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Effect of Video Games for Rehabilitation on Mobility in Autonomous Older People

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Abstract

BACKGROUND: Autonomous elderly are generally healthy persons in stable clinical status, who do not have any exacerbations, despite of the presence of chronic polymorbidity. Video games for rehabilitation (VGR) could provide more fun and emotion in the routine physiotherapy (PT) sessions and to attract more people stay physically active.

AIM: The aim of the study was to evaluate the effect of self-designed 3D camera VGR on mobility and motor abilities in generally healthy older people.

MATERIALS AND METHODS: The type of the research is an experimental single-centered study, pre-test and post-test design, conducted at a physical rehabilitation outpatient center. The study is conducted with fifty healthy older people, divided into two groups. The assignment into two groups was according to the preference of the participants to attend video games after routine PT sessions for 7 weeks, 3 times weekly. The experimental group (EG) included 24 women (mean age 76.75 ± 6.89) and the control group consisted of 26 women (mean age 73.69 ± 6.89). The persons were allocated according to their willingness to participate in the study and inclusion (age above 65 years, cooperative, agreeing to participate, and willing to sign a consent form) and exclusion criteria (current exacerbation of a chronic disease, sudden onset of an acute illness, or trauma). The effect on the calf muscle mass, balance, and gait in both groups after the intervention, was evaluated by calf centimetry, Romberg test, functional reach test, 5 times sit-to-stand test, and 10-m walk test.

RESULTS: The applied video games positively affected the functional mobility, strength, and endurance of the lower limbs in the EG. Significant differences between the groups were found regarding static standing balance ($p < 0.01$), functional balance ($p < 0.05$), and maximum speed gait ($p < 0.05$) assessed by Mann–Whitney U-test, Wilcoxon, and Student’s t-test.

CONCLUSION: The present self-designed video game applied as an additional intervention was more effective than conventional PT alone in mobility, balance, and gait in apparently healthy older people.

Introduction

In general, healthy older persons are those, who are in a stable clinical condition and do not have any exacerbations, despite of the presence of chronic multimorbidity. The global ageing and rising life expectancy is associated with ageing physiological changes like mobility decrease combined with behavioral changes leading to disability [1]. The prevalence of the diminished mobility leads gradually to disability develop during aging, but the related factors are not well clarified. A great variety of factors could be associated with disability as age, sex, overweight, smoking, physical inactivity, musculoskeletal and cardiopulmonary diseases, diabetes mellitus, etc. [2]. The effect of ageing processes manifests in changes and impairment of all body systems, including musculoskeletal and nervous system, deteriorate motor abilities, reduces the active and passive range of motion in the joints. Skeletal muscles also undergo atrophic changes, with a reduction in muscle strength, and endurance which can contribute to fatigue, weakness and reduced tolerance to exercise. Age-related changes in nerve pathways slow the conduction velocity of nerve impulses to skeletal muscles and prolong their reaction time. Changes in the nervous system cause muscles to have reduced tone and ability to contract [2]. Mobility limitations have been reported as increasingly prevalent in older persons affecting about 35% of persons aged 70 and most persons over 85 years. They are associated with increased risk of falls, hospitalization rate, a deterioration of quality of life, and mortality [3].

The gait of older people changes in connection with disturbances in the corresponding nerve centers and weakness of the lower limbs muscles. For these reasons, the support time in the gait cycle is increased and the gait is altered [4], [5]. It leads to a disturbance in biomechanical factors of balance (center of gravity, line of gravity, support area, and stability limits) [4], [6], [7]. Postural stability also depends on the coordination of movements in the lower limbs, and the ankle joint which is very important factor in physiological musculoskeletal control [4], [5], [8].

The video games for rehabilitation (VGR) stimulate limb movements and improve their function. They are suitable for self-administration at home as the therapist can remotely monitor engagement, individual progress, and make adjustments to the program. The ability to maintain user profiles is provided, which helps the player assess their own progress through multiple sessions over a long period of time and encourages them to improve their score. The role of the therapists is to select and adapt the games to meet the person's needs during the treatment [9], [10].

The previous studies discussed the role of VGR in different ages and health conditions. The feasibility of the video games implementation in the conventional physiotherapy (PT) sessions could play an important role in the rehabilitation of the persons as a part of motivation to adherence to the exercise programs. The subjects found the VGR are joyful, interesting, meaningful, and challenging. Gaming technologies provide new opportunities for therapeutically meaningful activities and could be a valuable supplement to the physiotherapy [11], [12].

Video game therapy has positive contributions to the traditional methods on functional mobility and general mood in older adults [13]. Additional performance of the active video games has beneficial effects on gait speed, cadence, balance, mobility, cognition, and extremity function for independent older people therefore strategies based on VGR are well-accepted by adults [1], [12], [14]. They considered that is valuable to provide opportunity to engage persons in therapeutically meaningful activities as video games.

The role of physical activity in the prevention and treatment of older persons are known, but the role of video games on mobility in such population need to be more studied.

Therefore, we decided to initiate the creation of video game, which was designed after prior consideration for neurorehabilitation but also with goal to be applied in healthy adults. We have focused on the benefits, and design principles of the VGR, to be meaningful and to provide the opportunity to increase the level of difficulty to be challenging and tailored to the capabilities of the player [9], [10].

The self-designed VGR is video game software which 3D camera has extremely accurate sensor to capture the player's movements. The player is required to make a specific, purposeful movement that is captured by the camera and controls the game. The camera reports the range of movement (in degrees) of the motion being performed, displayed on the screen throughout the game. Feedback on the result is given through digital and visual cues. Scores can be saved through an available user profile and trends monitored over time. Furthermore, the games are understandable and can be implemented with specific therapeutic goals [9], [10].

Aim

With the present study, we aimed to evaluate the effect of self designed rehabilitation video games on the mobility, balance, and gait of non-institutionalized healthy older people.

Material and Methods

Participants

Individuals were recruited from physical rehabilitation outpatient center NSA-EOOD Medical Center Sofia, Bulgaria. Nighty-two people were initially screened, of them 50 were eligible and volunteered to participate in the study. They were allocated into two groups, depending on their willingness to perform either only PT or PT combined with video games. The experimental group (EG) consisted of 24 women (mean age 76.8 ± 6.9 years) and the control group (CG) consisted of 26 women (mean age 73.7 ± 6.8 years) according to the preference of the participants to perform VRG after regular PT sessions. Inclusion criteria are as follows: Age above 65 years, cooperative, agreeing to participate, and willing to sign a written consent form. Exclusion criteria are as follows: Current exacerbation of a chronic disease, sudden onset of an acute illness, or trauma.

The characteristics of the participants are presented in Table 1. Persons in both groups did not differ in height, age, body weight, and body mass index.

Table 1: Characteristics of the participants

Indicators	EG (n = 24)	CG (n = 26)
	$\bar{x}$ ± SD	$\bar{x}$ ± SD
Height (cm)	149.13 ± 44.81	163.30 ± 14.36
Age (years)	76.75 ± 6.89 (66–89)	73.69 ± 6.76 (63–87)
Body weight (kg)	67.58 ± 8.00 (57–85)	65.50 ± 7.10 (47–78)
Body mass index	25.69 ± 2.69 (21–32)	24.61 ± 3.10 (19–31)

EG: Experimental group, CG: Control group, n: Number of the patients, $\bar{x}$ ± SD: Mean values and standard deviation.

After being informed of the entire protocol, each of them signed a written consent form, reviewed, and approved by the local university ethics committee to declare their willingness to participate in the study [10].

Measurements

For the purpose of the study, all tests of the follow-up subjects were assessed twice, at the beginning and at the end of the treatment.

The calf circumferences are assessed by centimetry. The measurements were performed in a straight face position, with the feet slightly abducted but with equally distribution of the weight. Calf circumference was measured using a centimeter tape, which was placed 10 cm below the inferior edge of the patella [15].

A quick test to assess functional mobility, strength, and endurance of the lower limbs is 5 times sit-to-stand test (FTSTS) [16]. Subjects sit in a standard 45 cm high chair, with arms folded across chest, with their back against the chair. On the command “start”, he gets up 5 times and sits on the chair as fast as he can. Estimated values for community dwelling elderly are: 11.4 s (60–69 years), 12.6 s (70–79 years), and 14.8 s (80–89 years) [17].

Changes in the static standing balance were monitored using the Romberg test and in the functional balance is the functional reach test (FRT) [18], [19].

When performing a Romberg test, the subject stands in an upright position with feet together and shoes off, and arms extended forward with open eyes, then closes the eyes, and the maintenance of balance without wobbling is recorded in seconds to 30 s [19], [20].

The FRT was performed in the following sequence: The patient stands without shoes next to a vertical edge of a wall or door (with the toes in line with this edge) and raises the arm nearest the wall to 90° of flexion at the shoulder joint, with the forearm extended and the fingers clenched into a fist (the arm does not touch the wall so as not to provide additional support). The therapist places one adhesive tape on the wall at the level of the patient’s shoulder and a second one corresponding to the projection of the III metacarpophalangeal joint (MCPJ) of the patient’s elevated arm. The patient is required to reach forward as far as possible without losing balance and without lifting the heels off the floor. On reaching forward the maximum possible distance, the therapist places a third adhesive tape on the wall corresponding to the projection of the III MCPJ of the same arm. Measure the distance in centimeters from the second to the third tape (from the projection of the III MCPJ in the starting position to its projection in the maximally reached forward position). Bigger distance (cm) means better functional balance. Three trials are performed, recording the greatest distance reached [18], [21].

Gait was assessed by 10-m walk test (10 MWT). The test was performed at both a comfortable speed and maximum speed without running. Two meters were provided before and after the test distance. During performance of the 10 MWT at preferable speed, the cadence was counted. Two trials are administered at the patient’s comfortable walking speed, followed by two trials at his/her fast walking speed, per the below instructions. The two trials, for each speed, are averaged and the two gait speeds are documented. The gait velocity (cm/s) was calculated when subjects perform the test at maximum speed [22], [23], [24].

Intervention

All the women, from both groups, included in the study were treated at the NSA-EOD Medical Center – Gurgulyat str. – Sofia with PT with duration of 30 min, 3 times weekly, for 7 weeks or 21 sessions in total. Subjects from the EG performed VGR after the routine PT sessions. The video games last 30-min with moderate intensity.

One of the games we implemented, is called “Catch the Ball,” which involves abduction, adduction, flexion, and extension at the shoulder joint. The figure of the game moves the eponymous ear of the moving arm according to the selected parameters and with the correct position of the upper limb by the player, the ball sent by the game is caught [10].

The other game is called “Avoid the Danger” and is for rehabilitation of the upper and lower limb. The hazards of the game appear on the screen at random positions (moving forward on the ground or in the air) within reach of the player. The goal is to overcome the hazards by lifting the figure game by flexing the elbow or the hip joints when one of the hazards [25] approaches the game figure [10].

Subjects from the CG performed a group-based, routine PT sessions, with aerobic, breathing, and callisthenic exercises. PT sessions were performed 3 times weekly for 30 min, for 7 weeks.

Statistical analysis

The analysis of the data was carried out with the SPSS version 19.0. The data were tested for normal distribution by conducting Shapiro–Wilk Test and statistical methods for analysis were selected (Student’s t-test for calf centimetry, FTSTS, cadence, gait speed, and Wilcoxon and Mann–Whitney U-criterion for Romberg’s test and FRT). The significance was set up at $p \leq 0.05$.

Results

The changes in the mean values of calf centimetry and FTSTS, objectifying changes in muscle mass, functional mobility, and functional lower extremity strength, are presented in Table 2 and Figure 1.

Table 2: Changes in muscle mass and functional mobility during the treatment in both groups

Indicators	Group	Start (EG = 24; CG = 26)	7th week (EG = 24; CG = 26)
		$\bar{x}_1 \pm sd_1$	$\bar{x}_2 \pm sd_2$
Left calf circumference (cm)	EG	35.71 ± 2.36	36.36 ± 1.94**
	CG	35.06 ± 2.03	35.17 ± 1.77
	p	0.313	**0.031**
Right calf circumference (cm)	EG	35.78 ± 1.95	36.31 ± 2.46*
	CG	35.55 ± 2.03	35.31 ± 1.84
	p	0.682	0.049
FTSTS (s)	EG	10.13 ± 2.78	9.17 ± 3.15**
	CG	11.41 ± 2.47	10.56 ± 2.06
	p	0.097	0.074

$\bar{x}_1 \pm sd_1$: Mean values and standard deviation in the beginning, $\bar{x}_2 \pm sd_2$: Mean values and standard deviation at the end, s: Seconds, cm: Centimeters, FTSTS: Five times Sit-to-Stand Test. **p < 0.01, *p < 0.05 – significant differences for each group in the course of treatment compared to baseline values (Student’s t-test); p-significant differences between experimental (EG) and Control group (CG) (Student’s t-test).

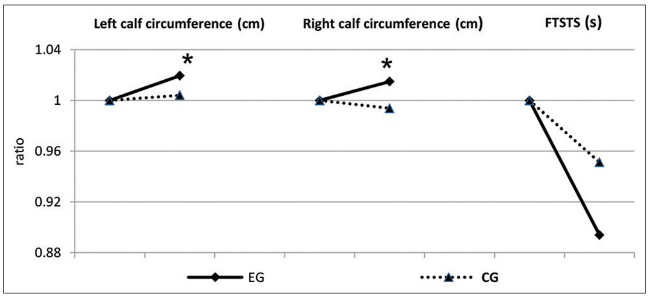

*Figure 1: Changes in the mean values of muscle mass and functional mobility over the course of treatment, presented as a ratio between the obtained and baseline values (taken as 1); an increase in the index indicates an improvement in calf circumference, while its decrease is an expression of improved mobility. FTSTS: Five times sit-to-stand test. * p < 0.05 - significant differences between the two groups*

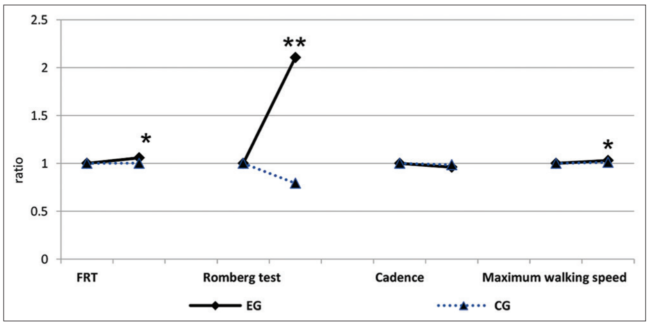

*Figure 2: Changes in mean values of balance (Romberg's test, FRT) and gait (cadence and maximum speed at 10-m Walk Test), presented as a ratio between obtained and baseline values (taken as 1); an increase in the index indicates improved functional balance, static standing balance, and gait velocity, while a decrease means improved cadence. FRT: Functional reach test. * p < 0.05 - significant differences between the two groups*

Pre-treatment left and right calf circumferences showed no significant differences between the two study groups. Muscle mass was significantly improved in the EG at week 7, in contrast to the control subjects. When comparing between the two groups, significant improvement was found after the application of VGR at the end of the follow-up period ($p < 0.05$).

There was no difference in the functional mobility and functional lower extremity strength between EG and CG, according to the baseline data. At the end of treatment, all subjects showed an improvement in mobility, clinically expressed by a shortening of the time to performing the FTSTT. The changes were significant in the EG ($p < 0.05$), with no significant between two groups.

The presented results show that the applied VGR after conventional PT improved calf muscle mass, functional mobility, and strength of the lower limbs, in contrast to the control subjects, confirmed by the significant changes during the course of treatment.

The results of static standing balance (Romberg test), functional balance (FRT), and gait (cadence in normal speed and the maximum speed in the 10 MWT) are presented in Table 3 and Figure 2.

Table 3: Changes in static standing balance, functional balance, and gait in the experimental and control groups

Indicators	Group	Start (EG = 24; CG = 26)	7th week (EG = 24; CG = 26)
		$\bar{x}_1 \pm sd_1$	$\bar{x}_2 \pm sd_2$
Romberg test (s)	EG	14.33 ± 5.57	16.85 ± 10.30*
	CG	14.07 ± 8.84	9.81 ± 7.41**
	p	0.930	0.009
FRT (cm)	EG	30.15 ± 7.13	31.75 ± 5.99*
	CG	28.63 ± 6.71	27.69 ± 5.87
	p	0.399	0.022
Cadence for 10 MWT (normal comfortable speed)	EG	16.58 ± 1.75	15.92 ± 1.98*
	CG	16.38 ± 1.69	16.15 ± 1.46
	p	0.691	0.637
Gait speed in 10 MWT (maximum speed) (cm/s)	EG	177.33 ± 27.89	182.29 ± 39.71*
	CG	161.08 ± 24.67	162.23 ± 25.07
	p	**0.037**	0.040

$\bar{x}_1 \pm sd_1$: Mean values and standard deviation in the beginning, $\bar{x}_2 \pm sd_2$: Mean values and standard deviation at the end, s: Seconds, FRT: Functional reach test, 10 MWT: 10-meter walk test. **p < 0.01, *p < 0.05-significant differences for each group in the course of treatment compared to baseline values (Wilcoxon t-criterion for Romberg test and for FRT and Student t-test for cadence and gait speed); p-significant differences between experimental (EG) and control group (CG), (Mann–Whitney U-criterion for Romberg's test, FRT and Student's t-test for cadence and gait speed).

After the implementation of VGR and PT, the balance significantly improved. At week 7, the EG participants remained stable for a longer time (by 2.52 s, $p < 0.05$) according to Romberg's test and reached a greater distance (by 1.6 cm, $p < 0.05$) according to FRT. Control subjects did not show positive changes at the end of follow-up. At the 7th week of treatment, due to the positive changes in the EG, the significant differences in the static standing and functional balance, and gait velocity in maximum speed between the two groups were found.

VGR significantly increased maximum gait speed and decreased cadence at normal comfortable speed (cadence decreased by 0.66, maximum speed increased by 4.96 cm/s). The controls also showed minimal improvement. Significant differences between groups ($p < 0.05$) at week 7 for maximum speed were associated with more marked positive changes in the EG at the end of the study.

Comparison between the two groups over the course of the treatment showed significantly better results on static standing balance, functional balance, and maximum gait speed in participants in the EG at the end of the treatment.

Discussion

This study proposes that self-designed 3D camera VGR is feasible and useful and has an additional therapeutic effect to the conventional PT sessions. The results of our research show that VGR significantly improve the functional mobility, balance, and gait of older people compared to the routine PT. Motor control of gait and balance is a complex process involving various structures of the central and peripheral nervous system, neuromuscular, and joint apparatus, which requires a targeted diagnostic and therapeutic approach for their restoration especially in older.

Our positive results in both calf circumferences and FTSTS we have found are associated with muscle strength and overcoming lower limb and trunk muscle imbalances [16], [17]. We believe that due to the effects of VGR which are associated with the prevalence of antigravity movements and thus increase the functional strength of the lower limbs' muscles [26], [27]. The muscle strength relates to functional mobility which may affects positively the rising from a seated position, ascending stairs, etc. Apparently, the rehabilitation video games implemented in the EG with antigravity and coordination movements increased functional capabilities (muscle strength, mobility, and muscle mass) of the lower limbs during the 7-week follow-up period. In line with the previous research, we find that active video game interventions have positive effects on walking and physical activity also, which is connected with increasing of the quality of life in older persons [10].

For precision of performance, the design of our VGR includes targeted movements, in purpose to improve the coordination and mobility of ankle, knee, and hip joints muscles, by flexion at the hip and knee with different levels of game's difficulties [28]. At the same time, improved coordination is associated with positive neuroreflex changes and increased mobility and muscle strength [29]. Other authors also reported that active video games lead to improvement in intermuscular coordination and balance [1], [14], [30].

The observed improvement in balance capabilities was also associated with the application of coordination and balance movements in the EG. The video game set meaningful tasks for the persons, considering their routine daily motor activities. The VGR application could stimulate the neural reorganization of the cerebral cortex, leading to psychophysical improvement both in healthy persons of different ages and in patients with motor or emotional problems, purposeful movements performed in different variations, situations and conditions are necessary [20], [31], [32].

The significant positive effect of our VGR in the EG on functional reaching possibilities, static stance and dynamic balance is also associated with in walking parameters. Many authors analyzed the gait parameters, gait velocity, and cadence in healthy elderly [1], [21], [25], [30]. Elderly adults show age-related decline in balance and gait with increased gait variability and an associated increased risk of falls. Virtual reality training has shown promising effects on balance and gait [5].

The statistically significant better results in walking speed we consider are due to the inclusion of real-life activities for the limbs and balance to improve proprioception, muscle strength, and lower limb mobility, but mostly we associate it with the inclusion of tasks to improve biomechanical control, such as movements with change of support area, line of gravity, and change of direction which is lacking in the CG. They affect the basic biomechanical factors of balance, with the requirements for older people regarding a slow or moderate pace of performance [4], [5], [33].

In older persons in the EG significantly increasing in maximum gait speed and decreasing in cadence were observed. Cadence and stride length have been reported as key determinants of walking speed in human locomotion. Step length and stride length in older adults increased when the speed increases. When older adults walked faster the increase in the hip and knee flexion moments were found. In older adults the rate of decline in walking speed is typically about 0.7%/year [25]. It is not clear enough whether the reduced gait parameters in elderly are related to aging only, or to reduced walking speed in healthy older people. Age-associated changes in balance, muscle strength, or joint mobility, are established, the specific mechanisms for deterioration in gait in the elderly are still unclear. Given the importance of maintaining walking in the elderly with respect to both health and function, it would be useful to identify specific age-associated changes or impairments that could potentially limit gait performance. If specific, functionally significant impairments are found, then PT protocols could be focused on diminishing these factors and to improve the gait in the elderly [25].

The research of Montero-Odasso *et al*., (2005) claimed that the decrease of gait speed could be a reliable predictor of negative events as falls, fractures, hospitalizations etc. in healthy well-functioning elderly. The authors defined three gait velocity groups: high (>1.1 m/s), median (1–0.7 m/s), and low (<0.7 m/s) [34]. A meta-analysis of Bohannon and Williams Andrews (2011) concluded that the gait speed ranged from a mean of 143.4 cm/s for men aged 40–49 years to a mean of 94.3 cm/s for women aged 80–99 years [22].

Beneficial effect in the EG was found on static stance and dynamic balance, functional mobility functional muscle strength, and gait parameters. We consider that VGR contribute to a better effect than PT alone.

There may be some possible limitations in this study. The followed subjects were predominantly with minimal motor functional deficits, and it would be of interest for future studies to monitor age-related declines in elderly and the opportunities for slowing the process. The study did not consider the possible influence of some contextual factors such as co-morbidities, which would provide additional information. Men should also be included in the research.

Conclusion

The current self-designed video game applied as an additional intervention was more effective than conventional PT alone in mobility, balance, and gait in apparently healthy older people.

Implications for Further Research

There is a need of future randomized clinical trials to specify the different aspects of video games design according to specific physical, emotional, and social needs and interests of elderly people. Telerehabilitation with video games should also be taken into consideration.

Consent to Participate

All participants written informed consent was obtained.

Human and Animal Rights

No animals were used in this study. All human procedures were followed in accordance with the principles of the Declaration of Helsinki.

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Author Contributions

D.L., A.D., and K.G-P. conceived of the presented idea and planned the experiments and contributed information from literature search. A.D., K.G-P., and M.M. carried out the experiment and data collection. D.L. did the data analysis and supervised the experiments. All authors have made significant contributions to this manuscript. They have read, agreed, and approved the final version of the paper to be submitted.

References

1. Suleiman-Martos N, García-Lara R, Albendín-García L, Romero-Béjar JL, La Fuente GA, Monsalve-Reyes C, *et al.* Effects of active video games on physical function in independent community-dwelling older adults: A systematic review and meta-analysis. J Adv Nurs. 2022;78(5):1228-44. https://doi.org/10.1111/jan.15138

   PMid:34935178
2. Yamada K, Yamaguchi S, Ito YM, Ohe T. Factors associated with mobility decrease leading to disability: A cross-sectional nationwide study in Japan, with results from 8681 adults aged 20-89 years. BMC Geriatr. 2021;21(1):651. http://doi.org/10.1186/s12877-021-02600-4

   PMid:34798834
3. Zunzunegui MV, Alvarado BE, Guerra R, Gómez JF, Ylli A, Guralnik JM, *et al.* The mobility gap between older men and women: The embodiment of gender. Arch Gerontol Geriatr. 2015;61(2):140-8. http://doi.org/10.1016/j.archger.2015.06.005

   PMid:26113021
4. Clark WH, Franz JR. Age-related changes to triceps surae muscle-subtendon interaction dynamics during walking. Sci Rep. 2021;11(1):21264. http://doi.org/10.1038/s41598-021-00451-y

   PMid:34711893
5. Osoba MY, Rao AK, Agrawal SK, Lalwani AK. Balance and gait in the elderly: A contemporary review. Laryngoscope Investig Otolaryngol. 2019;4(1):143-53. http://doi.org/10.1002/lio2.252

   PMid:30828632
6. World Health Organization. Haidelberg Guidelines for Promoting physical Activity among Older Persons. Geneva: World Health Organization; 1996. Available from: https://apps.who.int/iris/handle/10665/108545
7. Gil A. Project "Edu Senior" and improving the Quality of Life of Seniors. Scientific Symposium "Social Services in Partnership to Promote Active Aging in Good Health". Częstochowa, Poland; 2012.
8. Andriacchi TP, Ogle JA, Galante JO. Walking speed as a basis for normal and abnormal gait measurements. J Biomech. 1977;10(4):261-8. http://doi.org/10.1016/0021-9290(77)90049-5

   PMid:858732
9. Lyubenova D, Lyubenov N. Optimizing video games in neurorehabilitation. Neurosonol Cereb Hemodynamics. 2021;17(2):93-105.
10. Lubenova D, Dimitrova A, Grigorova-Petrova K, Mitova M. Video games for rehabilitation: A new approach to influence the quality of life in practically healthy elderly persons. Open Access Maced J Med Sci. 2022;10(B):2498-503. https://doi.org/10.3889/oamjms.2022.10813
11. Deutsch JE, Borbely M, Filler J, Huhn K, Guarrera-Bowlby P. Use of a low-cost, commercially available gaming console (Wii) for rehabilitation of an adolescent with cerebral palsy. Phys Ther. 2008;88(10):1196-207. http://doi.org/10.2522/ptj.20080062

    PMid:18689607
12. Fager SK, Burnfield JM. Patients' experiences with technology during inpatient rehabilitation: Opportunities to support independence and therapeutic engagement. Disabil Rehabil Assist Technol. 2014;9(2):121-7. http://doi.org/10.3109/17483107.2013.787124

    PMid:23600732
13. Warburton D, Charlesworth S, Ivey A, Nettlefold L, Sd Bredin S. A systematic review of the evidence for Canada's Physical Activity Guidelines for Adults. Int J Behav Nutr Phys Act. 2010;7:39. https://doi.org/10.1186/1479-5868-7-39

    PMid:20459783
14. Rutkowski S, Kiper P, Cacciante L, Cieślik B, Mazurek J, Turolla A, *et al.* Use of virtual reality-based training in different fields of rehabilitation: A systematic review and meta-analysis. J Rehabil Med. 2020;52(11):jmr00121. https://doi.

org/10.2340/16501977-2755
PMid:33073855

15. Wade D. Measurement in Neurological Rehabilitation. New York: Oxford Univrsity Press; 1996.
16. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical measurement of sit-to-stand performance in people with balance disorders: Validity of data for the Five-Times-Sit-to-Stand Test. Phys Ther. 2005;85(10):1034-45.
PMid:16180952
17. Bohannon R. Reference values for the five-repetition sit-to-stand test: A descriptive meta-analysis of data from elders. Percept Mot Skills. 2006;103(1):215-22. https://doi.org/10.2466/pms.103.1.215-222
PMid: 17037663
18. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: A new clinical measure of balance. J Gerontol. 1990;45(6):M192-7. https://doi.org/10.1093/geronj/45.6.m192
PMid:2229941
19. Forbes J, Munakomi S, Cronovich H. Romberg test. In: StatPearls. Treasure Island, FL: StatPearls Publishing; 2022. Available from: https://www.ncbi.nlm.nih.gov/books/NBK563187 [Last accessed on 2022 Nov 02].
20. Tityanova E. Textbook of Nervous Diseases. Clinical Neurology. Sofia: Koti Eood; 2021.
21. Jonsson E, Henriksson M, Hirschfeld H. Does the functional reach test reflect stability limits in elderly people? J Rehabil Med. 2003;35(1):26-30. https://doi.org/10.1080/16501970306099.
PMid:12610845
22. Bohannon RW, Williams Andrews A. Normal walking speed: A descriptive meta-analysis. Physiotherapy. 2011;97(3):182-9. http://doi.org/10.1016/j.physio.2010.12.004
PMid:21820535
23. Kollen B, Kwakkel G, Lindeman E. Hemiplegic gait after stroke: Is measurement of maximum speed required? Arch Phys Med Rehabil. 2006;87(3):358-63. http://doi.org/10.1016/j.apmr.2005.11.007
PMid:16500169
24. Lindholm B, Nilsson MH, Hansson O, Hagell P. The clinical significance of 10-m walk test standardizations in Parkinson's disease. J Neurol. 2018;265(8):1829-35. http://doi.org/10.1007/s00415-018-8921-9
PMid:29876762
25. Fukuchi CA, Fukuchi RK, Duarte M. Effects of walking speed on gait biomechanics in healthy participants: A systematic review and meta-analysis. Syst Rev. 2019;8(1):153. http://doi.org/10.1186/s13643-019-1063-z
PMid:31248456
26. Macaluso A, De Vito G. Muscle strength, power and adaptations to resistance training in older people. Eur J Appl Physiol. 2004;91(4):450-72. https://doi.org/10.1007/s00421-003-0991-3
PMid:14639481
27. Sanders M, Sanders B. Principles of resistance training. In: Bandy D, Sanders B, editors. Therapeutic Exercise. 2nd ed. USA: Lippincott Williams and Wilkins; 2008. p. 85-103.
28. Tinetti ME, Ginter SF. Identifying mobility dysfunctions in elderly patients. Standard neuromuscular examination or direct assessment. JAMA. 1988;259(8):1190-3.
PMid:3339820
29. Richardson JK, Sandman D, Vela S. A focused exercise regimen improves clinical measures of balance in patients with peripheral neuropathy. Arch Phys Med Rehabil. 2001;82(2):205-9. http://doi.org/10.1053/apmr.2001.19742
PMid:11239311
30. Fang Q, Ghanouni P, Anderson SE, Touchett H, Shirley R, Fang F, *et al.* Effects of exergaming on balance of healthy older adults: A systematic review and meta-analysis of randomized controlled trials. Games Health J. 2020;9(1):11-23. http://doi.org/10.1089/g4h.2019.0016
PMid:31800322
31. Cseppento C, Judea-Pusta C, Adrian M, Vicas L, Bochis C, Purza L, *et al*. Depressive disorder influence on the quality of life of the patient with degenerative pathology. Journal Medical Aradean. 2017;20 (2):5-8.
32. Ferreira V, Carvas N Jr., Artilheiro MC, Pompeu JE, Hassan SA, Kasawara KT. Interactive video gaming improves functional balance in poststroke individuals: Meta-Analysis of randomized controlled trials. Eval Health Prof. 2020;43(1):23-32. http://doi.org/10.1177/0163278718784998
PMid:30033748
33. Grigorova-Petrova K, Dimitrova A, Lubenova D, Zaharieva D, Vassileva D. Feasibility of interactive video games for influence on balance in institutionalized elderly people. J Phys Educ Sport. 2015;31(15):429-32. https://doi.org/10.7752/jpes.2015.03064
34. Montero-Odasso M, Schapira M, Soriano ER, Varela M, Kaplan R, Camera LA, *et al.* Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. J Gerontol A Biol Sci Med Sci. 2005;60(10):1304-9. https://doi.org/10.1093/gerona/60.10.1304
PMid:16282564