Clinical Research

Potential use of dance game simulator in eye-leg coordination improvement: study on healthy participants

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ABSTRACT

BACKGROUND Game-based therapy has the potential to enhance patients' participation in neurorehabilitation by making it more engaging and inspiring. Thus, this research aimed to investigate the efficacy and validity of a dance game simulator to improve eye-leg coordination diagnosis and treatment.

METHODS 59 healthy participants aged 19–38 were assessed using a foot tapping test (FTT), lower extremity motor coordination test (LEMOCOT), modified agility ladder drill test, and total game score. The dance game system used 50, 100, and 150 beats per minute (bpm) songs to improve eye-leg coordination. The intervention group, consisting of 10 participants, received 15 sessions of 10-min play (3 songs each), while the control group, with 8 participants, had only 2 sessions: 1 at the start and 1 at the end. Rank correlation test compared game-based tests to validity, and *t*-tests analyzed pre- and post-game treatment results.

RESULTS The validity of the LEMOCOT and the dance game with 100–150 bpm tempo in 59 healthy participants is showing correlation coefficients of r = 0.302 (right leg) and r = 0.305 (left leg), with $p<0.01$ for each leg. The dance game simulator improved FTT, left LEMOCOT, modified agility ladder drill test, and the overall dance game score after 15 sessions in the intervention group. However, these improvements were not statistically significant compared to the control group.

CONCLUSIONS Game-based therapy offers an efficient alternative to traditional eye-leg coordination testing, providing a practical, clinically effective home rehabilitation method. Further research could enhance neurorehabilitation outcomes.

KEYWORDS coordination training, neuromuscular testing, neurorehabilitation, physiotherapy measurement method, simulation training

Industry 4.0 introduces a trend of automation, big data management, and machine learning, while Industry 5.0 enhances health education and healthcare by integrating human-machine interaction and internet of things for data-driven health analysis and decision making. Rehabilitation is a key domain that may benefit from these advancements.[1] In rehabilitation, the foundation for effective and efficient services is advancements in sensor monitoring and measurement, as patient progress can be stored in real-time and transformed for further analysis. A 2020 review classified the benefits of implementing rehabilitation technologies, including the use of sensor systems in healthcare and physical rehabilitation, home medical assistance systems, and continuous health monitoring.[2]

Advances in rehabilitation technology include sensor-based activity recognition, such as Kinect remote sensors, orthopedic exercise monitoring, and smartphone-based activity tracking.[3] Electromechanically-assisted training improves walking

ability and speed significantly within 3 months in patients with stroke more than rehabilitation without the device.[4] In addition, sensorimotor exercises have significantly improved balance and functional reach tests.[5] Game-based therapy enhances engagement in repetitive and intensive treatments, such as stroke rehabilitation in the neurological field.[6] It has improved pediatric balance, gross motor function, and standing balance, and children have a strong interest in game-based therapy.[7] In addition, game-based therapy offers physical and cognitive benefits for older adults by reducing fall risk and enhancing cognitive function.[8]

Several methods of sensorimotor measurement of lower extremity coordination are used, including the foot tapping test (FTT),[9] lower extremity motor coordination test (LEMOCOT),[10] and agility ladder drills test for fitness. The validity and reliability of these tests have been previously reported.[11] However, instruments such as LEMOCOT rely on manual execution without effectively utilizing information technology. Although research regarding sensorimotor aspects of this test is widely applied in neuromuscular rehabilitation, little research has been reported regarding the use of visual-sensorimotor combination simulators based on measurable motion platforms.

To address the lack of established standards to evaluate game-based therapy, game-based scores from participants were assessed to confirm the theoretical concept validity related to similarly measured clinical variables in lower extremity coordination tests. Therefore, this study aimed to analyzed the validity and efficacy of a game-based dance motion simulator for measuring eye-leg motor coordination.

METHODS

Study design and participants

Participants in the validation and quasi-experimental studies were selected voluntarily from Universitas Binawan, Kalibata, East Jakarta, Indonesia in 2022 using purposive sampling. This study involved 59 healthy participants aged 19–38 years who had not experienced any leg or foot injuries in the month before the study. All of the participants provided informed consent for the use of their data and patient identification. The FTT, LEMOCOT, modified agility ladder drill test, and total dance game score data were collected as part of the validation study protocol.

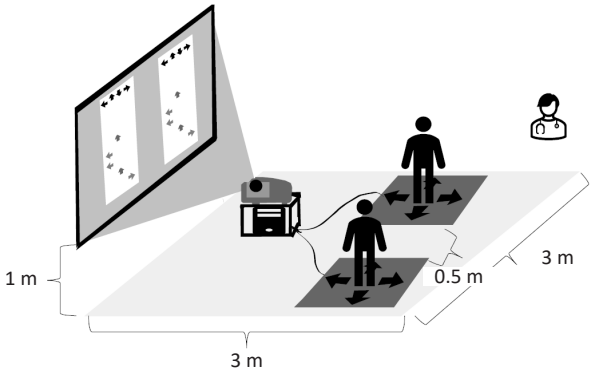

Figure 1. Dance game platform infrastructure developed for lower limb coordination test and exercise

Interventions

In this quasi-experimental study, 59 participants were divided into control and experimental groups using purposive sampling, with a minimum sample size of 10 participants per group, as determined using the Lemeshow formula. A game simulator inspired by Dance Dance Revolution, StepMania (MIT License, USA),[12] was used to assess changes in the participants' eye-leg coordination. Participants in both groups were permitted to choose music within the following categories: music-1: <50 beats per minute (bpm), music-2: 50–100 bpm, and music-3: 100–200 bpm. The participants were instructed to press the pad accurately according to the arrow direction on the screen while the music played (Figure 1). Participants from the intervention group underwent 15 sessions of 10-min training, each consisting of three songs, for 2 to 3 weeks according to their training schedule. In contrast, participants in the control group only have an initial measurement session and an evaluation session. The total score for each song was recorded and calculated.

Outcome measures

Foot tapping test (FTT)

The FTT is a clinical assessment of lower extremity coordination. The participants swiftly moved the sole of their foot from the metatarsal area to the phalanx via dorsiflexion-plantar flexion movements for 10 sec, ensuring that their heel remained on the ground. The physiotherapist counted the number of taps for each foot and both feet.[13]

Lower extremity motor coordination test (LEMOCOT)

The LEMOCOT is commonly used in healthcare and rehabilitation settings to evaluate the functional

capacity and performance of patients recovering from neurological conditions. Participants were instructed to touch two target markers on the floor with their big toes as quickly as possible for 20 sec and the number of times each foot successfully touched the target was recorded.[10]

Modified agility ladder drill test

The modified agility ladder drill test was specially designed to measure physical fitness for sport rehabilitation. The agility ladder test developed by Smits-Engelsman et al[14] in 2019 was adapted so that the participants could quickly stand on both feet and step according to patterns for 60 sec (Figure 2). A physiotherapist recorded the number of successful sets completed in 1 min.[14]

Statistical analysis

The Kolmogorov–Smirnov and Shapiro–Wilk tests were used to assess normality, the Spearman's rank correlation test was used for validation, and the paired sample *t*-test was used to analyze quasi-experimental data. The validity between the coordination and game-based platform tests was quantified, and the treatment effects of game-based tests on lower motor coordination were identified. Data management was performed using SPSS software version 22 for Windows (IBM Corp., USA).

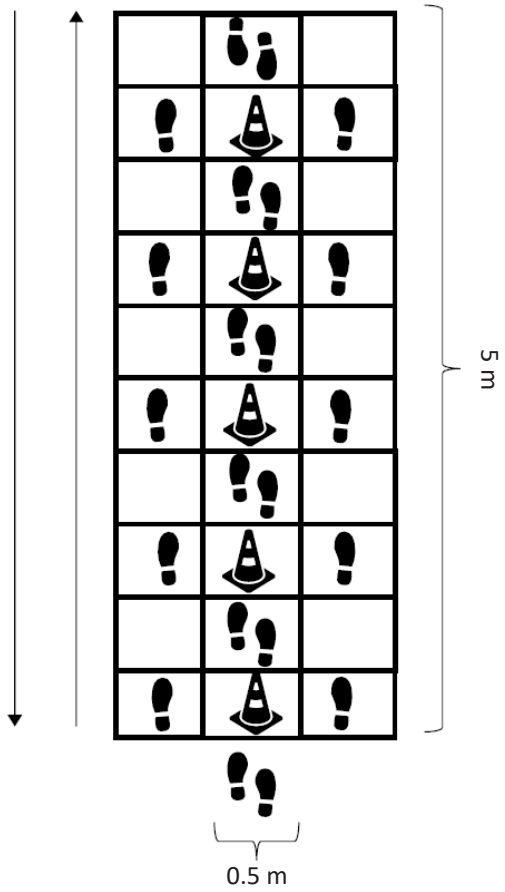

Figure 2. Modified agility ladder drill test

RESULTS

A total of 59 individuals (13 males and 46 females) from Universitas Binawan participated in this study. The distribution of demographic characteristics is summarized in Table 1.

The lower extremity coordination measurement of the FTT, LEMOCOT, and modified agility ladder drill test for all participants has been recorded (Table 2). The simulator scores represented how accurately the participants hit the dance pad and were shown on the screen. The numbers generated from the game simulator ranged from 5 to 10 digits; therefore, logarithm 2 was used to simplify the analysis. The lowest average score was 15.71 (7.7), which was attained at 100 bpm music, and the highest score was 21.64 (1.11) during 150 bpm music.

A statistical correlation analysis was conducted to validate the game-based assessment against the conventional coordination test. Coordination tests such as FTT, LEMOCOT, and modified agility ladder drill test were then analyzed with scores from the dance game simulator platform (StepMania) (Table 3). The log2-transformed scores from the 100- and 150 bpm music categories were significantly correlated with the scores of the leg movement coordination test in a low-to-moderate manner. However, the game scores were

Table 1. Characteristics of the study participants

Characteristics	Mean (SD)	Min–max
Age (years)	21.41 (3.5)	19–38
Height (cm)	160.07 (9.6)	143–186
Weight (kg)	63.3 (16.9)	41.65–131
BMI (kg/m^2)	24.5 (5.4)	17.07–41.10
Systolic blood pressure (mmHg)	120.73 (14)	97–171
Diastolic blood pressure (mmHg)	79.10 (10.57)	61–111
Oxygen saturation (%)	97.88 (1.66)	90–99
Heart rate (bpm)	88.93 (15.8)	62–133

BMI=body mass index; bpm=beats per minute; SD=standard deviation

Table 2. The frequency distribution of coordination measurements and the scores from dance game simulation for each bpm categories

Variables	Mean (SD)	bpm, min–max
FTT		
Right	43.54 (7.8)	23–59
Left	41.29 (7.1)	26–58
Both feet	41.27 (8.7)	23–68
LEMOCOT		
Right	45.02 (15)	22–86
Left	41.22 (12.8)	24–77
Modified agility ladder drill test	8.46 (1.7)	5.6–12.6
Dance game simulation		
Log2 dance score: 50–100 bpm	19.39 (2.2)	15.14–22.83
Log2 dance score: 100 bpm	15.71 (7.7)	0–22.88
Log2 dance score: 100–150 bpm	21.64 (1.11)	17.93–22.98
Log2 total score	22.34 (1.21)	18.12–24.44

bpm=beats per minute; FTT=foot tapping test; LEMOCOT=lower extremity motor coordination test; SD=standard deviation

not correlated with the FTT or modified agility ladder drill test scores.

For efficacy investigation, the paired sample *t*-test results between the control group (n = 8; two participants dropped out after more than three absences) and the intervention group (n = 10) are shown in Table 4. The pre- and post-test results of the right and left FTTs significantly different in the control group (n = 8). In the intervention group (n = 10), the pre- and post-test results of the right and left FTTs (p = 0.011 and 0.006, respectively), left LEMOCOT (p = 0.012), and modified agility ladder drill test (p = 0.014) were significantly different. The Levene's test was not significantly different between the groups. After 15 rounds of game-based training, the FTT, LEMOCOT, and modified agility ladder drill test scores were not significantly affected.

DISCUSSION

Motor coordination tests are commonly used to assess motor skills, coordination, and attention in clinical settings. The game-based dance measurement test has demonstrated potential clinical consistency in evaluating eye-leg movement coordination compared to the LEMOCOT. In the current study, functional parameters measured by the FTT, LEMOCOT, and modified agility ladder drill test significantly improved, especially in the intervention group, though only minimal clinically important differences were observed in the control group. Additionally, in the 100- and 150 bpm music categories, the scores significantly improved in the intervention group in this study, suggesting implicit learning accuracy in eye-leg coordination.

The LEMOCOT score and the 100–150 bpm music dance game simulation score were significantly correlated in this study. The game-based test showed moderate reliability for right and left leg coordination. Similarly, the total game-based score when all music types were used was correlated with the LEMOCOT score. Motor coordination relies on the accuracy of muscle work, which relies on sensory information and body position to produce functional movements.[15] Similar to the game-based dance approach, the nature of the LEMOCOT, which focuses on the speed and

Table 3. Spearman's rank correlation coefficient of FTT, LEMOCOT, and modified agility ladder drill test with the result of each bpm on dance game simulator platform

Variables	r			
	Log2 dance score: 50–100 bpm	Log2 dance score: 100 bpm	Log2 dance score: 100–150 bpm	Log2 total score
FTT				
Right	0.000	0.095	−0.032	−0.029
Left	−0.036	0.164	0.028	0.024
Both feet	0.198	0.135	0.111	0.184
LEMOCOT				
Right	0.139	0.045	0.302*	0.362†
Left	0.229	0.004	0.305*	0.336†
Modified agility ladder drill test	0.112	0.178	0.118	0.099

bpm=beats per minute; FTT=foot tapping test; LEMOCOT=lower extremity motor coordination test
*Correlation is significant at p<0.05 (2-tailed); †correlation is significant at p<0.01 (2-tailed)

Table 4. Comparison of pre- and post-intervention results and differences between control and intervention groups

Variables	Control, mean (SD)		Intervention, mean (SD)		Within intervention group, *p*	Between group, *p*
	Pre	Post	Pre	Post		
FTT						
Right	45.63 (7.7)	56 (5.2)	43.6 (8.7)	53.1 (7.6)	0.617	0.378
Left	42.13 (6.3)	51.75 (7.1)	43.5 (5.8)	49.9 (9.9)	0.418	0.665
Both feet	47.13 (8.7)	49.50 (5.9)	45.7 (6.6)	47.8 (10.2)	0.205	0.683
LEMOCOT						
Right	57.88 (16.1)	53.88 (20.8)	45.5 (14.9)	54.3 (9.5)	**0.047**	0.959
Left	53.50 (14.8)	51.50 (17.6)	40.5 (7)	49.5 (11.1)	0.090	0.773
Modified agility ladder drill test	9.7 (2.3)	10.3 (1.6)	8.36 (1.9)	9.23 (2.1)	0.432	0.225

FTT=foot tapping test; LEMOCOT=lower extremity motor coordination test; SD=standard deviation

accuracy of the big toe when hitting the proximal target, may account for these findings.[10]

The FTT is used to measure lower limb coordination in individuals with Parkinson's disease.[9] This test involves tapping the participant's foot on the ground rapidly for 10 sec while minimizing or eliminating visual sensory input during the test.[13] In contrast, the agility ladder test are commonly used as physical fitness assessments of healthy individuals or in post-rehabilitation programs to evaluate balance, coordination, agility, and speed.[14] This assessment includes the deliberate execution of pre-planned motions to affect changes in direction rapidly. While these movements require visual scanning techniques, the essence of this evaluation test differs from that of game-based dance assessments in which participants must remain within specific areas.[16]

Directing the learner's focus to the outcomes of their actions through a multisensory approach by combining auditory and visual stimuli as well as point accumulation is more efficient than concentrating solely on physical movement training at home.[17] Moreover, interventions using music at various bpm in dance simulation games may improve brain plasticity due to its adaptive pattern. Movements with a repetitive pattern provide efficient neuromotor therapy, similar to neuromuscular electrical stimulation in rodent models, while providing an adaptive movement pattern generator.[18] Neuromuscular plasticity induced by repetitive movement may affect muscle activation patterns, proprioception, and motor unit recruitment in patients with chronic spinal cord injuries.[19] A dance simulation game can be adjusted from easy to difficult during each training session to stimulate the neuromuscular control learning process, as demonstrated by Lee and Zhang in 2018.[20] Dance simulation games can be considered neuromuscular exercises that involve activities similar to increasing core stability, resistance, balance, and agility in each gaming session. These features enhance postural control and function by challenging the lower limbs based on the game's cursor on the screen.[21] Furthermore, dance simulations can complement conventional, occupational, or physical therapy rehabilitation programs.

In this study, some measures of lower extremity coordination were improved in the intervention group after 15 training sessions. In a previous study,[22] twice weekly training with a 45-min video game resulted in good improvement in spatiotemporal gait after 6 weeks. In another study, 7 months of twice-weekly, 1-hour training sessions in traditional dance significantly improved balance and fine motor skills.[23] Despite differences in participant characteristics and outcome measurements among these studies, the current study helps assess the effectiveness of a short-term, game-based dance intervention on eye-leg coordination.

However, this study had several limitations. Although game-based therapy is an enjoyable and interactive method, the dance games used in the current study do not address specific functional tasks commonly required in rehabilitation, such as walking, running, or sit-to-stand movements, rendering this method more suitable for home use. Additionally, as the study included university students whose demographics and characteristics may differ from

those of clinical or hospital patients with neurological conditions, the generalizability of the findings may be limited. To improve the efficacy and validity of dance game-based approaches in the future, comparative studies with kinetic and kinematic parameters should be conducted to provide more objective and accurate measurements of eye-leg lower extremity coordination. Increasing the sample size in both the intervention and control groups may also yield a more accurate representation of the effectiveness of the dance game simulation method in enhancing eye-leg coordination.

In conclusion, this study demonstrated the validity of using dance game simulator scores as a game-based measure of lower extremity coordination, especially for eye-leg coordination, by comparing the scores to those of other clinical measurement tools. In addition, game-based training sessions improved eye-leg coordination. Therefore, incorporating dance game simulators into standard rehabilitation programs may complement traditional methods and enhance patient outcomes.

Conflict of Interest

The authors affirm no conflict of interest in this study.

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