Impact of Proprioceptive Training using Augmented Reality on Flexibility and Balance in Young Adults

Jae-Won Lee, Daekook M. Nekar, Jae-Ho Yu
Department of Physical Therapy, Sunmoon University
naresa@sunmoon.ac.kr

증강 현실을 사용한 고유 감각 훈련이 젊은 성인의 유연성과 균형에 미치는 영향

이재원, 네칼 대국, 유재호
선문대학교 물리치료학과

Abstract

This study investigates whether Augmented Reality (AR)-based interventions can be as effective as physical therapists (PT) regarding balance, positioning sensation, and flexibility. A sample of 39 regular people who voluntarily participated in this study were randomly distributed into two groups. Then AR was applied in the experimental group and PT was applied in the control group. Variables were measured by Tetrax(static balance), Y-balance test(dynamic balance), CSMI(proprioception), and sit and reach test(flexibility). All measurements were analyzed using paired t-test and independent t-test. The exercise program of this study improved the stability index (ST) of the static balance in both groups after the intervention, and there was a significant difference ($p < 0.05$) at normal eye close (NC) and Pillow with eye close (PC) positions. Moreover, regarding the case of dynamic balance, there were significant differences in AR and PT groups to reach in all directions ($p < 0.05$). In the case of positioning sensation, there was no significant difference in both groups ($p > 0.05$), and there was a significant difference in flexibility. ($p < 0.05$). When comparing the two groups, there was no significant difference in all categories ($p > 0.05$). As a result, AR can be considered an effective form of therapy and can be selected according to individual conditions.

1. Introduction

Augmented reality is a computer technology that brings digital information into reality and makes it seem as if it were in its original environment [1]. This is a different concept from virtual reality (VR) because it exists and interacts in time and space like reality. Furthermore, advances in science and technology have made digital information, reality, and interaction between users smoothers. As a result, research is being conducted in various fields such as games and medical care, and it is affecting society as a whole [2].

In particular, active research is underway in the medical field. The most frequently studied subjects in diagnosis, surgery, rehabilitation, education, and training, including pain, stroke, Parkinson's disease, Alzheimer's disease, and degenerative neuropathy. This medical condition reduces balance and increases the risk of falling due to instability. However, continuous research is needed to determine whether AR-based rehabilitation is as effective as a physical therapist (PT)'s rehabilitation [3]. Many studies are underway on whether AR-based rehabilitation can achieve the same effect as a PT. It is well-known that proprioceptive exercise program that includes relaxation exercises such as stretching, slow walking, during warm-up, and cool down exercises, greatly improve balance, muscle strength, and flexibility in old people and sitting women studies. However, there was no study to confirm the improvement of flexibility by applying both Swiss Ball and AR-based proprioceptive exercise. Therefore, the purpose of the present study was to assess the effects of AR on flexibility and balance in healthy young adults.

2. Materials and Methods

2.1 Participants

This study was conducted on forty-two healthy adults. The participants sample size was obtained using the G-power 3.1 software. Participants were recruited through the local community website and university announcements. Explanation regarding the purpose and method of the study was provided to participants and

those who volunteered to fill out a written consent form were included after eligibility assessment. Inclusion criteria was those who did not have a history of surgery or orthopedic surgery in the last six months. Those with not pain limiting current exercise performances and with no reasons that could negatively affect the research process. The exclusion criteria was those with neurological disease, cognitive damage, vestibular organ abnormalities, those who are taking drugs related to muscle strength and mental illness, and those who can no longer participate in the experiment due to COVID-19 during the experiment.

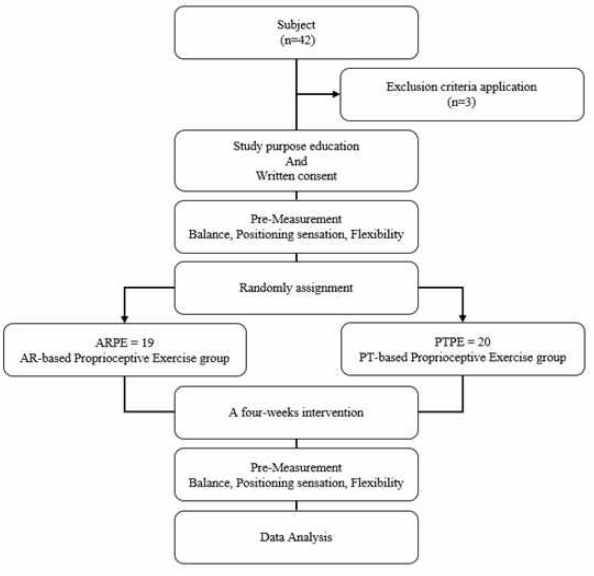
[Table 1] General characteristics of participants

Variables	ARPE (n = 19)	PTPE (n = 20)
Age(years)	22.67±2.90	21.76±1.41
Height(cm)	166.43±22.12	166.91±19.24
Weight (Kg)	78.33±30.31	64.26±14.29

Values expressed as mean ± standard deviation, ARPE: augmented reality proprioceptive exercise, PTPE: physical therapy proprioceptive exercise

2.2. Study procedure

All participants were randomly divided into augmented reality-based proprioceptive exercise group (ARPE) and proprioceptive exercise group (PTPE) conducted by physical therapists. Measurement were done twice before and after intervention for flexibility, dynamic ans static balance. The Proprioceptive exercise program lasts four weeks, twice a week with 35 minutes per session. In the first two weeks, two sets were repeated ten times, and three sets were repeated twelve times for the rest of the week. The study procedure is shown in [Figure 1].



[Fig. 1] Research flow diagram

2.2. Outcome measurement

2.2.1 Flexibility

Flexibility is measured by sit and reach tests. The subject sits with their legs straight and puts their bare feet on the side of the inspection tool. subject gathers their hands after one practice, slowly bends forward, pushes the measuring instrument, maintains it for a short period, and returns to its original position. The maximum reach was measured by reading the scale of the tip of the subject's 3rd finger and the edge of the measuring instrument.

2.2.2. Balance

Static balance is measured using Tetrax (Tetra-ataxiometric posturography, Israel). For the measurement, normal eye open (NO), normal eye close (NC), Pillow with eye open (PO), and Pillow with eye close (PC) were measured four times in order, and the unstable ground was prepared using a filler between the foot and the footplate. stability index (ST) and weight distribution index (WDI) were used for evaluation.

Dynamic balance measures the functional reach distance of the lower extremity with a Y-balance test. the subject placed their hand on the pelvis, stood on one foot on the central axis, and measured the value by pushing out the measuring instrument located in the anterior, posteromedial, and posterolateral with the opposite foot. Subjects practiced once in each direction and measured three times in each direction. Finally, the maximum reach was measured by reading the scale where the tip of the big toe and the edge of the measuring instrument meet.

2.3. Interventions

ARPE follows augmented reality (AR), and PTPE follows the exercise program conducted by the physical therapist. Before the experiment, the researcher explained to all participants about light education and research procedures for exercise programs and suggested that they wear comfortable clothes for accurate and safe experiments. The researcher checked the laboratory environment at all times and maintained it under the same conditions as safe.

2.4. Data analysis

In this study, descriptive statistics were used to evaluate general characteristics, and the mean (M) and standard deviation (SD) of each variable were calculated. All statistical analyses used 'IBM SPSS 20.0 Statistical Software'. Paired t-test was used for pre-post variables within each group, and independent t-test was used to compare the results between the two groups. The

statistical significance level was set as $p<0.05$.

3. Results

3.1. Flexibility

Regarding the result of flexibility, there was no significant difference between groups as a result of pre-measurement ($p>0.05$). After the intervention was applied, a significant difference was confirmed within the two groups ($p<0.05$), there was no significant difference between the two groups as a result of post-measurement ($p>0.05$).

Table 2. Comparison of flexibility within and between groups

	ARPE (n = 20)	PTPE (n = 20)	t
Pre-test	9.96±9.35	7.90±13.69	0.552
Post-test	12.63±9.10	12.08±10.90	0.170
t	-2.996**	-3.911**	

*p<.05, **p<.01, mean ± standard deviation, ARPE: augmented reality proprioceptive exercise, PTPE: physical therapy proprioceptive exercise

3.2. Balance

As a result of the static balance, there was no significant difference between groups in ST's and WDI's NO, NC, PO, PC ($p>0.05$). For the pre-post measurement of each group, there was no significant difference in all postures of WDI, NO, PO of ST in both groups ($p>0.05$), but a significant difference between ST's PC and NC ($p<0.05$).

Table 3. Comparison of static balance within and between the groups

			Pre-test	Post-test	t
ARPE	WDI	NO	6.02±2.64	6.46±2.87	-0.636
		NC	4.55±2.17	5.45±2.96	-1.778
		PO	5.02±1.99	4.77±2.86	0.610
		PC	4.47±2.56	4.70±2.16	-0.457
	ST	NO	12.53±2.96	13.33±3.54	-1.141
		NC	18.21±5.62	16.34±5.02	2.593*
		PO	16.88±4.27	14.99±3.07	2.026
		PC	28.67±6.67	26.03±5.22	2.252*
PTPE	WDI	NO	6.32±3.74	6.27±2.90	0.058
		NC	5.67±3.25	6.16±2.26	-0.803
		PO	5.40±3.37	4.77±2.74	0.998
		PC	5.23±3.31	5.06±2.59	0.333
	ST	NO	14.18±4.72	14.85±5.42	-0.825
		NC	19.41±8.22	15.61±4.60	3.249**
		PO	15.39±6.09	14.45±4.44	1.384
		PC	29.90±11.51	24.42±7.23	3.526**

*p<.05, **p<.01, mean ± standard deviation, ARPE: augmented reality proprioceptive exercise, PTPE: physical therapy proprioceptive exercise, ST: stability index, WDI: weight distribution index, NO: normal eye open, NC: normal eye close, PO: pillow with eye open, PC: pillow with eye close.

As a result of dynamic balance, there was no significant difference between groups in ANT, PM, and PL directions ($p>0.05$). After the intervention, the results within each group showed significant differences in the direction of ANT, PM, and PL in both groups ($p<0.05$). However, there was no significant difference in post-measurement results between the two groups ($p>0.05$).

Table 4. Comparison of dynamic balance within and between groups

		Pre-test	Post-test	t
ARPE	ANT	67.50±5.81	74.35±7.00	-5.320**
	PM	102.20±10.78	111.23±9.04	-5.183**
	PL	106.36±12.28	114.45±8.09	-3.343**
PTPE	ANT	68.23±7.33	73.88±6.24	-3.554**
	PM	100.14±16.96	113.25±11.37	-3.793**
	PL	107.87±14.50	119.01±12.50	-4.254**

*p<.05, **p<.01, mean ± standard deviation, ARPE: augmented reality proprioceptive exercise, PTPE: physical therapy proprioceptive exercise, ANT: Anterior, PM: Posteromedial, PL: Posterolateral

4. Discussion

The exercise program in this study consisted of the exercise of these muscle groups, showed dynamic balance improvement for all directions, and was consistent with those reported in previous studies. In AR-based research, the results of YBT are not significantly different. This indicates that the performance of AR-based strengthening and balance exercises is not different from the results of previous exercises performed by therapists [4]. In this study, no significant difference was found between groups. Salami et al. (2021) announced that static stretching of the hamstring could have a positive effect on improving balance ability as well as increasing flexibility [5]. Based on the results of previous studies, it can be confirmed that the application of warming up, including stretching in this study, greatly improved flexibility and had a positive effect on balance.

This study has several limitations. FIrst, it is difficult to generalize the findings to various range of ages since our participants were only healthy adults in their 20s. In addition, there were restrictions on controlling the daily life of the subjects.

5. Conclusion

The purpose of this study was to confirm whether augmented reality (AR) -based interventions can be as effective as therapists. We found that exercise with AR can improve flexibility and significantly improve balance ability to prevent injuries caused by falls. Second, both PT and AR interventions effectively improve

balance and flexibility, and AR does not differ in balance and flexibility compared to the treatment of therapists. We can suggest using AR-based interventions as intervention to assist the therapists.

References

[1] Laghari AA, Jumani AK, Kumar K, Chhajro MA. Systematic Analysis of Virtual Reality & Augmented Reality. International Journal of Information Engineering & Electronic Business. 2021 Feb 1;13(1).

[2] Rauschnabel PA. Augmented reality is eating the real-world! The substitution of physical products by holograms. International Journal of Information Management. 2021 Apr 1;57:102279.

[3] Yeung AW, Tosevska A, Klager E, Eibensteiner F, Laxar D, Stoyanov J, Glisic M, Zeiner S, Kulnik ST, Crutzen R, Kimberger O. Virtual and augmented reality applications in medicine: analysis of the scientific literature. Journal of medical internet research. 2021 Feb 10;23(2):e25499.

[4] Kang MH, Kim GM, Kwon OY, Weon JH, Oh JS, An DH. Relationship between the kinematics of the trunk and lower extremity and performance on the Y-balance test. PM&R. 2015 Nov 1;7(11):1152-8.

[5] Salemi P, Shadmehr A, Fereydounnia S. The Immediate Effect of Static Hamstring Stretching on Dynamic Balance and Gait Biomechanical Variables in Athletes With Hamstring Tightness: A Preliminary Study. Journal of Modern Rehabilitation. 2021 Jun 30;15(3):141-50.