ISSN: 2093-5374 / E-ISSN: 2093-5382

Effects of Augmented Reality based Dual-Task Proprioceptive Training on Postural Stability, Positioning Sensation and Cognition

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Received: September 05, 2023; Revised: November 11, 2023; Accepted: January 10, 2024; Published: March 30, 2024

Abstract

This study compared augmented reality (AR)-based proprioception training to traditional therapy to determine if the two tasks together were effective in improving postural stability, proprioception, and cognition. Forty-five healthy adults in their 20s were randomized into three groups: AR-based DT, AR-based proprioceptive exercise, and therapist-supervised exercise. Paired t-test and independent t-test were used to determine the within and between group effects, and the three groups were subjected to one-way ANOVA and Bonferroni's post hoc analysis. For postural stability, stability index and postural stability improved post-intervention in all groups ($p<.05$), with no differences between groups ($p>.05$). positioning sensation improved in all groups ($p<.05$), with no difference between groups ($p>.05$). Cognitive parameters showed significant differences in recognition and calculation in all groups after the intervention ($p<.05$), and no significant differences in ordering ($p<.05$). Thus, AR-based interventions have shown similar effects to therapists, improving cognitive performance on both tasks, and can be selected in some cases.

Keywords: Augmented Reality, Dual Task, Proprioceptive Exercise, Postural Stability, Positioning Sensation, Cognition.

1 Introduction

A double task (DT) is performing two tasks at the same time. It requires a high level of concentration as participants must perform two tasks simultaneously. (Macpherson, 2018). When adolescents underwent DT training to perform motor and cognitive tasks, their cognitive performance improved more than those in single-task training. Additionally, athletic performance improved after performing dual rather than single tasks. However, in controlled experiments, short-term effects for single-task training were better, contrary to improved long-term effects. Moreover, the degree of DT difficulty is an important factor in promoting learning ability; the higher the degree of difficulty, the greater the improvement in athletic and walking ability obtained after performing cognitively related DT in a study involving post-stroke gait training (Emilio et al., 2014; Bustillo-Cassero et al., 2020; Sandhiya & Yamuna 2014).

Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), volume: 15, number: 1 (March), pp. 88-103. DOI: *10.58346/JOWUA.2024.I1.007*

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Comparing the acute and chronic effects of simultaneously performing motor and cognitive tasks as a DT in different athletes showed that motor and cognitive task performances were impaired in the short term but improved in the long term. Athletes are accustomed to situations requiring multitasking abilities. The simultaneous activation of the cerebral cortices involved in exercise and cognitive functions reduces athletic performance in acute periods, although it is enhanced in chronic periods (Veldkamp, 2019). Augmented reality (AR)-based DT training is being developed to enhance cognitive task performance. As such, researchers are exploring the relevance of using AR technology to create cognitive training tasks that are closely linked to cognitive and physical function (Zhang et al., 2021), incorporating AR into medical technology (Sesmiarni et al., 2023; Liu et al., 2019).

Rehabilitation exercise programs vary in their therapeutic effects depending on posture. In conducting an in-home exercise program, a patient unfamiliar with the correct exercise posture might perform the exercises incorrectly, consequently experiencing a negative effect. The technology developed to eliminate these negative points is precisely AR-based exercise therapy. It corrects the position and movement of the body during exercise, provides exercise progress reports, and complements the unsupervised performance of the exercise programs (Laghari et al., 2021; Rauschnabel, 2021). Furthermore, AR-based exercise programs improve walking and postural stability in patients at risk of falling, such as the elderly, stroke survivors, and patients with Parkinson's disease, who had significantly reduced postural stability and walking abilities (Cavalcanti et al., 2019).

The effectiveness of AR-based exercise programs is comparable to that of therapist-based programs (Laghari et al., 2021; Rauschnabel, 2021). Among the studies comparing the effects of AR-based exercise therapy and exercise therapy performed by a therapist, a study on patients with Parkinson's disease comparing the effects of remotely supervised in-home AR-based and directly conducted in-hospital therapist-based postural stability training showed that mobility, dynamic, and postural stability improved in both groups. The in-hospital-trained group gained more functional improvement, although the difference was insignificant (Lee et al., 2014). In addition, using an AR program for exercise programs targeting normal adults in their 20s has been shown to be an effective treatment method, similar to PT, resulting in improvements in postural stability, as well as flexibility (Lee et al., 2022). Therefore, since no significant differences exist between AR-based non-faced and face-to-face exercise programs, remote AR technology can be used to provide low-cost, high-quality, and more economical treatment (Gandolfi et al., 2017).

In patients with subacute stroke, performing DTs during 4 weeks of postural stability training significantly improved postural stability, and auditory and short-term memory compared with conventional postural stability training (Wollesen et al., 2017). DT improved walking ability by increasing stride length and walking speed after a 12-week walking training for the elderly (Ehsani et al., 2019). In addition, in training delivered to young adults, the single-task training group showed large early improvements, whereas the DT training group showed minimal differences. When measured later, the single-task group only had improved single-task function. In contrast, the DT group showed improved motor and cognitive performance, indicating a positive effect (Liu et al., 2017).

Subsequent increases in cognitive processing were observed as the complexity of the DTs increased. However, increased central interference in DT performance interferes with cognitive and motor performance in the short term owing to distraction (Ghai et al., 2016).

Despite these findings, no studies have added a DT to proprioceptive exercises using AR. In addition, there was no training in which the DT was applied to healthy adults. Therefore, this study aimed to demonstrate that AR-based proprioceptive exercises are more effective in improving postural stability, position, and awareness when performing DT combinations.

2 Materials and Methods

1) Participants

The study was conducted on 45 healthy adults, aged 20-30, who were students at Sun Moon University (Table 1). The number of samples was calculated using 'GPOWER, 3.1.9.7', we set the effect size to 0.83 to obtain the required sample size of 45 (Faul et al., 2009). The inclusion criteria for this study were no history of surgery, trauma, or neurological disease related to musculoskeletal disease within the last 6 months; no pain limiting motor performance, no cognitive impairment in the past two years, no medication use related to muscle and mental illness no vestibular organ abnormality, and agreement to participate in the study. This study was approved by the Sunmoon University IRB (SM-202204-013-1). All participants provided informed consent after the purpose and procedures of the experiment were explained.

Table 1: Participants characteristics

	DT group(n=15)	AR group(n=15)	PT group(n=15)
Age (years)	24.53±2.77	22.73±1.73	21.64±1.49
Height (cm)	171.06±7.44	167.86±7.73	167.26±8.91
Weight (kg)	64.93±9.42	62.73±9.69	59.8±8.91

Values indicate mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy.

2) Experiment Procedures

Figure 1 depicts the research procedures. The height and weight of all participants were measured once before the experiment. The participants were randomly assigned to three groups: AR-based proprioceptive exercise (D-ARPE) with DT, AR-based proprioceptive exercise (ARPE), and therapist-supervised exercise groups. Used UINCARE Pro for the AR program. All participants, postural stability, leg length, and proprioception were measured thrice: before, during, and after the intervention. The proprioceptive exercise program lasted for 6 weeks and was applied 2 days a week for 25 min. The participants performed 2 sets X 10 reps during the first 3 weeks, and then increased to 3 sets X 10 reps after 3 weeks. The BOSU ball was used in the intervention that was performed with shoes on for safety.

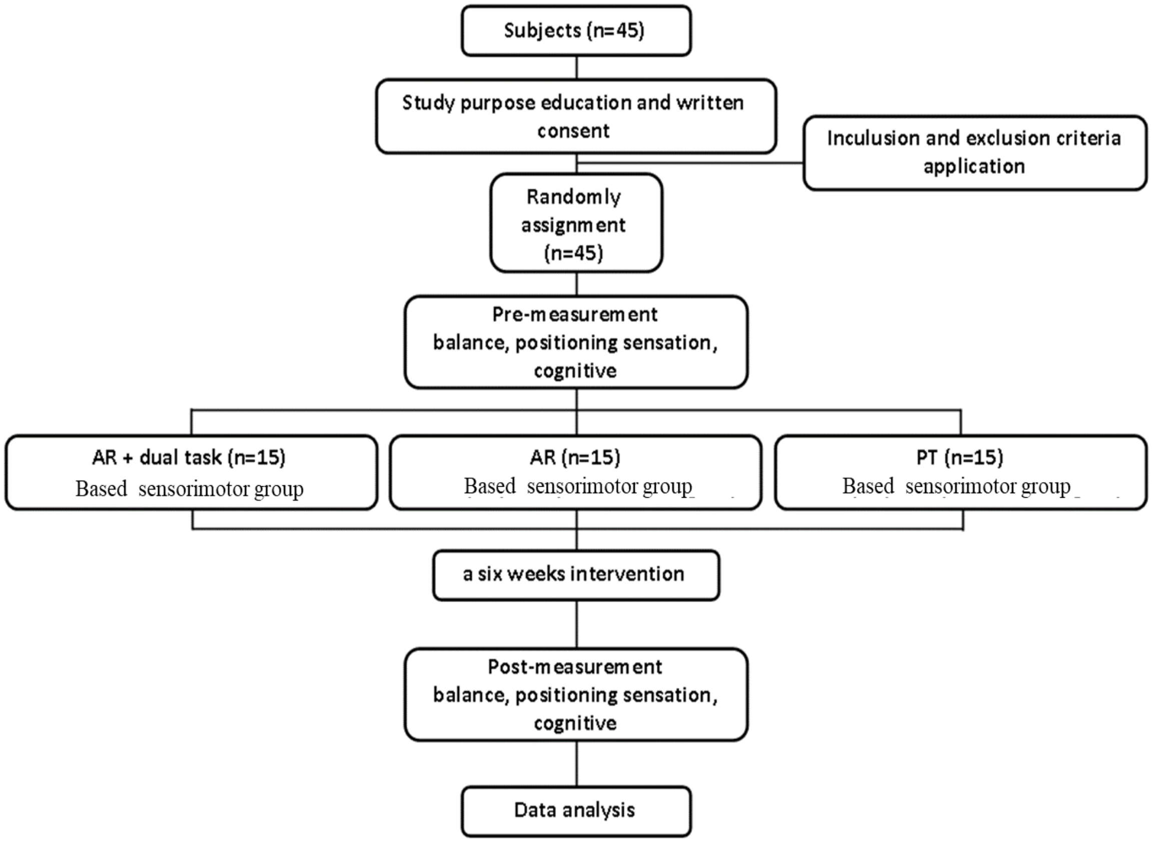

Figure 1: Experimental procedure

3) Measurement Tools and Methods

Postural stability, proprioception, and cognitive function were measured twice, before and after experiment using the TETRAX (tetra-ataxiometric posturography, Israel), Y-balance test, a central sensorimotor integration (CSMI) equipment, and cognitive assessment battery (CAB). All measurements and evaluations were performed by the same researcher to reduce the error margin.

- **Measuring Postural Stability**

Postural stability was measured TETRAX (tetra-ataxiometric, Israel). The participants were barefoot, and their feet were placed on the flats (A, B, C, D). Measurements were performed in the following order: stable surface with eyes open (NO), stable surface with eyes closed (NC), unstable surface with eyes open (PO), and unstable surface with eyes closed (PC). A pillow was used to create an unstable support surface (Figure 2). Measurements were taken twice: before and after intervention, for 32 s per item. The weight distribution index (WDI), stability index (ST) were used for evaluation. ST is a measure of stability during postural change, whereas WDI represents weight load and is expressed as a percentage (Akkaya et al., 2015; Gündüz et al., 2017).

Figure 2a-d: TETRAX

- **Measuring Dynamic Postural Stability**

The dynamic postural stability evaluation measured the functional reach of the lower extremities using the Y-balance test. The participant stood on the center box with one lower limb. After stretching the contralateral limb in three directions (anteriorly (AT), postero-medially (PM), and posterolaterally (PL)), the distance reached were summed, and the result was divided by three times the limb length. Multiplying this quotient by 100 resulted in the composite reach distance. Before commencing, the participants had shoes off to reduce interference with postural stability. Then, the participants performed the exercise in the three directions, with three measurements each. If participants could not touch the boxes (Figure 3) or maintain their posture, the results were invalidated and remeasured (Rauh et al., 2021).

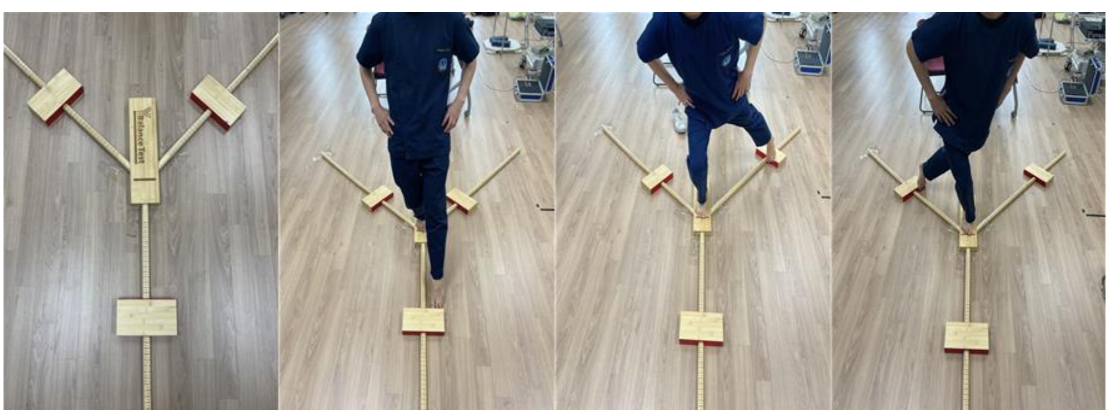

Figure 3a-d: Y-balance

Measuring Limb Length

Limb length was measured with the participant positioned supine on a bed. The measurer passively pulled on the participant's limb to align the pelvis and measured the dominant limb with a stem from the ASIS to the most prominent part of the medial malleolus in cm (Hoyle and Latour, 1991).

- **Measuring Proprioception**

Proprioception was measured an isokinetic measuring equipment, CSMI (Human Co, USA, 2010) as follows: The measurer trained the participant to bend the joints and move their legs, and then arbitrarily set the leg positions of the participant. We then instructed participants to memorize the initial position and asked them to create an initial target angle with eyes closed (Figure 4). To reduce the error, we took three measurements and calculated the average value (Seven et al., 2019).

Figure 4: CSMI

- **Measuring Cognitive Function**

The cognitive function was evaluated using a neurocognitive test CoTras. The CoTras consists of six short tests (cognition of speed, attention, episodic memory, visuospatial, language, and executive function). The evaluation was conducted in a quiet space. Among the CoTras items, the “sequencing test, cognitive test,” which is a memory test, was selected, and three tests were selected from two items of “adult diagnostic computation,” which is a computational test.

4) Intervention Method

- **Intervention Method**

Of the three groups, the D-ARPE group will be subjected. In this study, the cognitive task and the peculiar training using the BOSU ball was performed simultaneously during the DT practice. Cognitive tasks included subtraction task, word memory, and ordering tasks. In the subtraction task, after the experimenter assigned the participant a numerical value for n, the participant was asked to calculate the number -7 for n while simultaneously performing the BOSU ball-based training. For example, like as serial subtraction, participants repetitively perform subtraction on an arbitrarily assigned number "100-7=93, 93-7=86...". In the task of remembering words, the experimenter audibly pronounced 10 words during the proprioceptive training and then checked whether the participant remembered the words pronounced during the proprioceptive training. In the subsequent task, the participants memorized and confirmed the words and numbers presented by the experimenter during proprioceptive training (Strobach, 20191).

- **Proprioceptive Exercise Program**

The exercise program is structured as follows (Table 2). AR follows AR verbal commands and visual feedback, PT follows the therapist's commands.

Table 2: Proprioceptive exercise program

Types of exercise	Explanation
	1. Subject raises one leg over the BOSU ball and lunges toward the raised leg 2. Then do the same with the other leg.
	1. The subject steps up onto the BOSU ball with both feet, raises one leg, bends the pelvis and knees 90 degrees, and lowers them down again. 2. Then do the same with the other leg.
	1. The subject steps up onto the BOSU ball with both feet. Bend his legs into a squat position. 2. Then do the same with the other leg.
	1. The subject supports one foot on the BOSU ball, sends the opposite foot forward, and repeats the feed backward. 2. Then do the same with the other leg.
	1. The subject lifts one leg from the top of the BOSU ball, spreads it out to the side, and returns to the predetermined position (while trying to keep the posture constant). 2. Do the same on the other side.

5) Data Analysis

All statistical analyses were using the IBM SPSS 28.0.1.1. Technical statistics were used to assess the general properties. All mutations in the population yielded mean (M) and standard deviation. A paired sample t-test was used for pre-and post-variation of the intra-population exercise programs. A one-way ANOVA was used to examine the results between groups. All statistical levels (α) were set at <0.05. Post hoc tests used Bonferroni.

3 Results

1) Postural Stability

TETRAX pre-intervention measurement showed no significant differences in postural stability among all groups ($p > 0.05$; Table 3). Pre- and post-intervention results for each group showed within-group differences in ST during PO and PC in all groups, and significant differences in ST during NC in the

D-ARPE group ($p < 0.05$; Table 4). No differences in ST during NO among the groups ($p > 0.05$; Table 4). There was no difference when measured after arbitration ($p > 0.05$; Table 3).

Table 3: Comparison of postural stability between groups

			DT	**AR**	**PT**	**F**	***p***
Pre	WDI (%)	NO	5.63±3.37	6.61±3.43	4.92±2.82	1.04	.36
		NC	5.52±3.29	6.45±2.99	4.76±3.09	1.09	.35
		PO	7.08±3.07	5.6±2.81	5.53±3.18	1.26	.29
		PC	6.13±2.68	5.24±2.59	5.05±2.69	.72	.49
	ST (%)	NO	16±7.32	14.3±4.1	15.02±4.51	.36	.70
		NC	19.62±6.13	19.07±6.9	18±3.9	.31	.74
		PO	21.87±7.91	18.65±5.02	16.91±2.98	2.95	.06
		PC	26.02±6.17	24.62±4.34	22.63±5.46	1.51	.23
Post	WDI (%)	NO	5.62±2.82	5.82±2.79	4.77±3.09	.56	.58
		NC	5.2±2.65	6.29±3.32	4.69±2.92	1.12	.34
		PO	6.29±3.17	5.77±2.17	5.42±2.9	.38	.69
		PC	5.53±2.83	5.77±2.54	5.01±2.63	.32	.73
	ST (%)	NO	15.96±6.75	14.09±4.25	15.59±4.68	.52	.60
		NC	17.67±6.07	17.68±4.77	16.71±3.62	.19	.83
		PO	19.51±7.84	17.23±5.09	15.47±2.63	1.96	.154
		PC	21.83±6.3	21.71±4.3	20.48±5.4	.29	.75

mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy, ST: stability index, WDI: weight distribution index, NO: eye open, NC: eye close, PO: eye open with pillow, PC: close eye with pillow.

Table 4: Comparison of postural stability within a group after intervention

			Pre	**Post**	***t***
DT	WDI (%)	NO	5.63±3.37	5.62±2.82	0.04
		NC	5.52±3.29	5.2±2.65	0.78
		PO	7.08±3.07	6.29±3.17	1.68
		PC	6.13±2.68	5.53±2.83	1.67
	ST (%)	NO	16±7.32	15.96±6.75	0.06
		NC	19.62±6.13	17.67±6.07	4.64***
		PO	21.87±7.91	19.51±7.84	12.91***
		PC	26.02±6.17	21.83±6.3	18.68***
AR	WDI (%)	NO	6.61±3.43	5.82±2.79	2.35*
		NC	6.45±2.99	6.29±3.32	0.36
		PO	5.6±2.81	5.77±2.17	-0.20
		PC	5.24±2.59	5.77±2.54	-0.65
	ST (%)	NO	14.3±4.1	14.09±4.25	0.33
		NC	19.07±6.9	17.68±4.77	1.71
		PO	18.65±5.02	17.23±5.09	5.42***
		PC	24.62±4.34	21.71±4.3	10.86***
PT	WDI (%)	NO	4.92±2.82	4.77±3.09	0.52
		NC	4.76±3.09	4.69±2.92	0.12
		PO	5.53±3.18	5.42±2.9	0.54
		PC	5.05±2.69	5.01±2.63	0.08
	ST (%)	NO	15.02±4.51	15.59±4.68	-1.09
		NC	18±3.9	16.71±3.62	1.78
		PO	16.91±2.98	15.47±2.63	7.77***
		PC	22.63±5.46	20.48±5.4	16.24***

p<0.05*, p<0.001***, mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy, ST: stability index, WDI: weight distribution index, NO: eye open, NC: eye close, PO: eye open with pillow, PC: close eye with pillow.

2) Dynamic Postural Stability

There was no difference in the Y-balance pre-intervention measurement for PL, PM, and ANT ($p > 0.05$) among all groups (Table 5). Measurements within group after intervention showed differences in PL, PM, and ANT in all three groups ($p < 0.05$; Table 6). Post-intervention between-group measurements showed no significant differences in ANT, PM, or PL ($p > 0.05$; Table 5).

Table 5: Comparison of dynamic postural stability between groups

		DT	**AR**	**PT**	**F**	***p***
Pre	ANT (cm)	59.31±4.82	58.42±9.26	64.18±9.68	2.13	.13
	PM (cm)	95.24±7.86	91.82±13.47	94.38±14.6	.31	.73
	PL (cm)	98.89±6.79	94.87±13.76	103±12.59	1.89	.16
Post	ANT (cm)	63.27±5.13	65.71±10.39	67.71±9.83	.97	.39
	PM (cm)	101.22±7.89	98.22±11.52	100.87±13.06	.33	.72
	PL (cm)	105.2±7.5	103.09±11.48	106.33±12.23	.36	.70

mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy, ANT: Anterior, PM: Posteior & medial, PL: Posterior & lateral.

Table 6: Comparison of dynamic postural stability within a group

		Pre	**Post**	***t***
DT	ANT(cm)	59.31±4.82	63.27±5.13	-7.77***
	PM(cm)	95.24±7.86	101.22±7.89	-7.47***
	PL(cm)	98.89±6.79	105.2±7.5	-.52***
AR	ANT(cm)	58.42±9.26	65.71±10.39	-6.41***
	PM(cm)	91.82±13.47	98.22±11.52	-4.23***
	PL(cm)	94.87±13.76	103.09±11.48	-5.70***
PT	ANT(cm)	64.18±9.68	67.71±9.83	-2.90*
	PM(cm)	94.38±14.6	100.87±13.06	-3.93**
	PL(cm)	103±12.59	106.33±12.23	-5.82***

$p<0.05$*, $p<0.01$**, $p<0.001$***, mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy, PT: physical therapy, ANT: Anterior, PM: Posterior & medial, PL: Posterior & lateral.

3) Proprioception

There was no difference in proprioception among the groups in the pre-intervention measurement results ($p > 0.05$; Table 7). Post-intervention within-group measures showed significant differences ($p < 0.05$; Table 8). There was no difference between the group measures after intervention ($p > 0.05$; Table 7).

Table 7: Comparison of positioning sensation between groups

	DT	AR	PT	F	*p*
Pre	3.98±3.1˚	4.04±1.89˚	4.29±2.53˚	.06	.94
Post	1.8±1.63˚	2.27±1.97˚	1.64±1.38˚	.56	.58

mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy.

Table 8: Comparison of positioning sensation within a group

	Pre	Post	*t*
DT	3.98±3.1˚	1.8±1.63˚	2.99*
AR	4.04±1.89˚	2.27±1.97˚	4.09**
PT	4.29±2.53˚	1.64±1.38˚	5.09***

p<0.05*, p<0.01**, p<0.001***, mean ± standard deviation, DT: dual task, AR: augmented reality, PT: physical therapy.

4) Cognition

Comparative analysis before and after DT arbitration revealed a significant difference in cognitive and calculation abilities (p < 0.01; Table 9). There were no differences in ordering (p > 0.05; Table 9).

Table 9: Compare cognition within groups

DT	Ordering	Recognition	Calculation
Pre	79.4%±30.33%	76.8%±10.48%	84%±7.48%
Post	90.6%±10.18%	86.4%±8.36%	91.87%±6.1%
t	-2.03	-4.52***	-5.01***

***p<0.01, mean ± standard deviation

4 Discussion

Poor proprioception and lack of dynamic and postural stability lead to repetitive injuries and instability, causing many problems when performing dynamic movements. Additionally, people with postural stability problems rely on proprioception. Therefore, in the process of implementing postural stability rehabilitation training, proprioceptive training is essential (Alghadir et al., 2020). postural stability training with an instability tool such as the BOSU ball has a positive impact on postural stability, gait, and postural stability and acts effectively as proprioceptive training (Martinez-Amat et al., 2013). Research on AR-based rehabilitation training using these tools is ongoing. Four weeks of AR rehabilitation training in older adults improved postural stability, mobility, and stability of the lower extremities and reduced the risk of falls (Im et al., 2015). This means that AR rehabilitation training can improve postural stability without the need for therapist supervision. Furthermore, 4 weeks of single- and DT postural stability training in older adults with osteoporosis showed improvements in postural stability (Konak et al., 2016). These findings suggest that DT is more effective when performed continuously. The study found no difference between the D-ARPE, ARPE, and therapist-supervised exercise groups. Previous studies have demonstrated that training with unstable tools can improve stability, similar to this study’s findings in all groups.

Dynamic postural stability is an important criterion in the prediction, prevention, and rehabilitation of lower-extremity musculoskeletal injuries (Powden et al., 2019). The interventions in this study increased dynamic postural stability, YBT performance, and muscle strength. In this study reported that

YBT performance was affected by lower-extremity muscle strength (Lee et al., 2015a). In this study found that muscle loss around the hip reduces pelvic stability and affects the ankle and foot positions to maintain it causing an adverse effect on lower-extremity postural stability and functional movements (Jaber et al., 2018). Furthermore, in this study reported that athletes with ankle ligament injuries showed improved dynamic postural stability, muscle strength, ROM, muscular endurance, and functional ability through proprioceptive exercises with a BOSU ball (Ahern et al., 2021). Kang et al. (2015) reported that the ANT reach was correlated with ankle dorsiflexion body extension and postural stability and that hip flexion and body flexion have a positive effect on PM and PL reach. Jelinek et al. (2019) reported that knee and ankle stability and proprioception contribute to postural stability control and affect YBT. In conclusion, the body, hip, knee, and ankle play important roles in the YBT range, with the ankle and knee stability muscles in the ANT and the knee and hip stability muscles in the PM and PL being the main factors. The study's exercise program, which consisted of exercises for these muscle groups and stability, showed strong improvements in postural stability in all directions, which is consistent with results reported in previous studies. In studies involving YBT, the effects of AR-based exercises were not significantly different from conventional treatment. An 8-week Otago exercise program improved dynamic postural stability in middle-aged adults. This indicates that AR-based rehabilitation training is not different from therapist-supervised conventional exercises (Almarzouki et al., 2020). Moreover, the results of comparing the single- and DT groups showed a further improved postural stability effect in the DT group (Hoshyari et al., 2022). In contrast, this study found no significant differences among the groups, with improved results within the groups.

Proprioception plays an important role in the control of human movement. In addition, it plays an important role in joint stability, kinematic sensitivity, and postural stability control. Further, it is a key element in joint sensation, body movement, and alignment (Han et al., 2016). Roijezon et al. (2015) reported that proprioceptive deficits may appear as a result of traumatic injury to ligaments and muscle tissue and are also associated with pain disorders that develop gradually thereafter. Furthermore, Riva et al. (2019) reported that decreased proprioception was associated with excessive visual field dependence and lack of interaction with uneven ground, increasing the risk of falls. They found that the likelihood of ankle sprain recurrence in a proprioceptive training group decreased by 35% compared with that in a control group (Rivera et al., 2017). In addition, Tsauo et al. (2008) reported that 8 weeks of proprioceptive training in knee osteoarthritis patients reduced secondary injury rates. This suggests that steady proprioceptive training can improve postural stability and movement preventing traumatic injury (Relph and Lee, 2016). Lee et al reported that, as a result of 8 weeks of single- and DT proprioceptive training in stroke patients, the DT group showed greater improvement in proprioception (Lee et al., 2015b). This suggests that DTs are more effective than single tasks. There were no differences between the groups in this study, we showed improved results when comparing before and after intervention within groups.

Routine activities, such as crossing the street, require the management of motor and cognitive tasks while processing external information. Cognitive decline often leads to reduced physical performance and gait disturbances. This change manifests in an increased risk of falls. Rave et al. (2014) reported that intervention between a single-task motor group and DT motor-cognitive group in older adults resulted in improved simultaneous attention and reduced fall risk in the DT group. Jamie et al (2017) noted that a combined physical and cognitive intervention improved cognitive function in healthy older adults with cognitive impairment and was more effective than sequential training. In addition, as a result of performing dual and single tasks in patients with brain damage, Parkinson's disease, and Alzheimer's disease, they reported that postural stability and cognition were further improved by performing DTs (Fritz et al., 2016). This suggests that performing DTs has a better effect on cognition than performing single tasks. In this study, cognitive ability and arithmetic skills improved in the DT group that underwent motor and cognitive training.

This study has some limitations. First, it targets healthy adults in their 20s; therefore, generalizing the results to all age groups should be done with caution. Second, there were limitations in the control group because they could not participate in the daily life of the experimenters. The third is UINCARE Pro recognition ability, which is an AR program. This is the delay in the process of re-recognition due to a sudden body recognition error in performing the exercise. However, in the present study, AR-based exercise and exercise performed by a physiotherapist showed similar results, and there was no significant difference between the D-ARPE group, ARPE, and therapist-based groups. Currently, it is possible to visit many rehabilitation hospitals in the vicinity due to the development of transportation means in each area. However, with many media offerings and diverse natural disasters, patients increasingly prefer in-home training. Additionally, the AR program can receive instant feedback without a therapist, improve exercise accuracy, and is suitable for use during in-home training.

5 Conclusions

The purpose of this study was to confirm the improvement in postural stability, position sense, and cognition due to DTs when applying DTs to AR-based arbitration. The results are as follows: First, motor programs and DTs improved postural stability, cognition, and position sense. Second, the exercise programs performed in D-ARPE, ARPE, and therapist-based exercises were effective in improving postural stability and proprioception. DTs and AR had similar effects on postural stability ability and proprioception when compared with therapist-based exercises. The DT-ARPE resulted in additional cognitive improvements. AR-based interventions have been shown to have similar effects to therapists and are effective for cognition and can be an option in some cases.

Funding: This research was supported by the Culture, Sports and Tourism R&D Program through the Korea Creative Content Agency grant funded by the Ministry of Culture, Sports and Tourism in 2022 (Project Number: SR202106002).

Institutional Review Board Statement: The study was approved by the Institutional Review Board of Sunmoon University (SM-202204-013-1).

Informed Consent Statement: Informed consent was obtained from participants and IRB approval was obtained.

Data Availability Statement: The original data for the study can be made available upon reasonable request from the corresponding author.

Acknowledgments: We would like to thank everyone who participated in this study.

Conflicts of Interest: No conflicts of interest.

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