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Comparison of the Immediate Effects of Different Intervention Times in a Visual Feedback-Based Balance Training Program

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Abstract

Background: Balance plays a crucial role in daily life and rehabilitation processes, with balance disorders commonly affecting the elderly, patients with neurological disorders, and individuals with exercise-induced injuries. This study aimed to compare the immediate effects of different intervention times in a Visual Feedback-Based Balance Training (VFBT) program to determine the optimal training duration.

Design:

Methods: This randomized controlled trial included 48 college students in their 20s from University A in Gyeongbuk. Participants were randomly assigned to 10-minute, 20-minute, and 30-minute groups to participate in the VFBT program. The training program included maintaining static balance, weight shifting training, and pursuit object training. The Wintack system was used to assess participants' center of pressure (COP) and plantar pressure before and after training.

Results: The 10-minute group showed significant differences in the left foot area ($p<0.05$). The 20-minute group showed significant differences in total COP length and area ($p<0.05$). The 30-minute group showed significant differences in the left and right foot area, maximum and average pressure, and total COP movement area ($p<0.05$). The 30-minute group showed significant differences in the left foot's maximum pressure and total COP movement distance compared to the 10-minute group ($p<0.05$), but there were no significant differences between the 20-minute and 30-minute groups.

Conclusion: The effects of visual feedback-based balance training improve with increased training time, with the 30-minute training showing the most prominent effects. However, beyond 20 minutes of training, additional time did not proportionally increase the effects. This study provides foundational data that can contribute to the development of effective balance training programs, highlighting the need for future research to evaluate long-term effects across various age groups.

Key words: balance, center of pressure, postural control, rehabilitation, visual feedback

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Ⅰ. Introduction

Balance is the ability to maintain the body's center of gravity over its base of support and to continuously sustain proper body alignment and posture(Nichols, Miller, Colby, & Pease, 1996). Balance disorders are common among the elderly, patients with neurological disorders, and individuals with exercise-induced injuries. Various training methods have been developed to improve these balance issues(Zampogna et al., 2020). Visual Feedback-Based Balance Training (VFBT) is a training method that utilizes visual information to enhance an individual's balance ability(Wang et al., 2021). To implement visual feedback-based balance training, it is generally combined with visual information devices such as monitors or screens, along with virtual reality programs to provide an immersive environment(Li et al., 2018; Yang, Chung, Lee, Lee, & Lee, 2021). Depending on the training environment, wearable devices may be used to collect real-time data or display the information on other display devices(Wang et al., 2021).

Visual feedback training has the advantage of allowing users to assess their posture and balance control in real-time during the training. It also helps in preventing excessive exercise and other related issues(van den Heuvel et al., 2013). Previous studies on visual feedback-based balance training have reported improvements in balance ability and motor learning, as well as the effectiveness in preventing injuries related to balance loss, such as falls. Additionally, the training has shown benefits in rehabilitation programs for patients with neurological disorders or exercise-induced injuries(Han, Liu, Hu, Wang, & Xue, 2023; van den Heuvel et al., 2013; Yang et al., 2021).

Most studies related to visual feedback-based balance training have focused on comparing the effects of balance training with other interventions. However, there is a lack of research specifically addressing the optimal duration for visual feedback-based balance training programs(Houston, Lee, Unger, Masani, & Musselman, 2020; Schwenk et al., 2014; Yeo, Koo, Ko, & Park, 2023). Therefore, this study aims to compare the effects of different training durations on a visual feedback-based balance training program by applying it with varying durations across different groups.

Ⅱ. Methods

This study was designed as a randomized controlled trial. The research participants were college students in their 20s enrolled at University A in Gyeongbuk. Detailed information about the study procedures and potential side effects was provided, and the study was conducted with those who expressed willingness to participate. The inclusion criteria for participants were adults in their 20s, with a BMI not classified as overweight or excessively underweight, and no balance issues resulting from musculoskeletal or neurological injuries, including fractures, within the past six months. Out of the 51 individuals who expressed interest in participating, 48 met the criteria and were included in the study after excluding 3 grous. All participants provided informed consent and were informed that they could withdraw from the study at any time. The IRB approval number for this study is HR-002-01.

Participants were randomly assigned to different groups. The visual feedback balance training groups were divided into 10-minute, 20-minute, and 30-minute groups. Participants in each group underwent balance assessments, weight-shifting training, and posture adjustment training using games according to their respective group training programs. The details of each group's training program are shown in Table 1.

Table 1. The program of visual feedback balance training programe

Visual feedback balance training program	VFBT10	VFBT20	VFBT30
Maintains static balance	20 sec	1 min 30 sec	3 min
Break time	10 sec	30 sec	1 min
Pursuit object standing	3 min 50 sec	10 sec	10 min
Break time	20 sec	1 min	1 min
Weight shifting training (anterior-posterior)	2 min 30sec	3 min	6 min
Break time	20 sec	1 min	1 min
Weight shifting training (medial-lateral)	2 min 30 sec	3 min	8 min
Total time	10 min	20 min	30 min

VFBT; visual feedback balance training

For the visual feedback-based balance training program, the MFT Challenge Disc 2.0 (Germany) was used. This equipment consists of a 44 cm diameter force plate and specialized software. The force plate is connected via Bluetooth, and movements on the disc are displayed in real-time on a separate connected monitor. Changes and auditory signals on the screen provide smooth feedback input, which is advantageous for effective training. To enhance participants' immersion in visual feedback, a 65-inch monitor was used during the training. The visual feedback-based balance training program was designed by referencing previous studies and included visual feedback-based posture adjustment training, dynamic balance training, and weight-shifting training with targets or pathways.

Participants trained to recognize the representation of their center of gravity displayed on the screen while standing on the balance disc and aimed to minimize shifts in their center of gravity during the allotted time. If their center of gravity deviated from a certain threshold, visual and auditory feedback were provided on the screen to help them maintain their posture throughout the training session.

Participants trained to move their center of gravity up and down or side to side according to the tasks displayed on the screen. When they we reable to move their center of gravity in the correct direction within the given time, the speed of movement or task completion time was adjusted to promote higher levels of weight-shifting ability.

The weight-shifting tracking training involved tasks that required shifting the center of gravity not only in vertical and horizontal directions but also along diagonal and curved paths. Participants were in structed to move their center of gravity along various straight and curved paths shown on the screen, with audiovisual feedback provided if they deviated from the path, enabling focused training on weight-shifting.

Outcome measures

In this study, the Wintack system(Medicapture, France) was used to measure the effects of the intervention. This equipment consists of a 120 cm long force plate equipped with 12,288 sensors, capable of capturing 200 images per second. Participants' center of pressure(COP) and plantar pressure were measured using this device before and after the experiment. Measurements were taken over a 30-second period, and the resulting values were used for analysis. The assessment of COP changes included parameters such as sway distance, sway area, anterior-posterior and medial-lateral sway velocities. Additionally, plantar pressure data was analyzed, incorporating variables like the pressure area under each foot and weight distribution ratio between the left and right feet.

Statistical analysis

The general characteristics of the participants were described using means and standard deviations. A homogeneity test was conducted between groups before the experiment. Paired sample analysis was performed to compare the pre- and post-experiment effects within each group. To compare the effects between groups according to the intervention, one-way analysis of variance(ANOVA) was used. The statistical significance level was set at $p < 0.05$.

III. Results

Comparison of the general characteristics of the participants revealed no significant differences in gender, age, height and weight, and BMI (Table 2).

Table 2. Participants' General Characteristics(N=48)

	VFBT 10 group (A) n=16	VFBT 20 Group (B) n=16	VFBT 30 group (C) n=16	f	p
Ages (yeas)	23.06±1.69	22.62±1.54	23.06±1.69	1.290	0.285
Sex(male/female)	8/8	8/8	8/8	0.021	0979
Heights(cm)	167.437.73	168.75±8.33	167.43±7.73	0.256	0.775
Weights(kg)	61.37±7.98	61.75±8.73	61.37±7.98	0.222	0.801
BMI(index)	21.86±1.50	21.62±1.22	21.86±1.50	0.562	0.574

VFBT; visual feedback balance training, $^{*}p<0.05$

For the 10-minute group, significant differences were observed in the left area ($p<0.05$). In the 20-minute group, significant differences were found in the center of pressure (COP) length ($p<0.05$). Post-hoc analysis revealed significant differences in the overall COP area ($p<0.05$). For the 30-minute group, significant differences were noted in the left and right areas ($p<0.05$), as well as in the maximum and average pressure on both the left and right sides ($p<0.05$). Additionally, significant differences were observed in the overall COP movement area (Table 3).

Table 3. Comparison of Changes in foot pressure (N=48)

		VFBT 10 group(A) n=16	VFBT 20 group(B) n=16	VFBT 30 group (C) n=16	f	p	Post hoc
Lt. maximal Pressure	pre	583.62±79.91	601.31±83.24	600.25±79.58	0.240	0.787	
	post	582.31±113.52	591.87±93.60	560.12±79.84			
	Pre-post	-1.31±64.18	-9.43±43.82	-40.12±41.81	2.582	0.087	
	t	0.082	0.861	3.838			
	p	0.936	0.403	0.002*			
Rt. maximal pressure	pre	589.25±575.62	531.68±96.79	563.82±82.14	1.594	0.214	
	post	575.62±105.79	533.31±102.53	536.37±69.26			
	Pre-post	-13.62±41.38	1.62±55.15	-27.18±35.67	1.655	0.203	C>A
	t	1.317	-0.118	3.049			
	p	0.208	0.908	0.008*			
Lt. average pressure	pre	287.06±38.17	274.31±32.32	280.00±28.41	0.592	0.558	
	post	282.56±39.72	272.75±36.77	269.00±31.79			
	Pre-post	-4.50±14.29	-1.56±19.30	-11.00±11.62	1.572	0.219	
	t	1.259	0.324	3.784			
	p	0.227	0.751	0.002*			
Rt. average pressure	pre	288.81±35.52	262.18±39.42	269.50±30.66	0.290	0.220	
	post	279.06±34.80	260.81±28.93	260.87±25.67			
	Pre-post	-9.75±23.30	-1.37±21.96	-8.62±11.95	0.849	0.435	
	t	1.673	0.250	2.886			
	p	0.115	0.806	0.011*			

VFBT; visual feedback balance training, $p<0.05$

Comparing the effects of visual feedback-based balance training based on training time, the 30-minute group showed a significant difference in the maximum pressure of the left foot compared to the 10-minute group ($p<0.05$), though there was no significant difference between the 20-minute and 30-minute groups. Significant differences were found in the overall COP movement distance between the 30-minute and 10-minute groups ($p<0.05$) (Table 4).

Table 4. Comparison of changes in foot area and COP (N=48)

		VFBT 10 group (A) n=16	VFBT 20 group(B) n=16	VFBT 30 group(C) n=16	*f*	*p*	Post hoc
Lt. foot area	pre	106.18±13.68	120.50±25.01	116.37±18.34	2.266	0.115	
	post	110.25±14.76	121.00±24.10	119.18±18.13			
	Pre-post	3.60±4.08	0.50±9.57	3.18±5.46	0.955	0.393	
	t	-03.727	-0.209	-2.332			
	p	0.002*	0.837	0.034*			
Rt. Foot area	pre	111.50±15.28	119.50±20.63	118.68±17.07	0.978	0.384	
	post	113.00±14.30	119.62±18.30	122.68±18.23			
	Pre-post	1.50±5.03	0.12±8.88	3.31±5.79	0.890	0.418	
	t	-1.192	-0.056	-2.287			
	p	0.252	0.956	0.037*			
Total COP length	pre	125.64±35.49	117.73±40.82	130.66±35.94	0.484	0.619	
	post	141.00±56.89	103.46±35.61	116.59±27.91			
	Pre-post	15.36±36.01	-14.26±24.44	-14.07±29.92	5.001	0.011	B,C>A
	t	-1.706	2.334	1.881			
	p	0.109	0.034*	0.079*			
Total COP area	pre	117.67±107.91	114.03±120.52	126.83±150.93	0.043	0.958	
	post	134.40±136.56	50.66±51.77	64.28±58.38			
	Pre-post	16.72±143.58	-63.36±97.72	-62.55±102.82	2.494	0.094	
	t	-0.466	2.593	2.433			
	p	0.648	0.020*	0.028*			

VFBT; visual feedback balance training, COP; center of pressure

*$p<0.05$

Visual biofeedback integrates afferent information from the vestibular and somatosensory systems to contribute to postural control. Training utilizing visual biofeedback helps reduce postural sway, thereby improving postural control abilities(Loughlin & Redfern, 2001). One method that can potentially alter neuromuscular activation patterns is to engage in exercises on unstable surfaces rather than stable ones. Exercising on unstable support surfaces promotes postural control and dynamic balance(Franklin, Osu, Burdet, Kawato, & Milner, 2003). Exercises performed on unstable support surfaces enhance proprioceptive feedback and increase neuromuscular control of joints and muscles. These exercises improve balance ability through increased rotational forces and angular momentum generated by distal torque, which stimulates the core muscles(Behm, Colado, & Colado, 2013).

In previous studies on visual feedback-based balance training, the training durations commonly ranged from a minimum of 10 minutes to a maximum of 30 minutes. For instance, Lajoie et al. (2017)

conducted a study where visual feedback balance training was performed for 30 minutes per session, three times a week over a 12-week period(Lajoie, Teasdale, Bard, & Fleury, 1996). Granacher et al. (2019) conducted an intensive visual feedback-based balance training program over 6 weeks, with sessions lasting 20 minutes each, conducted daily. This study demonstrates that even short training durations can lead to significant improvements in balance ability(Granacher et al., 2010). Similarly, Muehlbauer et al. (2012) implemented visual feedback-based balance training three times a day, with each session lasting 10 minutes. Their findings indicate that relatively brief training periods can also have a positive impact on balance ability(Muehlbauer, Besemer, Wehrle, Gollhofer, & Granacher, 2012).

In the VFBT 10-minute group, significant differences were observed in the left foot area. Although the effect of the 10-minute training is relatively short, it suggests that VFBT training influences balance control on the left foot. However, the effects observed in the 10-minute group may be limited, indicating that longer training durations might be necessary. In the VFBT 20-minute group, significant differences were found in Total COP length and overall COP area. This indicates that even a moderate training duration of 20 minutes can reduce the level of body sway necessary for maintaining balance. The Total COP length showed a significant difference compared to the 10-minute group, suggesting that a 20-minute training duration can yield similar improvements in sway reduction as the 30-minute training group. In the VFBT 30-minute group, significant differences were observed across all indicators, including foot area, maximal pressure, average pressure, Total COP length, and Total COP area before and after training. Notably, significant differences were observed in the left foot maximal pressure and Total COP length compared to the 10-minute group. This suggests that a 30-minute VFBT training regimen has a greater impact on balance sense and pressure distribution control.

Comparing the effects by training duration, the 30-minute group showed a significant difference in maximal pressure on the left foot compared to the 10-minute group, but no substantial difference was observed between the 20-minute and 30-minute groups. This suggests that once the training duration exceeds 20 minutes, the effectiveness may reach a certain level, beyond which further increases in duration may not yield proportionally greater effects. Additionally, the 30-minute group exhibited a significant difference in overall COP movement distance compared to the 10-minute group, indicating that longer training may be more effective in improving overall balance control.

The study's participants were all university students in their 20s, which limits the diversity of the sample. Future research should include a broader range of age groups and health conditions to provide more generalized data. This study evaluated only the immediate effects of the training, and thus, there is a need to compare the long-term effects through sustained interventions. The study did not account for individual differences such as baseline balance ability or exercise experience, which might influence the results. Therefore, the findings should be applied with caution, considering these limitations.

V. Conclusion

This study demonstrates that the effectiveness of visual feedback-based balance training varies with training duration. Specifically, the 30-minute training duration showed the most pronounced effects overall, with more significant improvements in balance control and pressure distribution as training time increased. Future research should evaluate the long-term effects of various training durations and methods to contribute to the development of more effective balance training programs.

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