EFFECTS OF EXERGAMING ON BALANCE, SENSORY REWEIGHTING AND MEDIOLATERAL STABILITY IN OLDER ADULTS

Summary of the Ph.D. Thesis

MARIANN SÁPI, MA, BSc

Supervisors:

Sándor Pintér M.D., Ph.D.
Doctoral School of Clinical Medicine,
University of Szeged
Hungary

Andrea Domján Ph.D.
Department of Physiotherapy,
Faculty of Health Sciences,
University of Szeged,
Hungary

Director of Doctoral School of Clinical Medicine:
Lajos Kemény M.D., Ph.D., D.Sc.

Ph.D. program titled:
Clinical and Experimental Research in Reactivating and Organ-Saving Surgery

Szeged, 2021

1. INTRODUCTION

Slipping, stumbling, or any other kind of unintentional loss of balance which results in a fall and subsequent hospitalization due to injury, is a serious global concern for people over the age of 60 according to the World Health Organization. According to the National Bureau of Statistics there are 2.6 million people aged 60 or above in Hungary, which is almost 1/3 of the total population, and of this age group 60% were women. Consequently, interventions that improve the quality of life of senior citizens are essential. Therefore, it is important to design training programs that can help prevent future falls and their potential consequences, such as immobility, premature nursing home placement, surgical, lifesaving interventions or permanent disability.

To perform our daily activities, to maintain various positions, to automatically respond to voluntary body and extremity movements, and to react to external disturbances postural control and balance are essential. Despite balance being a commonly used term, there is no universal definition of human balance. In order to maintain a specific posture, such as standing, sitting, performing voluntary movements or reacting external disturbances, such as a push or a slippery surface, we have to keep our center of gravity (CoG) within the base of support (BoS). Humans have the ability to sense if their stability is compromised and consequently activate the body's postural control to compensate the force of gravity in order to prevent falling. Balance is a series of complex processes, in which not only a few specific regions of the brain play important roles, but rather almost every region of the brain. In particular, certain structures, such as the cerebellum, the basal ganglia, the thalamus, the hippocampus, the inferior parietal cortex, and frontal lobe (defined in general) may be of key importance in balance skills.

Due to the complexity of postural control, it can no longer recognized as one system or a set of righting and equilibrium reflexes. According to Horak (2006) "many systems need to be evaluated to understand what is wrong with a person's balance".

Postural equilibrium ensures the coordination of sensorimotor strategies to stabilize the CoG during both self-initiated and externally occurring disturbances in postural stability. To interpret complex sensory environments sensory inputs from somatosensory, visual and vestibular systems must be processes. If sensory environment changes, subjects need to re-weight their relative dependence on each of these sensory systems to preserve their stability. Thus, to plan an adequate balance training or fall prevention program it is important to understand the multiple mechanisms underlying postural control.

Age-related declines in balance are well documented. Deficits due to aging may manifest in cognitive function, in neuromuscular control mechanisms, and in the following 3 sensory systems: the visual, the somatosensory, and the vestibular. Regardless of whether sensory reweighting deteriorates or remains unchanged with age, therapists should aim to plan programs that can develop these previously mentioned sensory systems and thus decrease the risk of falls.

In one study, osteoporosis-related fractures in Hungary were investigated and thus offered incidence data not only on hip, but also on several other fractures between 1999 and 2003. According to the data reported 404,380 Hungarian women and 206,009 men over the age of 50 had at least one fracture, and a possible reason behind this phenomenon might be attributed to the difference between each gender's change in the level of sex hormones during various stages in life. The changes may contribute to older women having a more significant decrease in bone mineral density. Besides age-related hormonal changes, multitasking increases gait variability, and this has a direct relationship to the prevalence of falls. Furthermore, elderly women with an abnormal balance while walking are more likely to fall. According to the findings of Qazi et al., a static posturography test demonstrated that the mediolateral (ML) component of postural sway is most strongly associated with long-term fracture risk in postmenopausal women. In addition to that, sideward falls are the most frequent cause of hip fractures among older adults. For this reason, it is essential to implement training programs that improve sensorimotor control in the critical ML direction.

There is evidence from numerous studies that several types of trainings have beneficial effects on older adults' balance. It has been suggested that resistance training (RT) is a form of physical activity for the elderly that could be effective and safe. This training method is capable of reversing the effects of sarcopenia, and can improve body posture, balance, and physical resistance. According to the review of Kim et al., the effects of aquatic-based exercises (AE) and land-based exercises (LE) on dynamic balance imply that AE can be an appropriate alternative to LE in terms of making clinically meaningful improvements in balance.

Exercise games that are played in a virtual, but realistic environment (exergames) have become popular in various fields of research and rehabilitation recently. In the last decade, non-immersive virtual reality (VR) (without the use of a head-mounted device) exergame trainings with the Kinect system have been proven to be effective in improving postural control among older adults. In a review, 12 randomized controlled trials have been analyzed with the aim to summarize the effects of exergames on mobility and balance in comparison to no exercise or health education in older adults without neurological conditions. It has been suggested that in comparison to no intervention, exergames developed balance and mobility in older adults without neurological conditions.

Yang et al. compared the effects of Kinect exergames and conventional exercises among older adults. Their results showed that overall balance ability and improvement in the functional reach test was more enhanced following Kinect exercise training in comparison with traditional exercise.

2. AIMS

We found very few studies that have investigated the effects on balance improvement for older adults for commercially available Kinect gaming training compared to exercise training, conventional physical therapy, or to a no intervention control group.

2.1 HYPOTHESIS I.

The aim of our initial study was to confirm that the Kinect training using commercially available games might be more prominent than conventional balance training on improving functional balance of healthy older adults. In our study we compared the effects of these different types of training groups at the same time in healthy older adults, focusing on only the functional balance tests complemented with a posturography evaluation.

2.2 HYPOTHESIS II.

In the past 3 years, the effect of exergaming on sensory reweighting among older women has received little attention despite its clinical importance for physiotherapists. Our second study we examined the potential effects of a Kinect exergame training on balance in the ML direction in healthy older women.

2.3 HYPOTHESIS III.

Because of the limited number of studies available on this topic, in our usability study we investigated whether Kinect exergame balance training might have a beneficial impact on the sensory reweighting in women aged over 60.

3. MATERIALS AND METHODS

3.1 Ethical aspects

The Ethics Committee of the University of Szeged, Hungary, approved the study (registration no. 125/2015 SZTE). A signed informed consent was obtained from all individuals before their participation in the research. The training programs were located in the gym of Albert Szent-Györgyi Health Center's physiotherapy department. The measurements took place at the Faculty of Health and Social Studies (University of Szeged). All procedures were performed according to the Declaration of Helsinki. Our study ran between July and November 2015.

3.2 The demographic data of conventional balance training versus the Kinect exergaming program

Thirty subjects participated in the Kinect training group (29 women and 1 man, 69.57±4.66 BMI: 26.21±2.60), 23 volunteers (22 women and 1 man, 69.12±4.19 BMI: 25.95±2.60) attended the conventional balance training, and 22 participants (18 women and 4 men, 67.18±5.56 BMI:27.09±5.45) were allocated to the no-intervention control group.

3.3 The demographic data of the Kinect exergaming usability study

Overall, 14 female volunteers (mean age 67.87 ±4.96 years, BMI 25.21 ± 2.3 kg/m^2) participated in the study without any dropouts.

3.4 Study design and participants' enrolment in conventional balance training versus the Kinect exergaming program

Healthy community-dwelling older adults (free from known musculoskeletal, neurological, and cardiopulmonary disorders), older than 60, were recruited for our study on improving balance abilities through local announcements in senior centers of the city Szeged, Hungary. Exclusion criteria included self-reported cognitive impairment, disorders of the heart and circulatory system, musculoskeletal, respiratory, and autoimmune diseases, neurological conditions, hearing or vision loss, artificial limbs or prosthetics, sores on lower limbs or feet or corns, and taking medication that could affect the postural control. Altogether 117 volunteers signed up for the training program, but due to any of the exclusion criteria 24 subjects had to be excluded from the study, while 3 volunteers declined to participate. On the arrival of subjects (on a first-come, first-served basis), 90 participants were allocated either to the Kinect training group or to the conventional balance training group or to the no-intervention control group. There were 30 participants in the Kinect training group, whereas 7 and 8 subjects, who were allocated to the conventional balance training and control group respectively, had to be excluded from the study due to their scheduling issues and loss of interest in the evaluations.

3.5 Study design and participants of the Kinect exergaming usability study

Community-dwelling older women above the age of 60 were recruited via local announcements in the senior centers within the city of Szeged, Hungary. Exclusion criteria included self-reported comorbidities (such as cognitive impairment; disorders of the heart; circulatory, musculoskeletal, and respiratory ailments; autoimmune diseases; and neurological conditions), hearing or vision loss, prosthetics or artificial limbs, wounds or corns on lower extremities, and the use of medication that could affect balance or participation in other organized physical training exercise programs. Twenty active, community-based volunteers signed up for the training program; however, due to the exclusion criteria, only 14 of them could participate in the study.

3.6 Types of trainings of conventional balance training versus the Kinect exergaming program

3.6.1 The Kinect training

Subjects were trained with the Microsoft Xbox 360 Kinect (Redmond, WA) videogames. Each training session took 30 minutes for each of the participants. Games that require more predictable movements and more simple elements (e.g., bowling or football, skiing, and just dance) were played in half of the total game time and those games that necessitate higher attention and fast reaction times (20.000 Leaks, Space Pop, Reflex Ridge, River Rush) were chosen to play for the second half of one training session.

3.6.2 Conventional balance training

Participants who performed conventional balance training were trained for 6 weeks, three times a week (altogether 18 trainings). The training consisted of three parts: the first few minutes of the training session contained light warm-up exercises (arm, leg and neck movements, marching in place) followed by the main part of the training, where participants performed static and dynamic balance exercises that also included reaching and leaning, weight shifting, forward, backward, and side stepping, change of direction exercises, squatting, lunging, and hopping tasks.

3.6.3 Control group

Members of the control group received no balance training, only pre- and postmeasurements (in 6 weeks).

3.7 The training of the Kinect exergaming usability study

The applied equipment consists of a motion-sensing RGB camera named Kinect, an Xbox 360 console, and video games developed by Microsoft. The training took place at Albert Szent-Györgyi Clinical Center's Physiotherapy Department 3 times a week over a 6-week period (total of 18 visits). Games were chosen based on the type of movements their performance required, with the main aspect being that games had to contain patterns of everyday functional movements which modeled usual, frequent natural motions. Commercially available Kinect games (20 000 Leaks, Space Pop, Reflex Ridge, River Rush) were played by the participants which demanded continual displacement of the participants' center of gravity (COG), transference of weight between lower limbs, and lateral trunk bending and frequent sidesteps.

3.8 The measurements of conventional balance training versus the Kinect exergaming program

The outcome measures were recorded before the training (at baseline) and at the subsequent days of the latest training sessions (at the end of the sixth week) by the physiotherapists.

Balance outcomes included Four-Square Step Test (FSST), Functional Reach Test (FRT), Timed Up and Go Test (TUG), Timed Up and Go dual-task (TUG-cog), and Limits of Stability (LOS) test (LOS-reaction time, LOS-velocity) measured on NeuroCom Basic Balance Master. The desktop configuration of this device uses a fixed dual-force plate to measure the vertical forces exerted through the subject's feet to COG and postural control.

3.9 The measurements of the Kinect exergaming usability study

In general, in order to assess an individual's ability to both integrate various senses of balance and compensation, while 1 or more of these senses may be lacking, NeuroCom Balance Master 6.0 and the m-CTSIB were used. The posturography measurements were performed at 3 separate intervals: before the first training, after the completion of the training program (posttraining), and 6 weeks after the last training session (follow-up). The Balance Master 6.0's software provided the location of both the COG and center of pressure across all tests for the m-CTSIB. This test differentiates sensory (somatosensory, visual, and vestibular) inputs involved in postural stability during a steady-state balance assessment, and it explored balance on various surface types, with and without vision.

3.10 Data collection and analysis of the conventional balance training versus the Kinect exergaming program

All analyses were performed using Statistica 13. Datasets were checked for normal distribution using the Kolmogorov– Smirnov test. Baseline differences in balance parameters between the groups (Kinect vs. conventional vs. control) were tested using one-way analysis of variance (ANOVA).

Effectiveness of the different trainings on balance parameters measured by FSST, FRT, TUG and TUGcog, LOS-RT, and LOS-V was tested using two-factor mixed ANOVA with time (pre vs. post) as the within-subjects factor, and group (Kinect vs. conventional vs. control) entered as the between-subjects factor. All values are given as mean – standard deviation. The post hoc test was the Newman–Keuls test. A value of $p < 0.05$ was taken as a significant training effect.

3.11 Data collection and analysis of the Kinect exergaming usability study

The following equations were applied to calculate the sway paths in the ML and AP directions

$$s_x = \sum_{i=1}^{n-1} \sqrt{(x_{i+1} - x_i)^2}$$

$$s_y = \sum_{i=1}^{n-1} \sqrt{(y_{i+1} - y_i)^2}$$

where n is the total number of samples; i is the sample number; s_x is the path length of ML ways; and s_y is the path length of the AP displacements of COG. The following statistical analysis was conducted using Statistica 13 software. All sets of data were checked for normal distribution using the Kolmogorov–Smirnov test. Factorial analysis of variance was used to analyze sway data of the m-CTSIB test on firm and unstable (foam) surfaces to evaluate the main effects and the influences of the 2 visual conditions (eyes open and eyes closed) at all 3 time conditions (baseline, after the training, follow-up) as within-subjects factors. All values are given as mean (SD). The post hoc test was the Newman–Keuls test. A level of significance of $p<0.05$ was applied.

4. RESULTS

4.1 Results supporting hypothesis I.

Both training groups showed progress in the follow-up measurements; however, more statistically significant improvements were found in favor of the Kinect balance training group (Timed Up and Go test [$p<0.05$], Timed Up and Go cognitive dual-task test [$p<0.05$], Four-Square Step Test [$p <0.05$], Functional Reach Test [$p<0.05$].

LOS-RT showed a significant training effect (time group interaction, $F(2,146) = 6.75$, $p<0.05$). Reaction time increased in the control group, while this value in the Kinect training group slightly decreased. We observed significant changes with respect to LOS-V test (time group interaction, $F(2,146) = 5.02$, $p<0.05$). Both the Kinect ($p<0.05$) and the conventional balance training group ($p<0.05$) significantly increased the velocity of LOS performance compared with the control group data, although only in the Kinect group was the movement velocity significantly higher ($p<0.05$) after than before the training.

4.2 Results supporting hypothesis II. and hypothesis III.

In the ML direction, the Kinect exergame training caused a significant decrease in the sway path on the firm surface with the eyes open ($p<0.001$) and eyes closed ($p=0.001$), and on the foam surface with the eyes open ($p=0.001$) and eyes closed ($p<0.001$) conditions compared with baseline data.

The follow-up measurements when compared with the baseline data also showed significant change in the sway path on the firm surface with eyes open ($p<0.001$) and eyes closed ($p<0.001$), and on the foam surface with eyes open ($p=0.003$) and eyes closed ($p<0.001$). There were no significant differences in sway path values on the firm surface between eyes open and eyes closed conditions during the baseline ($p=0.81$), after the training ($p=0.30$), and follow-up ($p=0.48$) evaluations. However, on the foam surface, results showed a significant interaction of vision × time for the sway path ($F2,246=3.70$, $P=.02$). Before the training, the sway path on the foam (unstable) surface with eyes closed was significantly longer ($p<0.001$), whereas after the training the absence of visual information did not result in a significant increase ($p=0.16$) of the sway path.

On the firm surface, there were no significant differences in sway path values in the AP direction between the baseline and the posttraining measurements.

5. DISCUSSION

5.1 Conventional balance training versus the Kinect exergaming program

The objective of our study was to confirm our hypothesis that Kinect training using commercially available games can be more effective than a conventional balance training focusing on improving balance of healthy older adults.

To our knowledge, there are only few studies that applied these tests to investigate the effect of an exergame balance training applying commercially available Kinect games to improve healthy older adults' balance abilities. Our results showed statistically significant improvement in the FSST only in the Kinect training group. The reason behind our result could be that the stepping movements in the FSST were also the basis of games participants played (i.e., 20,000 Leaks, Space Pop).

Our results suggest statistically significant improvement in the FRT in the Kinect training group, while the values of the conventional training group and the control group remained unchanged. These findings are similar to the study results of Chen, and Sato et al.

According to our results, both training groups' balance tests improved with superiority of the Kinect training group, whereas the control group remained unchanged. Our scores of the TUG presented both in the Kinect and in the conventional training group statistically significant enhancement compared with the control group. Furthermore, compared with the baseline results of the TUG time scores, a statistically significant decrease was shown only in the Kinect training group.

For our study, we also applied the TUG test with an additional cognitive task resulting in increased test times in all groups. The intervention groups' post-training time scores presented enhancement, moreover, the results confirmed statistically significant improvement in the Kinect training group. To our knowledge, there is no research with similar study design that investigated the balance tests with an added cognitive task. According to Pichierri et al., exergames can be considered dual tasks since the games are performed by a man– videogame interface, requiring cognitive and motor functions simultaneously. The TUG test with an additional cognitive task is also a dual task, and therefore, our results can confirm that the Kinect training has a major effect on performance with high cognitive and motor demands.

According to Monteiro-Junior et al., during exergames, participants move in a simulated virtual environment, where they need to perform random, constantly changing elements (open task). Kinect training may improve cognitive functions, since individuals need to understand and interact with a virtual environment context. Physical exercise and cognitive stimulation performed together show the potential that exergames may provide a new strategy to stimulate neuroplasticity and improve cognitive functions. As a result of exergaming containing anticipated visual tasks in a virtual environment, cognitive processing, and movements concurrently, therefore it might provide the possibility of training visuomotor integration.

We have not found any study so far that has been conducted on improving postural control through conventional and Kinect balance training in older adults that applied NeuroCom Basic Balance Master for the evaluation of LOS. As stated by Bourelle et al., the LOS test is associated with cognitive functionality, and they found that this evaluates motor and cognitive capabilities to respond to the complex task of initiating a movement with certain accuracy, in function of a visual stimulus.

Faraldo-Garcia et al., concluded that aging affects the reaction time, the movement velocity of the LOS performance. During LOS test, we found that both interventions enhanced the reaction time and the summed velocity compared with the follow-up results of the control group. Moreover, post-training results of the Kinect training compared with its baseline improved significantly.

5.2 The Kinect exergaming usability study

Several studies have previously confirmed the beneficial effects of exergames on postural control among older adults. This usability study shows that a simple Kinect game–based balance training might be beneficial for older women by improving balance in the ML direction. This study also demonstrates that exergaming might have a favorable effect in regards to the specific process of adjusting the sensory contributions to balance control, namely, sensory reweighting.

In light of the present findings following the training, improved sway results in the ML direction were observed when participants were standing on the foam surface with their eyes open. Significant decrease of ML sway might also implicate an improvement in proprioceptive function following the Kinect training. This finding is similar to the results of Sadeghi et al. which suggest that Kinect exergaming can improve proprioception by providing visual feedback and challenging motor skills and visual coordination.

In a study it has been suggested that virtual reality (VR) therapy enables patients to become immersed in an imaginary world, in which environmental perception is altered by artificial stimuli, thus resulting in a sensory conflict that can act on the vestibulo-ocular reflex (VOR). The central nervous system reacts to vestibular stimulus by reflexes such as the VOR, which stabilizes vision during head motion, and the vestibulospinal reflex, which induces a compensatory body motion to stabilize the head and body, and prevent falls.

Thus, types of exergames that require head movements in particular (rotation, lateral flexion, flexion) while players' eyes are focusing (gazing) at one point can function as VOR training. According to Swanenburg et al., exergaming that requires active stepping movements and that involves moving game projection is usable and facilitates gaze stability during head movements, which resulted in improved gait in healthy older adults. Based on this study's results, the applied Kinect games might improve sensory reweighting in favor of relying on vestibular inputs. In this study, while participants were playing the exergames, they had to keep their eyes on the screen while performing various head and limb movements. Games such as 20, 000 Leaks, River Rush, Reflex Ridge, Super Saver Football mini-game, Space Pop, and Skiing might especially challenge the VOR because they require frequent head displacement movements. Additionally, these games could also improve stability in the lateral direction because of frequent weight shifting and sideward stepping.

An important finding of our study is that the Kinect exergame training program significantly reduced postural sway on the foam surface with the eyes closed. Under this condition of the m-CTSIB, the central nervous system mostly relies on vestibular information.

According to Cone et al., the reason for the improved vestibular function might be due to the quick displacement of COG in different directions, causing rapid changes in the head position. Similarly, during pretest measurements in our study, closing the eyes on the foam surface resulted in a statistically significant increase in the sway scores in the ML direction; however, posttraining measurements did not show deteriorated sway results. The reason for this might be that after the training, participants shifted to the remaining, accurate source of sensory information, and mainly relied on the vestibular system. Another possible explanation might be that during exergaming, participants had to complete several tasks containing movements such as reaching out and lateral steps while they needed to often change their head position.

6. LIMITATIONS AND CONCLUSIONS

6.1 Limitations of the conventional balance training versus the Kinect exergaming program

One limitation to this study is that no sample calculus has been made and gender distribution is unequal. Moreover, to set up a more precise treatment regimen with Kinect games, further research would be necessary on investigating the exact amount of time, frequency, and regularity of trainings since our aim is to provide long-lasting balance interventions. In addition, another limitation is that no further follow-up results have been performed, which could verify the lasting effects of our trainings.

6.1.1 Conclusions of the of the conventional balance training versus the Kinect exergaming program

Several studies investigated the effects of the custom-made Kinect game training for older adults. According to our present results, the commercially available Kinect games are able to fulfill the requirements of a functional balance training, since these games make their players to move in functional movement patterns, while participants' attention is directed to problem solving and throughout entertaining tasks. We choose balance tests to get an objective estimation about our volunteers' postural control, which are based on movements performed in everyday life and in the games, players played. For this reason, Kinect game training is a suitable tool for training postural control of healthy older adults.

6.2 Limitations of the Kinect exergaming usability study

This usability study has encountered certain limitations as no sample size calculation was performed, and due to the lack of a control group and the relatively small sample size, the results should be interpreted cautiously. Therefore, these findings are not conclusive. In this study, only older women participated, but to examine whether there is a gender difference in sensory reweighting following exergaming, future studies should also include a group of male participants. Investigating the effects of exergaming in older individuals with vestibular dysfunctions could also be beneficial, as this population is especially at risk of falling.

6.2.1 Conclusions of the Kinect exergaming usability study

In this usability study, women's sway path decreased in the ML direction not only on the firm surface with eyes open, but also on the foam surface with eyes closed as a result of following the Kinect exergame training. These findings might support the idea that although the Kinect exergame training did not specifically contain direct challenging sensory tasks (e.g., tilting or unstable surface or closed eyes exercises), the reduced sway results suggest that exergames could additionally result in sensory reweighting. The reason for this might be that the games contained tasks that needed constant gaze stabilizing and frequent head displacements. Therefore, this study's improved sway results in the ML direction might contribute to decreased risk of falls among older women.

7. ACKNOWLEDGEMENTS

I would like to thank my supervisors,

Dr. Sándor Pintér, and **Dr. Andrea Domján**

for their patience, guidance, support, and encouragement throughout this process and up until the last moments of completing this thesis.

I am very grateful to physiotherapists Anna Fehér-Kiss, Márta Borsics and Vivien Mészáros for all the help and assistance that you have provided me during the study, and I am also thankful to the senior volunteers for participating in this study.

I appreciate the valuable comments and linguistic corrections of Candace Smith, Katalin Balázs, Csilla Keresztes and Roman Pentsa.

Lastly, I would like to thank my parents for their endless support throughout my studies. I am also grateful to my grandma, and to all my family members and friends for their encouragement during the whole research process.

I would not have been able to accomplish this thesis without you.

LIST OF PUBLICATIONS
included in the dissertation

I. **Sápi M**, Domján A, Fehérné Kiss A, Pintér S. Is Kinect Training Superior to Conventional Balance Training for Healthy Older Adults to Improve Postural Control? Games Health J. 2019 Feb;8(1):41-48. doi: 10.1089/g4h.2018.0027. **IF: 1.782**

II. **Sápi M**, Fehér-Kiss A, Csernák K, Domján A, Pintér S. The Effects of Exergaming on Sensory Reweighting and Mediolateral Stability of Women Aged Over 60 Years: Usability Study JMIR Serious Games 2021;0(0):e0 doi: 10.2196/27884 **IF: 4.143**

Cumulative impact factor of the publications directly related to the thesis: 5.925

PRESENTATIONS
related to the subject of the dissertation

Sápi M, Domján A, Fehérné Kiss A, Pintér S: Esésprevenció videójáték tréninggel hatvan év felettiek körében In: Trauma a Dóm árnyékában: 12. Dél-Magyarországi Traumatológus Kongresszus: Részletes program és előadás összefoglalók (2017) 42.p pp. 32-33.

Sápi M, Domján A, Fehérné Kiss A, Pintér S: Fejleszthető-e a hatvan év felettiek egyensúlya a Microsoft Xbox 360 Kinect játékprogramokkal? REHABILITÁCIÓ: A MAGYAR REHABILITÁCIÓS TÁRSASÁG FOLYÓIRATA 26:3 pp. 207-207 (2016)

POSTER PRESENTATION

Sápi M, Domján A, Fehérné Kiss A, Pintér S: Az aktív videójátékokkal végzett testmozgás hatása az idősödők egyensúlyára In: Magyar Életmód Orvostani Társaság I. Kongresszusa Budapest, 2019. febr. 15-16.

PRESENTATIONS
not related to the subject of the dissertation

Domján A, **Sápi M**, Fehér-Kiss A, Mirk B, Kasza B, Pintér S: Improving neuromuscular efficacy by activating the local stabilizers of the cervical spine In 22nd European Congress of Physical and Rehabilitation Medicine: Abstract book (2020) pp. 185-185. 1 p.

Fehér-Kiss A, **Sápi M**, Tagai A, Domján A: Tactile plantar stimulation improves anticipatory postural adjustment in older adults with diabetic neuropathy in 22nd European Congress of Physical and Rehabilitation Medicine: Abstract book (2020) pp. 187-187. 1 p.

Fehér-Kiss A, Varga M, Rónyai E, Sápi O, **Sápi M**: A 2-es típusú diabetes mozgásterápiájára vonatkozó evidenciák áttekintése a fizioterapeuta szempontjából In: A Magyar Gyógytornász-Fizioterapeuták Társasága XI. Kongresszusa és 11. Pre-Kongresszusa (2017)