.4	8.8 ± 4.4	0.5 (-0.1 to 1.1) 0.11	0.2 (-0.4 to 0.7) 0.04	-0.3 (-1.1 to 0.5) -0.07			
Depression	VRG	11.5 ± 4.0	4.9 ± 2.0[a]	7.3 ± 2.4[a]	6.6 (4.6 to 8.5)[b] 2.09	4.3 (2.9 to 5.6)[b] 1.29	-2.3 (-3.4 to -1.3)[b] -1.07	8.743 (.001*)	45.526 (.000*)	18.966 (.000*)
	MIG	10.6 ± 4.6	7.1 ± 3.4[a]	8.4 ± 3.2[a]	3.5 (2.1 to 4.9)[b] 0.87	2.2 (0.2 to 4.2)[b] 0.56	-1.3 (-2.6 to 0.0) -0.39			
	CG	13.2 ± 4.3	13.4 ± 4.2	14.0 ± 4.6	-0.3 (-0.6 to 0.1) -0.06	-0.8 (-1.9 to 0.2) -0.19	-0.6 (-1.6 to -0.4) -0.13			

* p <. 05. [a] Comparison with control group through post-hoc analysis ($p < .05$); [b] effect over time through post-hoc analysis ($p < .05$). CI, confidence interval; M ± SD, mean ± standard deviation.

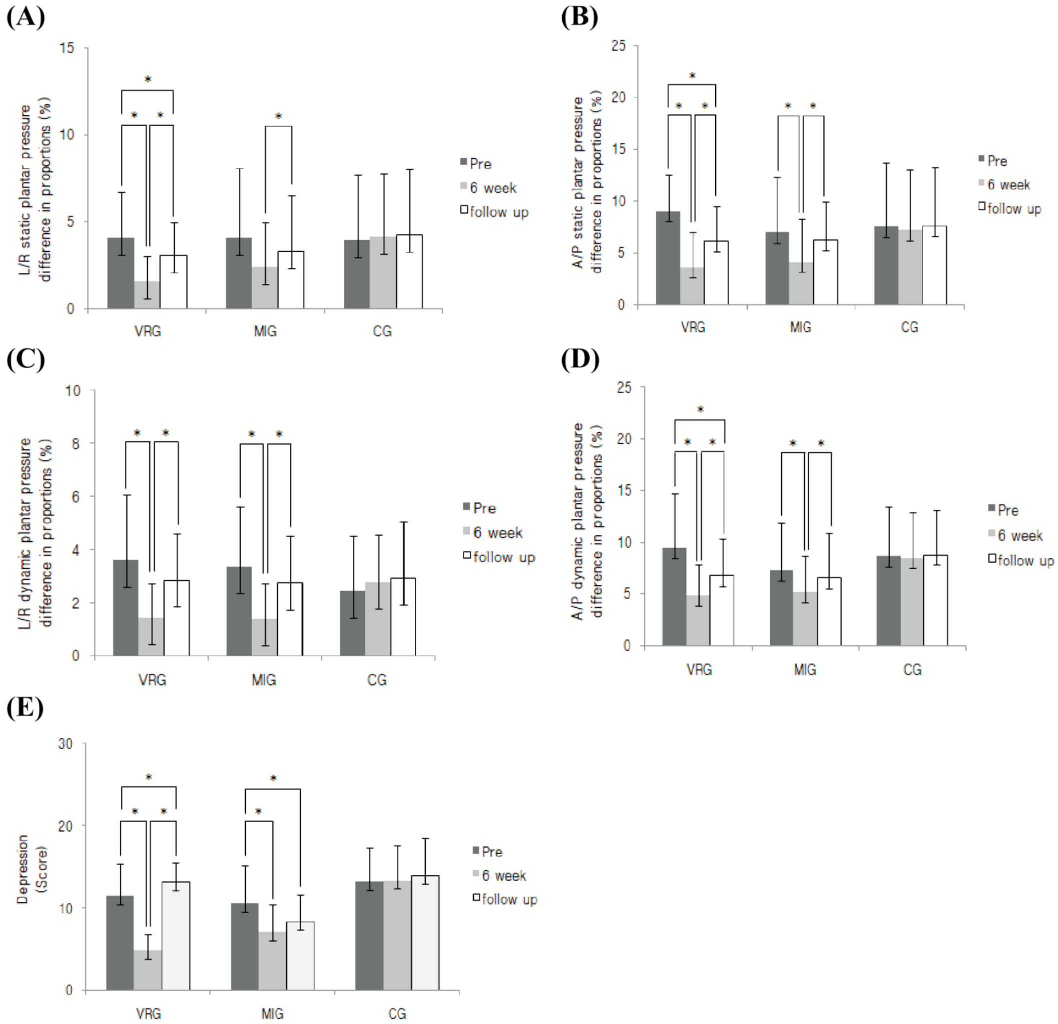

Figure 4. Plantar pressure difference and depression comparison according to period. (A) L/R static plantar pressure; (B) A/P static plantar pressure; (C) L/R dynamic plantar pressure; (D) A/P dynamic plantar pressure; (E) Depression.

In addition, in a study that conducted mental imagery like MI on depressed adults was effective in improving anhedonia, a major symptom of depression.[34] MI is a potential tool in the planning and preparation process.[35] Management is essential as the onset of depression results in a selective decrease in actual motor functioning.[35] Therefore, it is important to prevent depression in isolated older adults. These individuals require psychological stability and enjoyable physical activity. VR and MIT should continue during the quarantine period.

This study has some limitations. First, due to the unavoidable pandemic, the number of participating subjects was small. Moreover, since the older convalescence hospital patients were hospitalized due to various symptoms of disease and underlying diseases, it was not possible to proceed with the experiment according to the classification of the diseases. Second, it was difficult to directly compare the results with previous studies. This is because there are few studies that suggest a reference value or a comparison between groups in relation to the study of plantar pressure in older adults for both trainings. Therefore, further multifaceted studies on plantar pressure and depression in older adults using VR and MIT are required.

5. Conclusions

The results of this study showed that the VR and MIT induce an appropriate weight distribution on the soles of feet of isolated older adults. They are also effective in improving depression. These interventions can assist in preventing falls in isolated older adults. Therefore, VR and MIT are recommended as alternatives to physical activity during quarantine for older individuals.

Acknowledgement

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Conflict of interest

The authors declare no conflicts of interest.

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