# Benefits of Exergame Exercise on Physical Functioning of Elderly People

Niina Katajapuu, Mika Luimula
Turku University of Applied Sciences,
Turku Game Lab
niina.katajapuu@turkuamk.fi

Yin Leng Theng, Tan Phat Pham, Jinhui Li
Nanyang Technological University Singapore
Centre for Healthy and Sustainable Cities

Aung Pyae
University of Turku
Department of Future Technologies

Keizo Sato
Tohoku University
Department of Biomedical Engineering

***Abstract* — The study introduces five exergames developed by researchers from Finland, Singapore, and Japan. These exergames utilize Microsoft Kinect motion detection sensors. The exergames were tested in Singapore in 2016. A total of 30 participants using exergames completed the six-week intervention study. In this study, we wanted to measure the changes in body functions and activities in elderly population who conducted exercise under three settings: (i) using exergame, (ii) using conventional exercise, and (iii) continuing everyday activities. The main outcome of this study measured with SPPB and Berg Balance Scale was that both types of exercise, game and conventional, were useful for elderly people's physical functioning.**

***Keywords— Serious games, gamification, digital physical therapy, aging, physical functioning***

## I. INTRODUCTION

The world population is greying rapidly. The United Nations projected that the number of persons aged 60 years and above will increase from 629 million in 2002 to 2 billion by 2050, with 54% of the world's older population residing in Asia [1]. Singapore is one of the fastest ageing countries in Asia [2]. The demographic ageing is happening at an alarming rate. As presented in Figure 1, in 1970, one in 15 Singaporeans was aged 65 years or older. By 2030, according to Ministry of Health Singapore, every third Singaporean will be aged 65 years or older [3]. A great number of people in this group are now at their 50's, an age providing them with a good possibility to affect their own future wellbeing. Technologies for enhancing the independent living of the aging population have been widely studied. In their study [4], Peek et al found that aging people wish to access (health) technologies which benefit them but want to avoid becoming too dependent on technology. Physical activity during the entire life span is strongly related to changes in the physical functioning in aging population [5.]

A high amount of physical activity is associated with better balance, higher muscle strength and quality of life [5-7]. Vice versa, a decreased walking ability has an association with a risk of disability [8]. In the field of technology, exergames have showed to have positive effects on functional health variables, such as balance and gait [9], which are important factors in physical functioning and activities of daily living. World Health Organization (WHO) has published an ICF (The International Classification of Functioning, Disability and Health), a framework explaining the interaction of four health related domains: 1) Body structures and functions, 2) activities and participation, 3) environmental and 4) personal factors. In this study, we measured the changes in body functions and activities level after exergame intervention. The study was planned to give a new exergame tool for elderly people to use in their own home environment in Singapore.

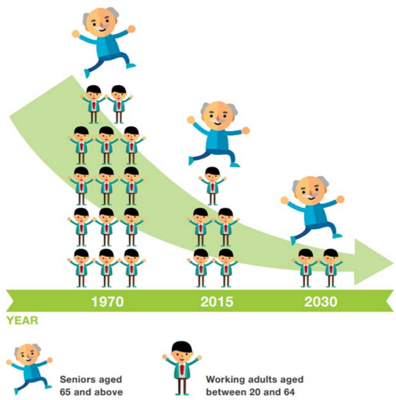


Fig. 1. The demographic dependency ratio is changing dramatically in Singapore [3].

A high number of research studies in the field of digital rehabilitation exist. These studies are in line with the Cognitive Infocommunication principles. In fact, these studies generally speaking focus on challenges of making the communication of information more natural for users (cf. [10]). Larsen et al. [11] published a systematic review concerning the physical effects of exergames in healthy elderly population. In the review, they came up with seven RCT's (N = 311), out of which six showed possible positive effects of exergaming on different physical health variables. In most of the studies, the intervention was carried out in an individual setting. To enhance the social interaction among elderly people, it would be interesting to see how the exergames affect health variables when used in a group setting with several exergames used in turns.

Pyae et al. [12] conducted a usability testing of an interactive digital game-based exercise called Skiing Game with 21 Finnish elderly participants in Finland. They used both qualitative and quantitative methods to investigate the elderly participants' user experiences in the gameplay, as well as the usability of the game. Furthermore, they investigated whether digital game-based exercises can be an alternative way of exercising for elderly people in Finland. Their findings showed that Skiing Game is a user-friendly game for the Finnish participants and that they were moderately engaged in the gameplay. Moreover, the researchers reported that digital game-based exercises can be an alternative solution for elderly people to exercise when they cannot access physical and conventional exercising. Pyae et al. [13] also conducted a cross-border usability study of Skiing Game in Japan with 24 Japanese elderly participants. Their findings also supported the idea that digital games provide an effective and effortless way of exercising for elderly people.

Sato et al. [14] highlighted that a low adherence rate to physical exercise is a problem among elderly people. Digital game-based exercises that involve the physical motion of players are a promising method of keeping them active and motivated in engaging in a regular exercise routine. The researchers designed and developed Kinect-based digital exercises for elderly people to examine the effects of the game on their physical health benefits, including muscle strength and body balance. They evaluated the game with 24 healthy community-dwelling elderly people (aged $71.46 \pm 4.8$ years old). Conducting the whole study took 2.5 months and included 2-3 game sessions per week. A significant improvement was found in the maximal isometric muscular strength of hip joint flexion, and knee joint extension and flexion, of ankle joint dorsiflexion. Digital game-based exercises were found to be effective in improving the muscular strength of lower extremities of elderly people. According to Pisan, Marin, and Navarro [15], falling is one of the leading causes of injuries and disabilities for elderly people, and physical exercises can reduce the potential risk of falling by 40%. The researchers designed and implemented a digital game-based training for elderly people to prevent or reduce the potential risks of a physical fall. They conducted a clinical test with 57 elderly patients, and the findings showed that elderly people were engaged in the game-based training and preferred doing exercises with the game system. Their findings also suggest that game-like digital exercises may result in the increase in elderly people's adherence to the exercise routines, which may lead to the lower rate of falling accidents among elderly people.

Derboven et al. [16] designed a social-based memory game for elderly people including an additional video chat. The main objective of their study is to understand how elderly people's experience is influenced by communication with other players (e.g. grandchild). They conducted the study with 15 pairs of old and young participants playing the game. Their findings suggest that not only the addition of the live video chat can improve the social contact between the elderly and the younger person but also a younger player with more experience in playing digital games can assist the elderly player who literally needs more help from others. Allaire et al. [17] investigated the differences in psychological functioning (e.g. depression and affect) between two elderly groups, those who played digital games regularly and those who did not. They conducted a study with 140 independently living elderly people. Their findings suggest that the group playing digital games regularly demonstrated better psychological abilities than the group who did not.

## II. Exergames

In this study, we included five different exergames developed by researchers from Finland, Singapore, and Japan. This section provides a brief description of each game as follows:

### *A. Skiing Game*

The game has been designed and developed by Turku Game Lab (Finland). Basically, Skiing Game utilizes snowy mountains and forests, familiar to the majority of the Finnish elderly, as the game context and contents. In Finland, skiing as a recreational and physical exercise activity is popular among not only younger people but also older people. The gameplay in Skiing Game is quite simple and easy. It is designed based on the simple double pole skiing technique, which is relatively easy for those who have previous experience in cross-country skiing. To play the game, the player has to do a simple calibration before he or she plays the game. When the player starts playing the game, he or she has to ski through many gates along the way. In a given game time, the player needs to reach the finishing line.

Furthermore, the player needs to avoid obstacles on the skiing trail that can cause the player to fall down. To be able to control the game, the player has to hold both hands (double pole skiing motion) as if he or she is steering a pair of skiing poles with both hands. To keep skiing, the player needs to continuously move both hands forward and backward. To accelerate the movement, the player has to perform this skiing action faster. The quicker the player moves both hands, the faster the movement in the game becomes.


Fig. 2. A screenshot from Skiing Game developed by Turku University of Applied Sciences.

It is important for the player to follow the skiing trail displayed in the game. To move left or right, the player simply needs to move the body to the left or right. In the uphill and downhill sections of the game, the player needs to either accelerate or slow down. When the player reaches the finishing line, the score screen will pop up, showing the player's total game time and the number of gates the player successfully went through. A screenshot from Skiing Game can be found in Figure 2. A traditional webcam and Xtreme Reality technology are utilized to detect the player's movements in the game.

### B. *Hiking Game*

This game has been designed and developed by Turku Game Lab (Finland). This game consists of three levels in Finnish summer. In the first level, a player walks through Finnish forest environment. While walking in the forest, a player is able to explore Finnish forest. The player is able to meet pines and spruces, as well as elks, and birds. The second level is about following a beautiful river by paddling canoe until player goes ashore a mountain in Lapland. Player will see salmons jumping ahead of his canoe. In addition, player will be again meeting animals in the riverside. In the last level, player is climbing up in the mountain. Compared to the first level now player is moving more vertically through causeways and ladders. We can again meet animals such as hedgehogs.

Fig. 3. A screenshot from Hiking Game developed by Turku University of Applied Sciences.

The game has been designed for both playing in groups and alone. Kinect sensor recognizes the player's movements, and the elderly people exercise together in front of the sensor. Based on the movement recognition, players are able to navigate through a predefined path successfully. The players are able to see the progress in the user interface as a vertical progress bar. This progress bar visualizes for the players 3-4 task locations in which they are able to take pictures of animals and other interesting objects. These pictures can be shared later with other players. Figure 3 shows a screenshot from Hiking Game.

### C. *Pikkuli Game*

The game has been designed and developed by Turku Game Lab (Finland). *Pikkuli* is Sun In Eye Production's well known animation series consisting of totally 26 five-minute stories. A bird called Pikkuli does not want to learn how to fly, so he swims.

Currently, seven Pikkuli games have been published in AppStore and GooglePlay. In addition, two motion detection games have been designed using Microsoft Kinect sensors. In the first motion detection game, the player has to help Pikkuli and his friends to move in a tree from branches on the right to branches on the left based on guidance icons visualized at the end of the branches. This game is a mixture of practicing fine motor skills and mental concentration. The player controls branches by moving his or her left or right hand up or down. In the second motion detection game, the player controls the little bird's flying by moving both hands at same time up and down (flying skills). Based on the flying skills, the player is able to avoid obstacles (e.g. other birds, clouds, and trees) and collect awards. Figure 4 shows a screenshot from a Pikkuli game.

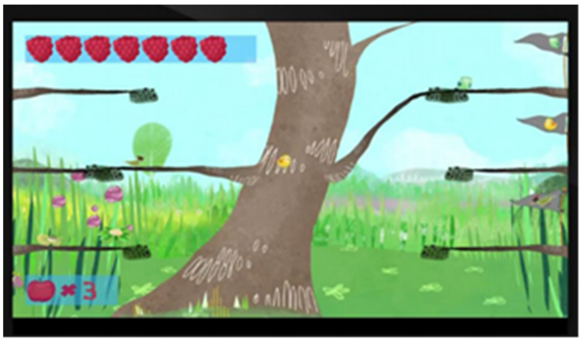

Fig. 4. A screenshot from a Pikkuli game developed by Turku University of Applied Sciences.

### D. *China Town Race Game*

The game has been designed and developed by the Centre for Healthy and Sustainable Cities, Wee Kim Wee School of Communication and Information, Nanyang Technological University (Singapore). Chinatown Race Game takes place in the context of Singapore's Chinatown. The objectives of the game are to promote the lifting of knee and bending of body left/right. Players need to lift their knees to increase the speed and bend left or right to control the left/right turning. The gameplay requires players to collect a coin item as well as to avoid barriers and people crossing the street. There are three game modes: (i) Single Player, (ii) Two Players with Cooperative mode, and (iii) Two Players with Competitive Mode. Figure 6 shows a screenshot from China Town Race Game.

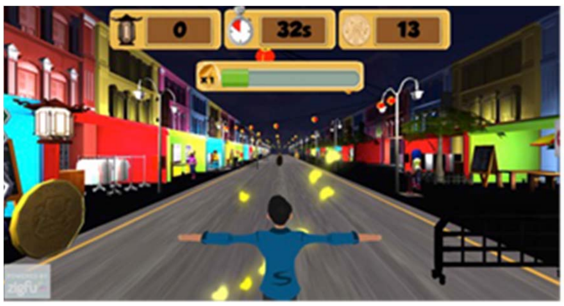

Fig. 5. A screenshot from China Town Race Game developed by Nanyang Technological University

### E. *RecReha Game*

The game has been designed and developed by RehaMed Ltd. (Japan). In RecReha, there are four games: Volleyball game, Soccer game, Rock-Paper-Scissors game, and Throwing game. In these games, the elderly need to use either upper or lower limbs to play the game. The main objective of these games is to encourage the elderly to engage in more physical activities through fun-based game exercises. Figure 7 shows a screenshot from Recreha game.


Fig. 6. A screenshot from RecReha game developed by RehaMed Ltd

### F. *Nature of Exercises*

In Skiing Game, the player must flex and extend their knees rhythmically at the same time with moving their arms front and back to make their skiing avatar move on the screen. To make the avatar move from middle to right or left, the player must move their center of mass to right or left to avoid hitting the obstacles. In Hiking Game, the player must march in place in a standing (or sitting) position to make the avatar move on screen. The faster they march, the faster the avatar moves in the virtual environment. In Pikkuli game, the player must lift and lower their arms from 0 to 90 to 0 degrees' ab and adduction to make the bird fly higher. The player must bend her knees from standing position to 90 degrees to make the bird fly lower. In China Town Race, the player has to lift their arms in 90 degrees abduction to reach the coins and lanterns. Players must also move their center of mass from left to right and back to hit the objects moving beside them. In RecReha Game, the player must bounce the virtual ball in a sitting position with their arms flexed and extended from elbow and shoulder joint or bounce the ball with their flexed knees, using mostly their hip flexors. They must also use the muscles of their torso to lean front and back to reach the balls.

## III. METHODS

A pilot study combining both between- and within-group design was conducted to examine the benefits of exergame exercise, conventional exercise, and life as usual on the physical functioning of elderly Singaporean people. The study was conducted between April and June 2016. A group of 30 adults (9 males, 21 females) aged 65 and above (Mean age = 71.34, SD = 6.62) were recruited in the study by using the convenient sample method. Subjects were recruited from two Singaporean senior activity centers and divided in three groups based on their living environments. The participation in the study was voluntary, and each participant was awarded a shopping voucher of S$70 equivalent for successfully completing 90% of the study visits.

The 30 participants were divided into subgroups of 10 persons each. The allocation was performed by the healthcare managers of the two senior centers. One week before the intervention, the baseline measurements were carried out by a senior physiotherapist. The baseline measures consisted of a physical activity questionnaire, balance being measured by using the Berg balance scale, physical functioning being measured by using Short Physical Performance Battery (SPPB), and handgrip muscle force being measured by using Jamar hand-hold dynamometer. (Table 1.)

The six-week intervention consisted of 50-minute exercise sessions repeated twice a week as stationary exercise. Exergame group (EG) used five exergames (described in detail in Chapter II lasting 1-2 minutes per exergame, and between every exergame, there was a stretching exercise before moving on to next. One session lasted for 45-50 minutes starting with a warm-up and ending with a cooling down period. The conventional group (CG) intervention was similar, except that they used normal physiotherapy exercises instead of the exergames. The third group, control group (CoG), continued their daily lives as usual. Both exergame and exercise groups were supervised by a final-year physiotherapy student and student assistants to confirm the safety in exercise. After the six-week intervention, the post-measurement were conducted by a senior physiotherapist (Table 2).

## IV. RESULTS

A total of 30 participants completed the six-week intervention study. Twenty-nine participants attended both pre and post measurements. One person in the control group could not attend the post measurements due to a post-operative status. In the pre measurements, four participants out of 30 expressed decreased ability to walk 10 meters without a walking aid. Two participants out of 30 expressed having some kind of a neurological status or disease, three expressed having some kind of a cognitive disorder and three persons expressed having some kind of a mental disorder. None of these affected participating in the study.

TABLE I. BASELINE CHARASTERISTICS

| | *Exergame group (EG)* | *Conventional group (CG)* | *Control group (CoG)* | *Total* |
|---|---|---|---|---|
| n | 10 | 10 | 10 | 30 |
| Gender (male) | 3 | 2 | 4 | 9 |
| Mean age (years) | 71 | 72 | 71,5 | 71,5 |
| Walking ability (n) < 10 m | 3 | 1 | 0 | 4 |
| Cognitive disorder (n) | 2 | 1 | 0 | 3 |
| Mental disorder (n) | 2 | 1 | 0 | 3 |
| Neurological disorder (n) | 1 | 0 | 1 | 2 |
| Berg balance score | 48,7 (SD 10,7) | 52,6 (SD 3,9) | 50,8 (SD 5,2) | 50,7 (SD 7,1) |
| SPPB score | 8 | 8,3 | 9,4 | 8,6 |
| Handgrip strength right (kg) | 25,4 | 22 | 27,9 | 37 |
| Handgrip strength left (kg) | 23,8 | 22,3 | 25,2 | 33 |

After the six-week intervention, the differences in SPPB, Berg balance score, and handgrip strength between the exergame group, the conventional group and the control group were investigated. Also the difference between pre and post measurements in the same variables was studied in all three groups (Table 2). There was no statistically significant difference in any of the variables within or between the groups. The exergame group showed the biggest change in Berg balance score between the pre and post measurements (pre-score mean 48.7, post-score mean 50.3), although the difference was not statistically significant. In control group, the Berg balance score decreased during the intervention, and in conventional group, the score remained almost the same (pre score mean 52.6, post score mean 53.4). In SPPB scores, the mean scores increased slightly in conventional and exergame groups; in control group, the mean score decreased, but the change was not statistically significant.

TABLE II. BETWEEN AND WITHIN GROUP COMPARISONS

| | *Between groups** | *CG*** | *EG*** | *CoG*** |
|---|---|---|---|---|
| SPPB score | 0,91 | 0,23 | 0,524 | 0,248 |
| Berg Balance score | 0,479 | 0,622 | 0,125 | 0,312 |
| Handgrip strength left | 0,683 | 0,553 | 0,611 | 0,916 |
| Handgrip strength right | 0,745 | 1 | 0,168 | 0,394 |

*Kruskall-Wallis test Sig.
**Wilcoxon signed rank test Sig.
CG (Conventional group)
EG (Exergame group)
CoG (Control group)

## V. CONCLUSION

The difficulty of comparing the results with those from previous studies is caused by the heterogeneity of the physical outcomes, the study designs and the length of the intervention periods. In our study, we measured the balance with Berg balance Scale (BBS) and physical functioning with SPPB. In studies by Stzrum et al. [18] and Franco et al. [19], the outcome variable (BBS) was the same. In the Franco's study, the duration of the intervention period was 3 weeks, whereas in our study, the duration was 6 weeks. Franco et al did not find any effect on the balance in either of the groups (exergame vs exercise), but this might be explained by the short intervention period. In Szturm et al.'s study, the exergame group improved their balance after 8 weeks' intervention, a finding conflicting with our study. The Berg balance scores improved significantly in the exergame group. In our study population, the baseline BBS scores were much higher in the exergame group compared to the respective group in the study by Szturm et al. It would be interesting to complete our study with participants with lower BBS scores. If the scores are high in baseline, the results of the intervention cannot be reached easily due to the ceiling effect. Sato et al. [20] produced findings similar to this study. In the pre-post comparison, Berg balance scores increased in intervention group but the scores in baseline were only 1 score lower than the maximum in both groups. More research should be done among the frail elderly with more severe balance problems to see the real effect of the intervention on balance.

## VI. DISCUSSION

In this study, we wanted to measure the changes in body functions and activities in the elderly population who conducted physical activities under three settings: (i) using exergame, (ii) using conventional exercise, and (iii) continuing their everyday activities. In the assessment of body functions by using handgrip strength measurement, the results correlate with the overall muscle strength in elderly people [10]. For body activities, we used the Berg balance scale, which consists of several activities related to balance, and SPPB, which consists four parts related to balance and walking abilities.

The main outcome of this study was the notion that both types of exercise, exergaming and conventional exercising, were beneficial for elderly people's physical functioning. Both exergame group (EG) and conventional group (CG) show better results in all measurements after the study; however, in the control group (CoG), the measurements remained same or results decreased. Even though the users' experiences of the exercise method was not our research question, it cannot be disregarded. The exergame group expressed enthusiasm towards exergaming, while the conventional group expressed frustration with their exercise program. When physiotherapists consider methods for enhancing the physical activity and physical functioning of a customer, different users have to be taken into account. Singaporean participants felt excited to have an opportunity to use Skiing Game; none of the users had previous experiences of skiing. To convince the stakeholders in the health care system, there should always be evidence of the efficacy of the chosen rehabilitation method.

This study could not prove the efficacy of exergames due to the nature of the study itself. The small sample size and the convenient sample method served a purpose in this pilot study but were not suitable for proving the efficacy. Similar studies in a randomized controlled setting with a bigger sample size are needed in order to prove the effect. However, the positive experiences and the feedback of exergaming showed that exergaming is a useful choice for enhancing the physical activity and physical functioning of elderly people.

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