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The effects of virtual reality training on gait, balance, and upper extremity function in patients with stroke: A meta-analysis

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Abstract

Background: The purpose of this study is to investigate the effects of virtual reality on gait, balance, and upper extremity functions compared to other independent variables or no variables. Additionally, the possibility of virtual reality for stroke patients was discussed.

Design: Meta-analysis.

Methods: The search for this study was a search term that combined stroke, virtual reality, and training, and the electronic search was conducted through EMBASE, MEDLINE, and Cochrane Library. As a result of the search, 21 studies satisfying the selection criteria of the target study were confirmed as the final analysis target. This study consisted of 21 randomized experimental studies and 21 randomized controlled trials, and the total number of participants was 642. [Experimental group (*n*=314), control group (*n*=328); total 642]. As a result of the study, upper extremity function was assessed using a box and block test, a modified Ashworth scale, and a scale including range of motion. The balance was evaluated by the berg balance scale. Gait was a Timed Up and Go test (TUG), stride length, and gait function. Scales including a walking rate scale were evaluated. The effect size for the intervention of the analytical study was meta-analyzed with the RevMan 5.3.3 program of the Cochrane library.

Results: The results of the study showed that the function of walking was statistically significant. Balance showed statistically significant results. The upper extremity function showed no statistically significant results.

Conclusion: Through this rehabilitation treatment by applying virtual reality environment to the rehabilitation of stroke patients in the future can be proposed as an effective intervention method for the balance and gait function of stroke patients.

Key words: Balance, Gait, Training, Upper limb function, Virtual reality.

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Ⅰ. Introduction

A stroke occurs when a blood vessel in the brain that supplies blood to the brain ruptures, bleeds, or becomes blocked. And also, they show various impairments and impairments in motor, sensory, mental, cognitive and language functions (O'Sullivan, 2014). Stroke-induced upper extremity injury is one of the most common disorders, resulting in dysfunction and muscle weakness in the contralateral upper extremity of the damaged brain hemisphere (Lloyd-Jones et al, 2010). Balance problems are very common and affect patients' ability to perform activities of daily living and restore mobility and increase the risk of falls (Loewen et al, 1990; Lamb et al, 2001; Kim et al, 2020). Balance is the ability to maintain a position on a surface of limited stability or support (Shumay-Cook et al, 2014; Lee et al, 2020). Posture control is defined as the movement of maintaining or restoring a state of balance in a certain posture or activity (Pollock et al, 2000). Hemiplegic gait disorder with muscle weakness, stiffness, and abnormal central nervous pattern muscle activity significantly reduces the efficiency of gait exercise (Fish et al, 1999). Gait uses a repetitive sequence of limb movements to move the body forward while maintaining postural stability. It is divided into stance and swing phases, and is further subdivided into initial contact, load response, mid stance, terminal stance, swing pre swing, initial swing, middle swing, and terminal swing. Physical therapy intervention plays an important role in improving balance disorders, pathological gait, and upper extremity injuries. Interventions for stroke patients include inhibition-guided exercise therapy (E Silva et al, 2017), robot-assisted treadmill training (T George Hornby et al, 2005), visual gait training (Sidaway et al, 2006), EMG (Langhorne et al, 2009), weight-assisted treadmill training (Jung et al, 2014), physical fitness training (Laver et al, 2015), virtual reality (Schuster-Amft et al, 2018), repetitive occupational therapy (Behrman et al, 2005), underwater gait training (Eyvaz et al, 2018). Recently, virtual reality has been used to apply real situations to the rehabilitation of stroke patients. Virtual reality is a computer-based technology that allows users to interact and receive immediate responses in a variety of sensory stimulus environments. By providing the patient with an environment similar to the actual situation, visual and spatial stimulation can be given, and effective motor learning can be induced through direct interaction with the environment through repetition (Zhang et al, 2001). Virtual reality technology uses motor learning and neuroplasticity as principles to optimize recovery after brain injury. It is reported that the application of virtual reality improves gait control ability, including re-education of gait and balance, and rehabilitation of upper and lower extremities of stroke patients. Virtual reality is the latest intervention in stroke rehabilitation and performs a higher level of functional tasks than conventional interventions (Cho and Lee, 2013). In addition, it has the advantage of inducing interest and motivation by performing various tasks in various environments (Flynn et al, 2007; Rand et al, 2004). However, despite the many advantages such as the ability to easily change and control the visual, auditory, and tactile inputs and the enthusiasm and motivation provided by the system, it is expensive and cannot be used in many places (Weiss and Katz, 2004).

Many studies have reported various effects on upper extremity damage, balance disorder, and gait disorder in stroke patients (Brunner et al, 2017; Laver et al, 2017). Most of these studies are quantitative studies such as randomized controlled trials. As the application of virtual reality programs to stroke patients increased in clinical practice, studies on the effects of virtual reality program training on stroke patients began to be published in Korea from the late 2000s (Shin, 2008; Seo, 2009; Choi, 2012; Jo, 2012). Effects of virtual reality training on upper extremity function and daily life of stroke patients (Kwon and Yang, 2013; Song and Park, 2016; Yoo et al, 2014; Lee et al, 2013), effect on balance and gait (Kim et al, 2011; Lee and Shin, 2013; Lee et al, 2012; Cheon et al, 2015) were conducted. Various virtual reality programs were used according to the study, and various variables were used as dependent variables.

However, it is difficult to synthesize and summarize the effects of the interventions because the intervention methods performed in these intervention studies are diverse and show inconsistent results. In order to comprehensively judge the effects of various studies, it is necessary to analyze the results of each study statistically and examine them comprehensively and systematically.

Meta-analysis is a statistical method that summarizes and analyzes research papers accumulated over many years as a very effective method of integrating evidence. In particular, it is a quantitative analysis method that systematically and objectively evaluates and synthesizes numerous studies that present contradictory results when they continue to accumulate (Song, 2006). In other words, meta-analysis is a research method that can draw comprehensive and macroscopic research conclusions by statistically integrating or comparing individual research results beyond the limitations of literature research (Korean Society of Adult Education, 2004). In Korea, one meta-analysis study was conducted on the effect of virtual reality intervention on balance in stroke patients (Noh, 2017). However, this study has limitations in not including foreign studies. Most of the studies in abroad are about systematic review some meta-analyses were being conducted.

By synthesizing and analyzing the previously accumulated therapeutic effects of virtual reality program training for stroke patients, it suggests the importance of virtual reality program training as an alternative treatment strategy and provides evidence-based data. Therefore, this study aims to synthesize and analyze the accumulated domestic and foreign interventional studies on virtual reality program training for stroke patients to see the effect on the therapeutic performance of gait, balance, and upper extremity function, which are closely related to daily life. These results will improve the excellence of physical therapy by presenting evidence-based data on the treatment of virtual reality program training, and suggest the direction of future virtual reality program training intervention research. Therefore, this study tried to confirm the intervention effect of the virtual reality program on gait, balance, and upper extremity function in stroke patients through systematic analysis.

Ⅱ. Methods

1. Data search and data selection

As of May 1, 2018, research literature related to virtual reality of stroke patients was collected. Overseas data were searched for ‘stroke’, virtual reality, training’ through Pubmed, the Cochrane Central Register of Controlled Trials (CENTRAL), MEDLINE, and EMBASE. The search was limited to English data from 1991 to October 1, 2018. A total of 2813 articles were searched.

Approval of request for exemption from deliberation by the institutional life review committee for data retrieval and collection; It took place from January 2018 to May 2018 after receiving (IRB No. SUIRB20). In addition, the data search was supplemented through the references of the searched papers. The search was limited to papers in English and papers published from 1991 to January 2018 that provided data from the DB. The data collection procedure of the study to be analyzed was based on a systematic literature review process. Literature search was conducted by a researcher and a research assistant with the advice of a meta-analysis expert. First, in MEDLINE, 1) mesh words, which are control words of simulation education intervention, were checked, and then all four mesh words were included. After including the related central keywords identified in the abstract, EMBASE checked the control words in EMTREE and performed the same method as above. In the Cochrane Library CENTRAL and CINAHL, the search was performed through the mesh identified in MEDLINE. Related articles were searched through a core electronic database. Duplicate data were removed from the literature managementDB (reference management database, [Refworks]). The original text of the selected thesis was reviewed after first checking the related thesis through the title and abstract of the thesis. Two researchers independently searched and selected the data, and inconsistent literature was matched through discussion. The authors and publication year, country, study design, age of subjects, number of subjects, characteristics of intervention type, and research results were extracted from the finally selected study and recorded in the electronic coding book. If the data did not match, the original text was reviewed and a final decision was made.

A total of 2813 articles were searched through thesis titles and abstracts in EMBASE, MEDLINE, Cochrane Library CENTRAL and CINAHL.Duplicate data were excluded through the reference management database ([Refworks]), leaving 499 articles.With the exception of 352 studies that did not meet the selection criteria, 47 studies were selected first. The original texts of the 47 first-selected studies were reviewed, and among them, the final 21 studies were selected, excluding studies that did not meet the selection criteria (Figure 1).

3. Risk of bias

For RCT research, the 7-item RoB (The Cochrane's Risk of Bias) tool developed by The Cochrane Bias Method Group was used. Methodological quality evaluation of the thesis was conducted after conducting an RCT research pre-test with a professor with experienced in meta-analysis. Two researchers evaluated each of the separate questions, and those that did not match were re-evaluated after reviewing the original text.

4. Data analysis method

The general characteristics of the research paper and the intervention method are analyzed by 12 questions (research conducting country, research design, subject, sample size, subject, intervention type, intervention period, number of interventions, intervention time, control group type, measurement tool, outcome variable) made by the frame. The average duration of one intervention, the total number of applications and the total number of weeks of application for the intervention method was investigated. For the effect size of upper extremity function, the Box and Block test, the modified Ashworth scale, and the joint ROM were selected. For the balance variables, the berg balance scale measurement tool was selected, and the gait variables were the stand-up walking test, stride length, and gait function. The walking rate was selected. The effect size of the intervention was meta-analyzed using the RevMan 5.3.3 program of the Cochrane Library. Analysis was conducted when there were 3 or more papers that provided the same outcome variable, and subgroup analysis was performed when there were 2 or more papers. When analyzing data, if there was a mean difference value and standard deviation before and after the experiment in the target paper, the values were used. If there are only the mean and standard deviation before and after the experiment, the mean difference value is the value obtained

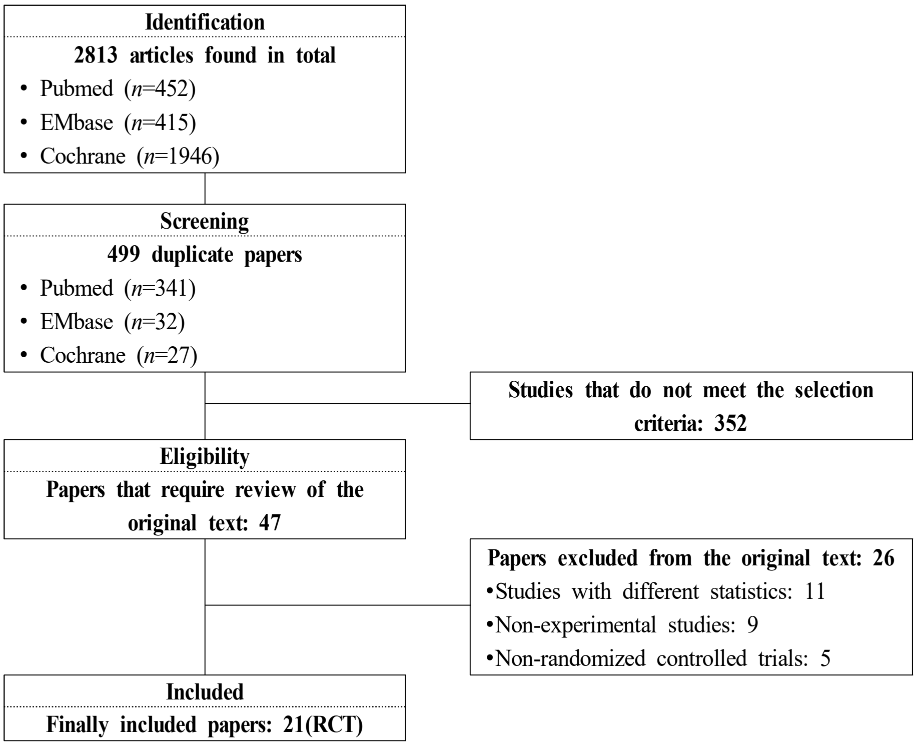

Figure 1. Flow diagram of study screening

Non-English papers, non-randomly controlled trials, papers using non-parametric statistical analysis, abstract presentations, and papers presented at conferences were excluded from the selection criteria for the exclusion criteria for this study.

by subtracting the pre-experiment from the post-experiment, and the standard deviation is calculated. The effect size was calculated using a random effects model in which weights were reset in consideration of variation among subjects of individual studies and heterogeneity between studies when homogeneity was not secured. The homogeneity of the subject studies was confirmed through Cochrane's chi-square test and I^2 test. I^2 value becomes 0% when there is no heterogeneity, 30-60% means moderate heterogeneity, and more than 75% means high heterogeneity. When data input was performed two or more post-mortem measurement of outcome variables, the average value was included, and the standard deviation was calculated using the pooled standard deviation formula. The statistical significance of the effect size (ES) was determined by the overall effect test and the 95% confidence interval (CI), and the significance level of 5% was the standard. As for the interpretation of the effect size, an effect size of ES=0.20-0.50 means a 'small effect', an effect size of ES=0.50-0.80 means a 'moderate effect', and an ES=0.80 or more means a 'large effect' (Cohen, 1988).

Ⅲ. Results

1. General characteristics of study subjects

Table 1 shows the general characteristics of 21 virtual reality intervention studies analyzed in this study. There were 3 titles before 2010 (14.3%), 6 films from 2011 to 2013 (28.6%), and 12 films from 2014 to 2016 (57.1%). The source of the study was in the order of 10 Korea (47.6%) 2 USA (9.5%) 2 Brazil (9.5)% Canada 2 (9.5%) Other countries (UK, Israel, Spain) 5 (23.8%) appear. As for the research design, all 21 papers were presented as RCT experimental papers. The mean age of the participants in the total study was 60 years, 8 (38.1%) 50-60 years old, and 10 61-70 years old (47.6%). The total number of participants in the study was 642. The types of interventions were virtual reality training (VRT) in 16 patients (76.2%) and VRT + general physical therapy (EST, NDT, occupational) in 5 patients (23.8%). As for the intervention period, the average intervention time for each virtual reality training (VRT) was 38.4 minutes/time, and the weekly average was 4.12 times/week to 4.5 weeks. In the intervention group, in which virtual reality training (VRT) and general physical therapy were added, 42.0 minutes/time for virtual reality training (VRT), and 4.2 times/week to 4.4 weeks for general physical therapy 19.0 minutes/time, and 4.0 times/week in 4.5 weeks. Finally, the outcome variables were physical activity, balance, muscle strength and endurance, and quality of life. Finally, the outcome variables were physical activity, balance, strength and endurance, and quality of life. Among them, the measurement variables of gait affecting daily living activities were the Timed Up and Go test (TUG) stride length, gait function, and gait rate. The Berg balance scale was selected as the balance variable, and the box and block test, the modified Ashworth scale, and the joint range of motion were selected as the measurement variables of upper extremity function. The effects of virtual reality training on gait, balance, and upper extremity function of stroke patients were reviewed.

Table 1. Descriptive summary of included studies (*N*=21)

Characteristic		Classification	n (%) or Mean
Total	Year	< 2010	3(14.3)
		2011 ~ 2013	6(28.6)
		2014 ~ 2016	12(57.1)
	Country	Republic of Korea	10(47.6)
		USA	2(9.5)
		Brazil	2(9.5)
		Canada	2(9.5)
		Other countries (UK, Israel, Spain)	5(23.8)
	study design	randomized controlled trial	21(100)
Participant	age (Mean=60.44)	50 ~ 60	8(38.1)
		61 ~ 70	10(47.6)
		> 71	1(4.8)
		unknown	2(9.5)
	Intervention	Kinds	virtual reality training(VRT)
			VRT + general physical therapy (EST, NDT, occupational)
	Environment	Group hospital / center	6(28.6)
		Individual hospital / center	15(71.4)
	moderator	physical therapist	10(47.6)
		Unknown	11(52.4)
	Duration (mean)	virtual reality therapy(VRRT)	38.4 min/time, 4.12 times/week 4.5 weeks
		VRRT + general physical therapy (EST, NDT, occupational)	VRT 42.0 min/time

			4.2 times/week, 4.4week + general physical therapy (EST, TDCS) 19.0 min/time, 4.0 times/week 4.5 weeks
Result and measuring tool	physical activity	FMA	5(18.5)
		JHFT	1(3.7)
		MFT	1(3.7)
		Manual dexterity (BBT)	5(18.5)
		Psychomotor function (GPT)	1(3.7)
		Motor function (WMFT)	2(7.4)
		Executive function (EFPT)	1(3.7)
		Executive function (TMT-B)	1(3.7)
		Executive function (EFRT)	1(3.7)
		CAHAI	2(7.4)
		Nine Hole Peg Test	1(3.7)
		Motricity Index	1(3.7)
		ARAM	1(3.7)
		TMWT	1(3.7)
		Stroke (CMSA-leg)	1(3.7)
		Motor and joint function (FM)	1(3.7)
		MBI	1(3.7)
	Balance	**Walking function**	
		Temporal gait parameter	1(4.8)
		Spatial gait parameter	1(4.8)
		Community-based walking activity (PAM)	1(4.8)
		Walking balance	
		BBS	6(28.6)
		TUG	4(19.0)
		FGA	1(4.8)
		FRT	1(4.8)
		Gait performance	
		Electrical walkway system	1(4.8)
		10m WT	2(9.5)
		MMAS	1(4.8)
		Static balance ability	2(9.5)
		BPM	1(4.8)
		GAITRite	1(4.8)
		WDI	1(4.8)

FMA=Fugl-Meyer Assessment(Scale); Upper extremity function (JHFT); MFT=muscle function test; BBT=Box and Block Test; WMFT=Wolf Motor Function Test; Chedoke Arm and Hand Inventory(CAHAI); FM=functional movement; MBI=Modified Barthel Index; TUG=time up and go; BBS=Berg Balance Scale; FGA=Functional Gait Assessment; FRT=Functional reach test; 10mWV=10m walking test; MMAS=Modified motor assessment scale; BPM=Balance performance Monitor; WDI=Weight Distribution Index; Functional independence measure(FIM); MMT=Manual Muscle Testing; SIS=stroke impact scale; IADL= Instrumental Activities of Daily Living; GDS=Geriatric depression scale; SF-36= Short Form Health Survey Instrument; SSQOL=Stoke specific quality of life scale; ARAT=The Action Research Arm Test; TMWT=Two-Minute Walk Test; CMSA-Leg=Chedoke McMaster Stroke Assessment Leg domain; PAM= the Patient Activity Monitor; DMMT=the digital manual muscle test (DMMT: elbow flexion and extension).

2. Effect of virtual reality intervention on gait

Measured variables on gait as an intervention effect of virtual reality training: Timed Up and Go test (TUG), stride length, and gait function A total of 6 studies were presented to measure the effect size of all four variables in walking rate on walking, and the number of subjects was 166, 84 in the experimental group and 82 in the control group. The effect size for gait was -2.19 (95% CI: -3.99, 0.38), and the effect size between the experimental group and the control group was statistically significant (p=.02). And the heterogeneity test did not show a significant result (p=.94), indicating homogeneity (Figure 2).

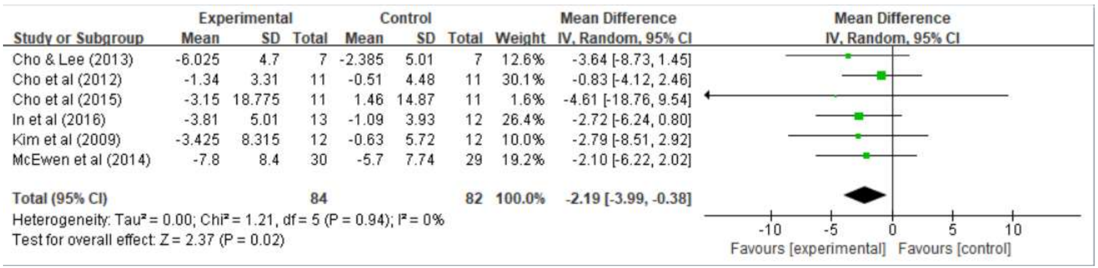

Figure 2. Forest plot of effect on gait in virtual reality rehabilitation intervention

First, four studies were presented to measure the effect size of the standing walking test, and the number of subjects was 120, 61 in the experimental group and 59 in the control group. The effect size for TUG was -1.74 (95% CI: -3.67, 0.19), and the effect size between the experimental group and the control group was not statistically significant (p=.08) (Figure 4).

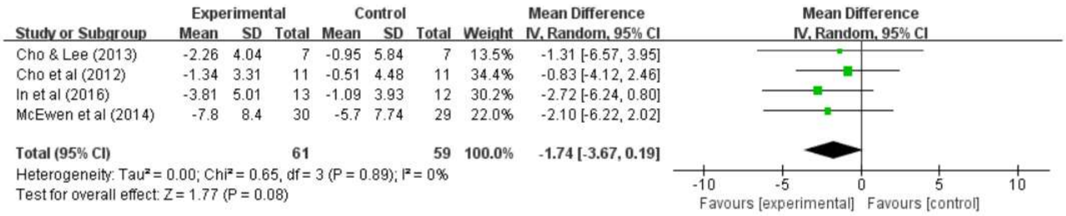

Figure 4. Forest plot of effect on gait in virtual reality rehabilitation (TUG)

A total of 3 studies were presented to measure the stride effect size, and the number of study subjects was 60, 30 in the experimental group and 30 in the control group. The effect size between the experimental group and the control group was -0.45 (95% CI: -0.97, 0.06), and the effect size between the experimental group and the control group was not statistically significant (p=.08) (Figure 6).

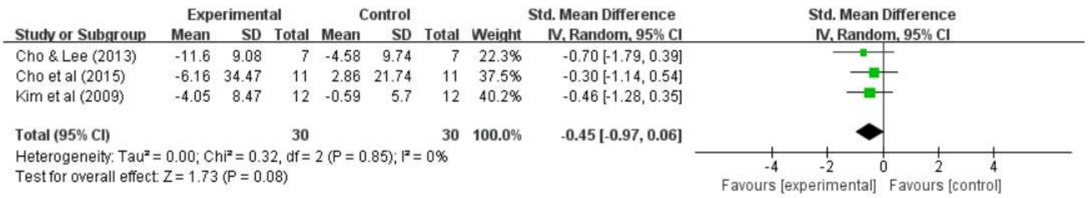

Figure 6. Forest plot of effect on virtual reality rehabilitation gait (Step length)

A total of 3 studies were presented to measure the effect size of the gait function, and the number of study subjects was 60, 30 in the experimental group and 30 in the control group. The effect size on the gait function was -0.30 (95% CI: -0.81, 0.21), and the effect size between the experimental group and the control group was not statistically significant (*p*=.25) (Figure 8).

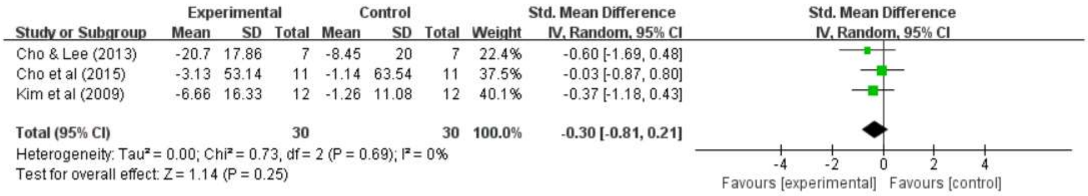

Figure 8. Forest plot of effect on virtual reality rehabilitation intervention on gait (Stride)

A total of 3 studies were presented to measure the effect size of the walking rate, and the number of subjects was 60, 30 in the experimental group and 30 in the control group. The effect size on the gait function was -0.22 (95% CI: -0.42, 0.02), and the effect size between the experimental group and the control group showed a statistically significant result (*p*=.03). However, the size of the effect was -0.22, indicating that the effect was small (Figure 10).

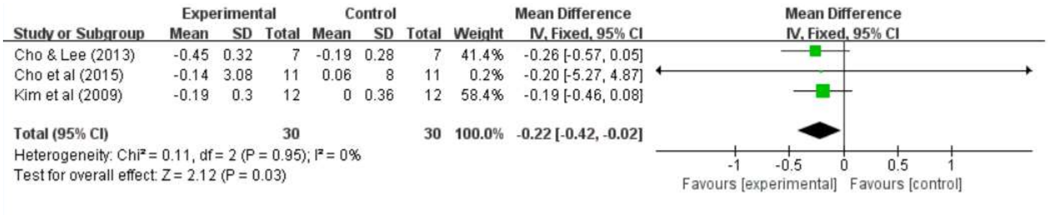

Figure 10. Forest plot of effect on gait in virtual reality rehabilitation intervention (Cadence)

2. Effect on Balance of Virtual Reality Intervention

As an intervention effect of virtual reality training, the effect size of the berg balance scale was tested as a measurement variable on balance. A total of 5 studies were presented to measure the BBS effect size, and the number of study subjects was 100, 50 in the experimental group and 50 in the control group. The effect size for BBS was -2.05 (95% CI: -3.55, -0.61), and the effect size between the experimental group and the control group was statistically significant (*p*=.005). The size of the effect was -2.05, indicating that the effect was very large (Figure 12).

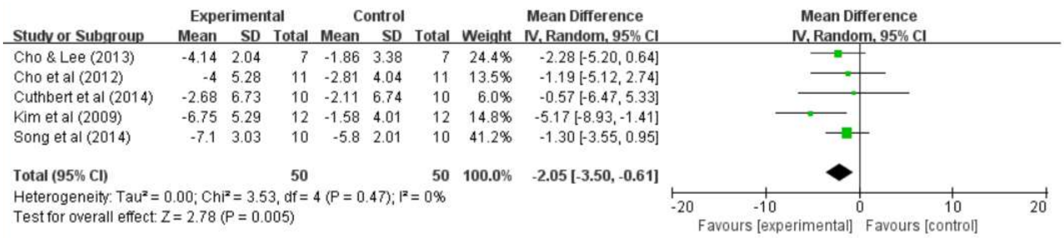

Figure 12. Forest plot of effect on the balance of virtual reality rehabilitation interventions (BBS)

As an intervention effect of virtual reality training, the effect size of each of the three variables was tested with the box and block test, the modified Ashworth scale, and the joint range of motion as the measurement variables on the upper extremity function. First, four studies were presented to measure the effect size of the box and block test, and the number of study subjects was 222, 113 in the experimental group and 109 in the control group. The effect size for the box and block test was 0.46 (95% CI: -1.03, 0.12), and the effect size between the experimental group and the control group was not statistically significant (*p*=.12) (Figure 14).

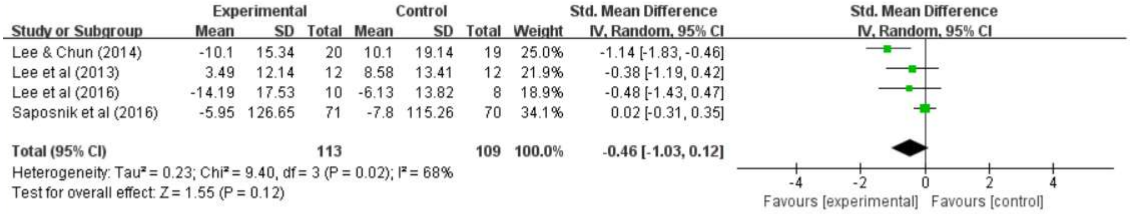

Figure 14. Forest plot of effect on upper extremity function of virtual reality rehabilitation intervention (BBT)

A total of 3 studies were presented to measure the effect size of the modified Ashworth scale, and the number of subjects was 83, 42 in the experimental group and 41 in the control group. The effect size for the modified Ashworth scale was 0.04 (95% CI: -0.26, 0.33), and the effect size between the experimental group and the control group was not statistically significant (*p*=.80) (Figure 16).

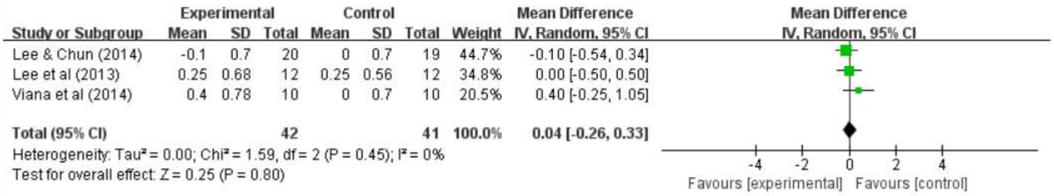

Figure 16. Forest plot of effect on upper extremity function of virtual reality rehabilitation intervention (MAS)

A total of three studies were presented to measure the effect size of the joint ROM, and the number of subjects was 60, 30 in the experimental group and 30 in the control group. The effect size for the joint ROM was 0.05 (95% CI: -0.56, 0.46), which was not statistically significant (*p*=.84). The effect of virtual reality training on upper extremity function was found to have no effect size in the measurement variable box and block test, the modified Ashworth scale, and the joint ROM (Figure 18).

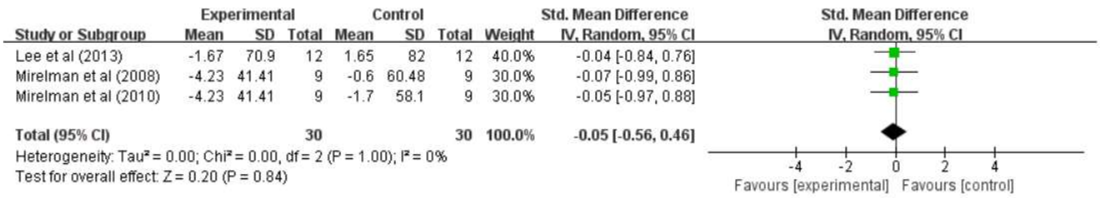

Figure 18. Forest plot of effect on upper extremity function of virtual reality rehabilitation intervention (ROM)

Ⅳ. Discussion

Impairment of gait, balance and upper extremity function due to stroke impairs activities of daily living and social participation, reduces quality of life, and increases the risk of falls (WHO, 2001; Mayo et al, 2002). Physiotherapy interventions play an important role in improving pathological gait and balance disorders and upper extremity injuries (Langhorne et al, 2009). Near virtual reality induces the rehabilitation of stroke patients to be applied in an environment similar to the real situation. The application of virtual reality is being applied in various ways, including re-education of gait and balance, and rehabilitation of upper and lower extremities. According to the study results of Cho and Lee (2013), it was reported that virtual reality training improves balance and gait control ability of stroke patients. This study focuses on confirming the effects of virtual reality training in stroke patients with gait disturbance, balance impairment, and upper extremity impairment through a systematic literature review. In this study, after applying virtual reality interventions to a total of 21 stroke patients, the effect was verified. Based on the results of this study, we would like to discuss the future research direction of virtual reality therapy intervention. As a result of the 21 studies (642 subjects in total) analyzed in this study, the effect size of the virtual reality intervention in stroke patients was 'small effect' according to the classification suggested by Cohen (1988), ES=0.20-0.50. , an effect size of ES=0.50-0.80 is interpreted as meaning a 'moderate effect', and an effect size of ES=0.80 or more is interpreted as meaning a 'large effect'. In this study, the effect size for stride length was -0.45, which was the highest among the effect sizes for walking in virtual reality. The effect size of the walking rate was -0.22, which showed a statistically significant result, but the effect size was small. The effect size on the balance of virtual reality training was -2.05, which was found to be very large. The effect size on upper extremity function was very weak with a box and block test of -0.45, a modified Ashworth scale of 0.04, and a range of motion of -0.05.

1. Effect size of virtual reality training on walking

The walking style of stroke patients is usually characterized by slow, excessive effort, urgency, and poor coordination. In addition, the method of movement shows a synergistic method of mass movement flexion and extension without selective control of the trunk and extremities (Caillet et al, 2003). Although the pattern of gait exhibited by each stroke patient varies considerably, stroke patients generally exhibit a significantly slower gait speed compared to normal people (Hsu et al, 2003). In this regard, Wagenaar and Beek (1992) reported that stroke patients were associated with decreased speed and shortened girth. von Schroeder et al (1995) showed that stroke patients showed a decrease in speed, an increase in the gait cycle, and an increase in the biceps support phase, compared to a normal person, and the paralyzed side showed a decrease in stance phase, an increase in swing phase, etc. was said to represent. The asymmetrical gait patterns in stroke patients include a slow gait cycle and gait speed, a difference in stride length between the paralyzed side and the non-paraplegic side, and a short stance phase and long swing phase on the paretic side (Mauritz, 2002). The cause of the gait pattern is slow movement due to a decrease in selective motor control ability, compensation for this on the uncompensated side, loss of proprioceptor sensory loss, and decreased movement control of the ankle joint such as stiffness, joint flexion due to abnormal coordination between flexor and extensor This is because a characteristic gait pattern called 'hemiplegic gait' appears by inducing a pattern or joint extension pattern (Sakuma et al, 2014). Due to this unique gait pattern of 'hemiplegic gait', stroke patients show an inefficient gait pattern that consumes a lot of energy when walking. After stroke, weakness in lower extremity muscle strength is a major factor in performing functional activities such as walking and maintaining posture. Foot dropping occurs due to pathological reasons such as weakness of the dorsiflexor, increased activity of the plantar flexor, and contracture, resulting in a decrease in the angle of dorsiflexion in more than 45% of patients (Bethoux et al, 2014). In this study, gait variables were selected as standing walking test, stride length, gait, and gait rate.

The results of this study showed that the gait rate function [standardized mean difference (SMD) - 0.22, 95% confidence intervals (CI) - 0.42 to −0.02] was statistically significant. It was found that there was no statistically significant effect on TUG, guaranteed distance and stride function. These results are similar to the results of Mirelman (2008) and Yang et al (2008) showing that the effect of virtual reality training on walking speed was not statistically significant. However, in the study result of Jaffe et al (2004), the VR intervention group had a significantly greater effect than the comparison group at the fast walking speed in the study on the effect of virtual reality training on slow walking speed and fast walking speed. In the study of Jung et al (2012), the VR intervention group showed improved results than the control group in the evaluation results of the standing walking test measurement tool (Cohen's d = 0.78), but it was not statistically significant between the two groups. These results show that contradictory results can be derived depending on the intervention method or measurement tool.

2. The effect size of virtual reality training on balance

In this study, the berg balance scale was selected as a tool to measure the effect of virtual reality training on balance, and the results were statistically significant (SMD −2.05, 95% CI -3.50 to −0.61), which was found to have an effect. Balance disorders are thought to be common after stroke, slowing recovery of daily activities and mobility, and increasing the risk of falls (Loewen et al, 1990; Lamb et al, 2001). In the study of Kim Jung-hwi (2005), after virtual reality training, dynamic average balance, anteroposterior stability limit, and left-right stability limit, which are dynamic balance variables, increased significantly in the training group (p<.01). There was a significant difference in both comparisons with the control group (p<.01). After virtual reality training, the berg balance scale score significantly increased in both the training group and the control group (p<.01), and there was a significant difference in the comparison of the mean difference between groups before and after training (p<.01). According to the research results (Ski æ ret-Maroni et al, 2016) and Kim et al (2011) that virtual reality-applied stepping exercise is effective in improving balance in patients with chronic stroke, balance ability of stroke patients through virtual reality games Nintendo Wii using reported to have an effect on improvement. Llorens et al (2014) reported a significant increase in BBS score and 10-m gait test over time in a study on the effect of virtual reality-based stepping exercise on balance improvement in chronic stroke patients. It is considered to have a significant impact on ability. However, in the study result of Kim (2005), it was found that the method using virtual reality did not show a significant effect on the evaluation of static balance because it consisted of a dynamic exercise task that moves the whole body. Therefore, there are still insufficient areas to conclude that virtual reality training has a significant effect on the balance of stroke patients, indicating that further research is needed.

3. Effect size of virtual reality training on upper extremity function

There was no significant effect on upper extremity function (box and block test, modified Ashworth scale, range of motion). Patients with hemiparesis after stroke show abnormal movement patterns due to abnormal muscle tone, hyperopia reflexes, joint movements, coordination, and association reactions, and the motor function of the damaged limbs is greatly reduced due to musculoskeletal disorders and sensory disturbances. As a result, it adversely affects physical activity related to daily life (Langhorne et al, 2009). In 9 studies with a total of 190 participants, the virtual reality training intervention showed a moderate to moderate effect compared to the non-intervention group in the results of the virtual reality training intervention on upper extremity function (Coupar 2012; Kim 2011a; Kwon 2012; Yavuzer 2008). In addition, virtual reality is starting to be used recently as an intervention to help functional recovery of patients with disabilities, and patients can provide various feedbacks through virtual reality similar to reality even after the onset of disease (Lucca, 2009). In addition, it was argued that the complex provision of upper extremity sensory and functional activity to stroke patients contributes a lot to upper extremity motor function rehabilitation (Scalha et al, 2011). Virtual reality training is repetitive and focused training for improving upper extremity function necessary for daily life, and the difficulty of training can be adjusted according to the patient's functional level and needs. In addition, it has the advantage of being able to experience various virtual environments through active exercises that can be done by oneself (Rizzo and Buckwalter, 1997a) suggested that virtual reality training would greatly affect the upper extremity function of stroke patients, but the results of this study showed contradictory results. However, a study that applied virtual reality as a rehabilitation method for upper extremity function of stroke patients (Merians et al, 2002) and a study that applied virtual reality to patients with cerebral palsy and Erb's palsy to increase the range of motion and movement speed of the hand (King, 1993; David et al, 2001) results. Broeren et al (2004) also reported that there was a meaningful recovery of upper extremity function as a result of intensive training using a virtual reality program that induces upper extremity use in chronic stroke patients. Considering the above results, it is implied that it is somewhat unreasonable to conclude that virtual reality training is not effective for upper extremity function of stroke patients. In this study, the upper extremity function was limited to the box and block test, the modified Ashworth scale, and the joint range of motion, indicating the need for further analysis through various measurement tools. In addition, the upper extremity function plays a greater role in daily life movements than walking and balance, so it is thought that it is not significantly affected by the virtual environment and stimuli compared to walking and balance. This study has the following limitations. Although studies were selected through literature review, only the results of studies published in English were considered. Therefore, all relevant publications could not be identified. In this study, as the gait, balance and upper extremity function measurement variables, the gait variable was the Timed Up and Go test (TUG), the stride length, gait, and gait rate were BBS, the upper extremity function was the box and block test, and the modified Ashworth scale. The measurement results were derived by limiting the joint range of motion. Therefore, it is somewhat difficult to generalize the results of this study as there is a possibility that different results may be obtained depending on the selection of the measurement variables depending on the intervention method. In future studies, it is suggested that more intervention methods and studies considering measurement variables are needed.

Ⅴ. Conclusion

The purpose of this study was to investigate the effects of virtual reality training on gait, balance, and upper extremity function in stroke patients by comparing the group with and without VR training intervention on gait and balance and upper extremity function and activity of stroke patients. As a result of the study, it was found that virtual reality had a significant effect on the gait and balance functions of stroke, but did not affect the upper extremity function.

Therefore, it is shown that virtual reality training can be an effective method to improve the balance and gait status of stroke patients. Although virtual reality training has many advantages that the subject can concentrate more efficiently during exercise through the virtual environment, the effect of virtual reality has not been sufficiently investigated, so it is thought that more studies should be conducted in future studies. When the use of virtual reality and interactive video games is used as an adjunct to general treatment (to prolong the total treatment time), or when compared with the same amount as conventional treatment, it is considered that virtual reality has the effect of improving balance and gait function. However, there was insufficient evidence to draw conclusions about the effects of virtual reality and video games on walking speed and overall motor function.

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Appendix. Figure

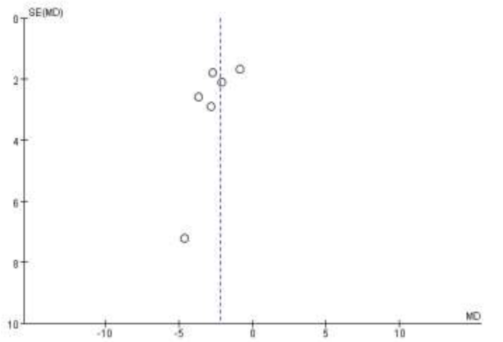

Figure 3. Funnel plot of virtual reality rehabilitation

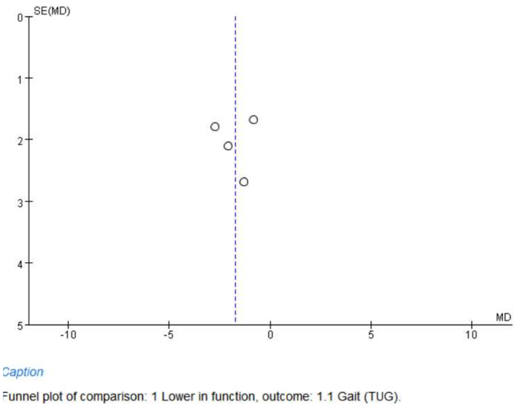

Figure 5. Funnel plot (TUG) of virtual reality rehabilitation gait

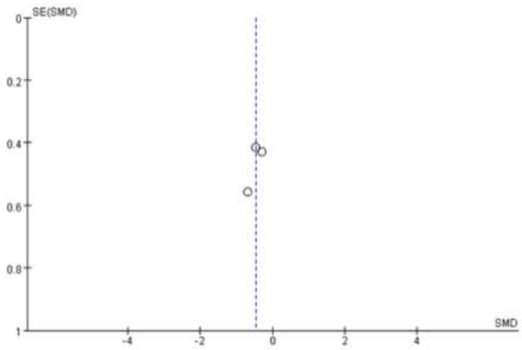

Figure 7. Funnel plot of virtual reality rehabilitation gait (Step length)

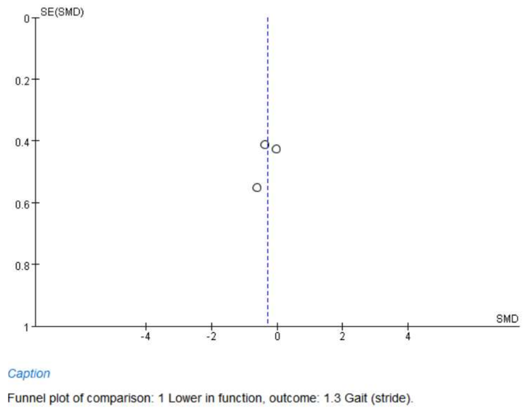

Figure 9. Funnel plot of virtual reality rehabilitation gait (Stride)

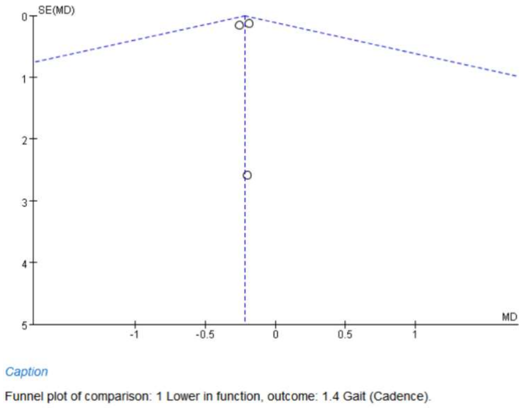

Figure 11. Funnel plot of virtual reality rehabilitation gait (Cadence)

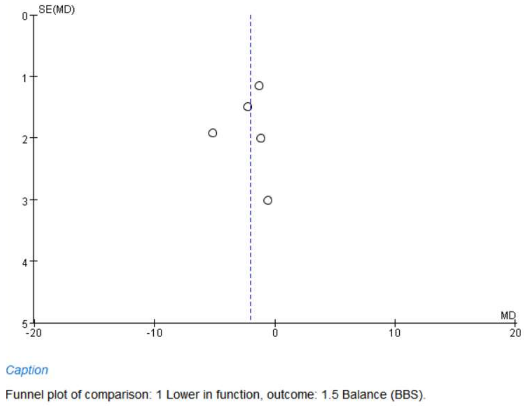

Figure 13. Funnel plot of virtual reality rehabilitation balance (BBS)

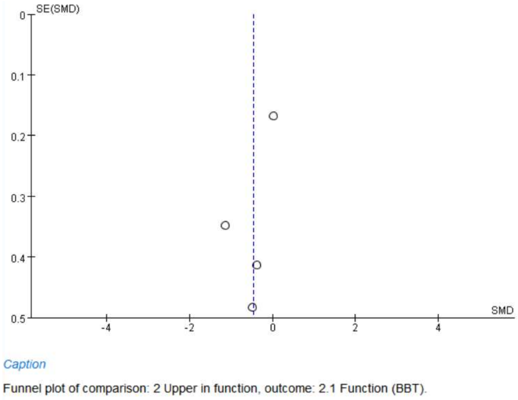

Figure 15. Funnel plot of virtual reality rehabilitation upper extremity function (BBT)

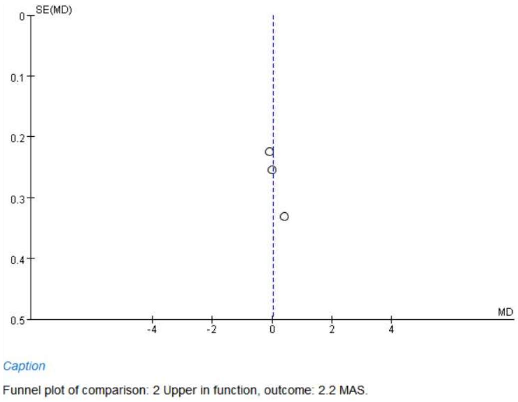

Figure 16. Funnel plot of virtual reality rehabilitation upper extremity function (MAS)

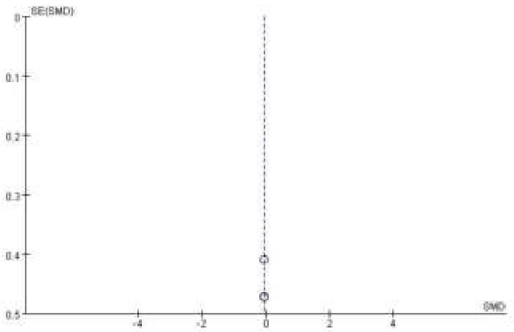

Figure 19. Funnel plot on upper extremity function of virtual reality rehabilitation (ROM)