Virtual reality-based rehabilitation in the treatment of sarcopenia among residents in rural caring facilities

[study protocol]

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Subject Characteristics and Ethical Statements

It was a prospective non-randomized controlled study, conducting at southern rural Taiwan from January 2019 to Octobor 2019. Older adults aged more than 60 and lived in the nursing home or went to daycare center regularly were recruited for screening. All the residents with sufficient cognitive function and physical fitness to perform training that lasts for 30 minutes and meeting the criteria of sarcopenia by AWGS as the following (1) muscle mass less than 7.0 kg/m^2 for men and 5.7 kg/m^2 for women by using bio-impedance analysis and (2) handgrip strength less than 26 kg for men and 18 kg for women or usual gait speed less than 0.8 m/s), participated the final VR-REH. Participants with the presence of significant cardiopulmonary disease with oxygen supplement, uncontrollable high blood pressure,recent infection, or other diseases prohibited to participate in sports exercise by the American College of Sports Medicine (ACSM) guideline are excluded(1). To determine the sample size, the G*Power software (version 3.1.9.2, for Windows was used. The alpha level and the power were set as 0.05 and 0.8. The effect size was set at high effect (0.8) and the minimal estimated sample size was 15 subjects.

VR-based rehabilitation programs

The program was combined with progressive resistant training and functional movement of dominant upper limb. The device of the VR included one computer, one Oculus Rift headset, one constellation, and one Leap Motion sensor (Figure 1). The Oculus Rift headset uses an organic light-emitting diode (LED) panel for each eye, each having a resolution of 1080×1200. These panels have a refresh rate of 90 Hz and globally refresh. Oculus Rift headset is portable, lightweight, and works with standard PC hardware. Constellation is the positional tracking system of Oculus Rift, used to track the position of the user's head as well as other VR devices, consisting of external infrared tracking sensors that optically track specially designed VR devices(2). The hand-hold sensor we used was Leap Motion rather than Oculus Touch controller since the hand dexterity of our participants was insufficient generally. The Leap Motion controller is a small universal serial bus peripheral device and could be mounted onto a VR headset. Leap motion is designed for hand tracking in VR by using two monochromatic infrared cameras and three infrared LEDs. It could observe a roughly hemispherical area, to a distance of about 1 meter(3).

The software used in the VR-REH contained 4 different commercialized VR games, including (1) Leap Motion Blocks ®(2) Slum Ball VR Tournament ®(3) VR Super Sports ®10th edition- Basketball (4) VR Super Sports ®10th edition- Soccer (Figure 2), listed in performing order.We analyzed the tasks according to the basis of the motor learning theory of Gentile and selected the game based on body stability and stationary conditions for initial practice(4) (Table 1). Each game was performed by the participants for 6 minutes with the assistance by a well-trained physiotherapist assistant (PTA). There was a one to two minutes break between each game for switching the setting and adjustment for the Oculus Rift headset. One designed mass would be held on the dominant hand of the participants and the weight increased gradually during the duration of the VR-REH, adjusted by each participant's ability. There was also one 5-minute warm-up and cool-down exercise before and after the VR-REH, respectively. Based on the recommendation of ACSM(1) and previous studies(5), the VR-REH lasted for 12 weeks, twice per week, and 40 minutes per time. There was at least 1-day break between each training.

Baseline screening and outcome measurements

Every participant went through fourevaluations in this study. The first evaluation was the baseline evaluation, which was done to make sure the subjects meet the definition sarcopenia before the VR-REH. The second, third, and fourth evaluation was conducted at 4, 8, and12 weeks after VR-REH, respectively.The primary outcomes included appendicular skeletal muscle mass (ASMM) index (ASMMI), dominant hand grip strength (HGS), and usual gait speed while the secondary outcomes were the range of motion (ROM) of joints of the dominant upper limbs, the strength of the biceps and tricepsbrachii muscles, and the scores of box and block test (BBT).

Anthropometry and Body Composition

Vector bioelectric impedance analysis (VBIA) was used in this study to measure the body composition of participants. VBIA was performed with the bioelectrical impedance vector analysis software by using the resistance–reactance graph method(6). Zeus 9.9 PLUS (Jawon Medical Co. Ltd., KungsangBukdo, South Korea) was used to analyze the body composition. The machine sent a minute electric current and measured the body composition by using personal data that have been saved (height, weight, sex, age, and newly calculated body impedance) via the tetrapolar electrode method (electrodes were located on both hands, both soles of the feet, and both ankles of participants with frequencies of 1, 5, 50, 250, 550, and 1,000 kHz and a current of 360 uA). ASMMI was defined as appendicular skeletal muscle mass (kg) divided by height squared (m^2)(7).

Measurement of dominant hand grip strength

The measurements of the HGS were determined by means of the JAMAR-Dynamometer (J A Preston Corporation, New York, USA) using all five notches. It is a hydraulic instrument measuring the isometric strength in kilograms and numerous studies have investigated the reliability of it in different older populations(8). Each participant was shown the correct handling and positioning of the instruments: they were asked to sit straight, with the upper arm in a neutral position and a 90° flexion of the elbow. The forearm was held in neutral position and the wrist at a 0 to 30° extension. The instrument was held freely: neither the hand nor the forearm was allowed to rest on a surface(9). Three measurements were done and recorded as the average of the three measurements and the participants rested for 1 minute in between measurements.

Measurement of the gait speed

We evaluated the usual gait speed bymeasuring the time it took for a participant to walk on a 6 meter-long corridor without barrier as suggested by AWGS(7). Timing started after the subject walking and stopped at the point when a subject reached a distance of 6 meters. The gait speed was measured twice and the final measurement was the average of the two. The participant was allowed to rest for 10 minutes in between measurements.

Measurement of range of motion of joints of dominant upper extremity

ROMs of dominant upper extremity that are easily limited in older adults were measured by goniometer under standard positions(10), including shoulder flexion, abduction, and external rotation; elbow flexion and extension; forearm supination and pronation; and wrist flexion and extension.

Measurement of dominant biceps and triceps brachii muscle strength

We used MicroFET®3(Hoggan Health Industries, West Jordan, UT) to measure the maximal voluntary isometric contraction (MVIC) of the biceps and tricepsbrachii muscles. MicroFET®3 is an electronic hand-held dynamometer that could detect 0-150 lbs force with high reliability and validity(11). To measure the MVIC of biceps brachii muscle, the participant was asked to lie on the treatment table with elbow forming a 90-degree angle to the horizontal such that the arm is perpendicular to the limb and the tester placed MicroFET®3 on the ventral side of the arm and align it with the ulnar styloid of the participant. Then, the tester exerted a resistant force towards the device and encouraged the participant to against the force with their maximum strength. To measure the MVIC of triceps brachii muscle, the procedure was the same as in measurement of biceps brachii muscle except that the tester placed the device on the dorsal side of the participant's arm(12). The MVIC was measured twice and the final measurement was the average of the two. The participant was allowed to rest for 1 minute in between measurements.

The box and block test

The set-up of the BBT includes a wooden box with 150 wooden blocks inside. The wooden box is divided into two compartments. One filled with blocks, and the other is empty. During this test, the patient is seated upright in a chair and needs to transfer the wooden blocks, one by one, from one compartment to the other. The patient is scored based on the number of blocks he or she can transfer from one compartment to the other in 60 seconds. The BBT has high test-retest reliability and validity and could measure the unilateral gross manual dexterity in different populations(13).

Table 1. Virtual-reality games corresponding to Gentile's skill categories (27)

		Action function			
		Body stability[c]		Body transport[c]	
Environment context[a]		No object manipulation[d]	Object manipulation[d]	No object manipulation[d]	Object manipulation[d]
Stationary regulatory conditions	No intertrial variability[b]		Leap motion block		
	Intertrial variability[b]				Basketball
In-motion regulatory conditions	No intertrial variability[b]				
	Intertrial variability[b]		Slum Ball VR Tournament		Soccer

[a] The regulatory conditions indicate relevant environmental features that constrain movement execution and may either be stationary (stationary regulatory conditions) or moving (in-motion regulatory conditions).

[b] With the indicator, intertrial variability is used to differentiate between regulatory conditions that change between trials (intertrial variability) and those that do not (no intertrial variability).

[c] Body orientation indicates whether an action requires the performer to move from one location to another (body transport) or not (body stability).

[d] Object manipulation indicates whether an object has to be controlled during the action performance (object manipulation) or not (no object manipulation).

According to Gentile, the easiest skill category can be found at the top left position. Moving either rightward or downward in the table renders the skill category more difficult.

Figure 1.

The hardware of the virtual-reality based rehabilitation. The participant sat or stood 1 meter in front of the screen and was supervised by one well-trained caregiver.

A: Oculus Rift Headset

B: Oculus constellation: sensor for headset

C: Leap Motion: sensor for hand movement

D: Hand-hold device

Figure 2.

The software of the virtual-reality based rehabilitation.

A: Leap Motion Blocks ®

Leap Motion Blocks ® offers a platform in which the subjects can play freely with blocks- they can create blocks, grab, push, pile and throw blocks around. The subjects are guided to perform a sequence of actions in the game. First, they need to pinch and stretch with both of their hands to create several blocks. Then, they need to push, pile and throw blocks around.

B: Slum ball VR tournament ®

In Slum Ball VR Tournament®, objects such as tin cans and balls will keep flying towards the player, and the player needs to hit the upcoming objects back to specific location.

C: VR Sports- basketball ®

D: VR Sports- soccer ®

In VR Super Sports ® 10th edition- Basketball, player needs to keep grabbing a basketball and throwing it out into the basket while the participant becomes the goalkeeper of a soccer game and needs to use both of their hands to block the upcoming ball.

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Figure Captions

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