Investigating the Finnish elderly people's user experiences in playing digital game-based skiing exercise: A usability study

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Elderly people's engagement in regular physical exercises is vital in old age. Digital games are promising to promote their engagement in physical exercises. The existing commercial games are not suitable for elderly people. More studies are required to undertake to investigate effective guidelines for designing digital games for elderly people. The main objective of this study is to investigate the Finnish elderly people's user experiences in playing a digital game-based exercise called 'The Skiing Game'. Furthermore, we aimed at studying the difference between elderly people's attitude towards physical and digital game-based exercises. Lastly, we intended to investigate if digital games can be an alternative solution for elderly people to exercise. We conducted a usability evaluation of the game with 21 Finnish elderly participants in Finland. The findings show that the Skiing game is a simple, easy, and user-friendly game for the elderly participants. Their in-game and post-game experiences were moderately positive. Their attitudes towards digital games were moderately negative. However, their attitudes have changed more positively after the gameplay. They also showed their interests in the game, and recommend that digital games can be an effective way of exercising for them. Through participants' observation, we recommend a number of usability and game guidelines for designing digital games for elderly people. The findings from this study can help researchers and practitioners in the related areas to gain insightful knowledge about adopting and utilizing digital games for promoting elderly people's physical exercise activities.

Keywords: usability, user experiences, physical exercise game, gamification

According to the American Psychological Association[1], elderly people experience natural and normal age-related changes, which may impact their quality of life. Physical decline and functional incapacity are common age-related changes for elderly people[2]. Manini[3] highlights that the ageing population will result in higher rates of physical disabilities that result from the ageing process and chronic diseases[3]. Physical health declines with age, and it is associated with the likelihood of disability[4].

The World Health Organization (WHO)[5] suggests that being engaged in physical activities can improve elderly people's physical health, functional capability, and cognitive skills. Physical activities include regular exercises (e.g. balance, stretching, and strengthening), activities of daily living (e.g. household chores), leisure activities (e.g. gardening and walking), and playing games (e.g. bowling). Physical exercise is an effective non-pharmaceutical intervention for elderly people to prevent from suffering cognitive decline and neurodegenerative disease (e.g. Alzheimer's disease)[6]. The positive effects of physical exercises on elderly people are not only prevention of age-related diseases, but also an improvement in the quality of life[7].

Participation in regular physical exercises can decline when a person becomes aged[8]. An ageing process can reduce the physical fitness of an elderly person, including strength, endurance, agility, balance, and flexibility. Consequently, he or she may encounter difficulties in doing activities of daily living, and become reliance on others

such as family members and caregivers. Furthermore, physical decline in old age can have negative impacts on an elderly person's well-being and quality of life such as social role changes, disengagement in social activities, and depression[9].

In recent years, people have used modern technologies to promote elderly people's physical activities such as ambient assisted living for ageing[10] and robots for frail elderly people's rehabilitation[11]. Among them, digital games have the potential to improve elderly people's physical abilities[12-14]. Different terms are used to define the concept of digital game-based physical exercises for elderly people, including serious games for healthcare[15], exergames[16], and gamification for healthcare[17]. To date, there have been a number of studies that investigated the usability and usefulness of existing games and technologies for elderly people's physical healthcare such as Nintendo Wii Fitness games[18,19], Kinect for Xbox Fitness games[20,21], and PlayStation PlayMove Fitness games[22].

IJsselsteijn, Nap, & de Kort[23] highlighted that the digital games market for elderly people is significantly large because the majority of game developers primarily focus on the young users. Furthermore, commercial games do not meet the needs of the elderly population. Elderly users encounter more usability problems in playing digital games, compared with the younger users due to their limited functional abilities and lack of prior experiences in gameplay[23].

Although there are an increasing number of studies on user experiences and usability guidelines for younger users in various contexts, little is known for an elderly population in digital games[24]. To date, there have been some promising studies for user experiences and the usability of digital games for elderly people[25,26]. Nevertheless, this is an on-going work, and it is important to investigate more widely in this specific area so that we can design more usable and useful digital games for elderly people's physical well-being.

In this study, we aim at understanding the usability of the Skiing Game for elderly people as well elderly participants' user experiences in the gameplay. Furthermore, we are interested in differences between elderly participants' attitudes towards traditional physical exercises and digital game-based exercises. In addition, we aim at investigating if digital game-based exercises can be an alternative solution for their physical exercise activities. We conducted a usability study with 21 Finnish elderly participants in Finland and collected their feedback towards the game, user experiences, and attitudes. We also observed their gameplay, interaction experiences, and challenges. Then, we analyzed and reported the findings, followed by usability and game design recommendations. The findings in this study can be useful and insightful for our future works as well as for other researchers and practitioners working in the related areas.

Background

Gamified Solutions in Healthcare (GSH)

GSH is a research project, which aims at promoting elderly people's quality of life through digital game-based solutions. This includes active ageing, cost-effective healthcare solutions, socialization, and safety for elderly people[27]. In this study, we only emphasize the 'Rehabilitation' services that aim at providing digital game-based exercises for elderly people to improve their engagement and motivation in a regular physical exercise activity[28]. Furthermore, it aims at providing digital game-based rehabilitative exercises for elderly people with physical disabilities (e.g. stroke patients).

Before we implemented rehabilitation services for elderly people, we conducted a few preliminary studies to understand the requirements of elderly people for their physical activities and exercises. We visited elderly service homes in Finland and observed their needs in daily activities, including physical exercises, social connection, and recreation. We also studied the usability and usefulness of existing digital games and technologies for elderly people. Then, we conducted a number of usability testing of commercial digital games with the Finnish elderly participants in Turku, Finland. We also evaluated the usability games developed by Puuha Group Finland and Turku Game Lab.

The preliminary findings were reported in the previous publications, including a literature review on digital games for elderly[27], understanding motivational factors for elderly people[28,29], a review of existing commercial games[27,30], a usability testing of commercial games, the SportWall game by Puuha Group Finland, and interaction devices for elderly people[29,31,32]. The findings from the preliminary studies are useful and insightful for our game design, development, and future usability testing of digital games for GSH project.

Based on the findings from the preliminary studies, we designed and developed a digital physical exercise game called the 'Skiing Game'[33]. Next, we evaluated this game with the Finnish elderly participants in Finland to understand the usability of the game and user experiences. In this paper, we report and discuss the findings from the usability testing of the Skiing game with the Finnish elderly participants. The main objectives of the usability testing are:

(i) To investigate the Finnish elderly people's feedback towards the usability of the Skiing game.
(ii) To explore the Finnish elderly people's user experiences during and after the gameplay, and
(iii) To understand their attitudes towards physical exercises and digital-game based exercise, as well as their differences.
(iv) To examine if digital games can be an alternative solution for promoting elderly people's participation in physical exercise activities, and
(v) To identify usability challenges and guidelines for elderly people in playing digital game-based exercises.

Research gap

As digital games have been used for promoting elderly people's physical well-being in terms of physical exercises and rehabilitation, researchers, especially in the area of Human-Computer Interaction (HCI), have become interested in understanding the usability and game design guidelines of digital games for an ageing population. To date, there have been a number of studies in the literature that investigated and proposed usability and game design guidelines for designing digital games for elderly people. For instance, IJsselsteijn et al.[23] reviewed and discussed digital game design to explore design opportunities to create digital games with engaging content and friendly interface that elderly users can easily and pleasurably use. Gerling, et al.[25] evaluated full-body motion-based games for elderly people, and they proposed seven usability guidelines for designing full-body interaction games for them. Planinc et al.[34] conducted a usability study of digital game-based exercises or exergames to investigate their appropriateness for elderly people.

Although digital games have shown the potential for elderly people's physical well-being, this research area has still many challenges to be addressed in terms of game design, interaction design, usability, and usefulness. IJsselsteijn et al.[23] pointed out that Digital games are promising as a tool to enhance elderly people's mental and physical workout; however, most digital games in the market are targeted at the younger players. Furthermore, Gerling et al.[25] highlighted that the contents of the commercial games are generally not suitable for elderly people.

According to Nap, Kort, and IJsselsteijn[35], senior gamers or elderly players do exist, but compared with the number of younger players, they are still a small audience in this context. Thus, it is important to know more clearly about elderly players' problems and challenges in playing digital games. It is still state-of-the-art, and unclear what motivates elderly players to engage in digital gameplay, what type of games they prefer to play, what problems they encounter with game interfaces and usability, and what their perceptions and attitudes towards digital gameplay are[35]. Marin, Lawrence, Navarro, and Sax[36] also pointed out that more studies should be undertaken to develop reliable guidelines, which would help game designers and usability practitioner to create more useful and usable games, especially for elderly people. Nawaz et al.[37] also highlighted that future studies should be carried out to investigate quantifiable results and more insights about the usability of digital games for elderly people.

Usability

In the literature, there are a number of definitions of the term 'Usability' that are different from one another. For instance, ISO/IEC 9126-1 defines that the capability of a particular software product to be understood, learned, used, and attractive to users, when used under specified conditions[38,40]. ISO9241-11 also defines usability as the extent to which a particular product can be used by specific user groups to achieve specific goals with effectiveness, efficient, and satisfaction in a specific context of use[39,40]. IEEE also defines that the ease with which a user can learn to operate, prepare inputs for, and interpret outputs of a particular system or component[40]. Based on the different definitions, we learn that the term usability contains common components such as the ease-of-use, efficiency, and effectiveness of a system. Furthermore, it is associated with users' learnability and satisfaction in using a system.

According to Nielsen, usability is defined as a quality attribute that assesses the ease-of-use of a particular system's user interfaces[41]. The author also states that a key element of 'usability' is utility that refers to the design's functionality that can fulfill what users need in using a particular system. The author also defines the five quality components of usability, including learnability, efficient, memorability, errors, and satisfaction. Learnability refers to how easy a particular system is for a first-time user and efficiency means how quickly a user can accomplish a task in using a particular system. Memorability refers to how easily a user can reestablish proficiency in using a particular system after returning from a long period of not using it. Errors mean how many errors a user makes in using a particular system and how easily and quickly they can recover from it. Finally, satisfaction means how pleasant a particular system is for a user to use the design. In this study, we are interested in the usability of the Skiing game for elderly people. Specifically, we aim at investigating the ease-of-use of the game for elderly people, as well as the learnability of it. We are also interested in elderly people's user experiences in playing the game in

terms of their positive and negative experiences before and after the gameplay. Through participants' observation in the usability testing, we aim at identifying usability challenges encountered by elderly people, as well as proposing usability guidelines and game design recommendations.

Skiing game

We designed and developed the Skiing game based on the following findings from the preliminary studies[27,28,31]. In our previous usability studies, we found that elderly people preferred game context and background that are familiar to them and close to real-life environments and activities. For instance, they like to play card games, sport-based games, and recreational activities (e.g. dancing and singing games). Furthermore, they like natural and user-friendly game play and actions, which can be familiar to them[30]. As an example, they like tennis, bowling, and dancing games. According to the findings from the previous studies[32], we observed that simple and easy interaction techniques are effective for elderly people while playing a digital game. They prefer controller-free natural interaction to play digital games (e.g. a motion detection device). The elderly participants in the previous usability tests recommended simple and easy in-game instructions to follow. Furthermore, they suggested that simple and clear feedback is important to play a game more easily.

In the Skiing game, we chose snowy mountains and a forest as the game context and background because Skiing as a physical activity is popular and familiar to most Finnish elderly people. The gameplay is simply designed based on an action of steering a pair of skiing poles. A player needs to move both hands forward and backward to ski in the game. He or she needs to move body either left or right to avoid obstacles in the game. In this game, we adopted a double pole skiing technique. Generally, this game is relatively easy and is a familiar exercise activity to the most Finnish elderly who had previous experiences with cross-country skiing.

To design and develop the Skiing game, we use the Unity 3D game engine. For the game interaction, we used a webcam with Extreme Reality (XTR3D) Technology to detect a player's upper-limb movements. Extreme Reality supports a software-based motion analysis. It can be integrated with any computing device by using a traditional web-camera to track a player's movements[42]. XTR3D technology includes a motion detection engine, which captures the 3D position (X, Y, and Z) of a player's skeletal position just in front of the camera in every frame. It creates a live 3D model of a player, which is analyzed by a software to recognize the gestures from the skeletal positioning of a player.

Methods

To evaluate the usability of the Skiing game, we conducted a usability test with the Finnish elderly participants at an elderly service home called 'Ruusuvalkama', which provides physical, social, and health services for elderly people in Finland.

Elderly participant recruitment

The recruitment of the Finnish elderly participants was undertaken by the staffs from the elderly service home. They advertised participant recruitment at their place, and if a particular elderly person is interested in taking part in this study, they assessed if he or she is fit to participate. There are a number of selection criteria in this recruitment. Specifically, an elderly person should be 60 years and above. His or her health condition should be stable. Furthermore, he or she needs to be physically and mentally capable, with no neurological or cognitive deficits. He or she can resist for playing a game for at least 15 minutes in a standing position. They also should have a capability of independent standing and walking 10 meters. The staff from the elderly services home selected the individual elderly participant carefully to meet the needs of our study. Once an individual participant agreed to take part in this study, we requested his or her consent.

Usability test design and procedure

We recruited a total of 21 Finnish elderly participants in this study. The average age of the participants is 76 years old. We conducted two-day usability testing at the elderly service home. On the day-one, 12 elderly people participated, and the remaining 9 participants joined on the day-two. Three researchers conducted the usability testing and the Finnish language was used to communicate the elderly participants. At the station one (room 1), one researcher conducted the pre-study session that includes questionnaires and interview questions investigating the participants' demographic information, their physical exercise activities, and their attitudes towards physical exercises. We also requested the individual's consent to be involved in this study. The pre-study session took about 5 to 10 minutes.

The second researcher took in-charge of the Station two (room 2) where the participants played the Skiing Game. The researcher guided the participants on how to play the game and monitored them to minimize their potential physical risks. The duration of the gameplay for the individual participant took about 20 minutes. In the station three (room 3), the third researcher asked the participants to complete the post-gameplay

questionnaires and interview. These include in-game and post-game GEQ questionnaires, SUS questionnaire, elderly participants' attitudes towards digital game-based exercises, and post-study interview questions. We observed the participants' behavior, user experiences, and responses towards the game by using a video recorder and note-taking. The detailed procedures of the usability study are mentioned in *Table 1*.

Table 1. Skiing Game usability testing design and procedures

Activity	Duration	Station
Introduction to the usability testing Pre-study interview	10 min	1
Game Tutorial guided by a researcher Skiing Game played by elderly participants Break-time	20 min 5 min	2
Post-study questionnaire Total	10 min 45 min	3

Questionnaires

Attitudes towards physical exercise questionnaire

In this study, before the elderly participants played the Skiing game, we investigated their attitudes towards physical exercise in their old age. Furthermore, we also investigated their attitudes towards digital game-based exercise after they have played the game. To investigate their attitudes, we created questionnaire based on the attitudes of older adults toward physical activity and exercise developed by Terry et al.[43]. The questionnaire items are provided in the data analysis section.

System Usability Scale (SUS)

To investigate participants' feedback towards the usability of the Skiing Game, we used SUS, which is easy and simple to understand for elderly people. It includes a total of 10 items that gives the subjective assessments of the usability of a particular system[44]. SUS is based on the 5-point Likert scale from Strongly disagree (1) to Strongly agree (5). It can be used to assess a wide range of products and services that include software and hardware systems, mobile devices, applications, and websites[45].

This scale can be also used for a small sample size, and it is easy to apply to participants. According to Sauro[46], while SUS is intended to measure perceived ease-of-use of a system, it can also provide not only usability but also learnability dimensions. Brooke[47] indicated that SUS is technology-neutral, and it has been continuously applied in many studies as technology has become more advanced over the past years without reinventing the questionnaires. SUS is an effective tool for measuring the usability of a system or product, and it provides a score from 0 to 100, which is easy to understand for participants[48]. The authors also advocated that it is a highly robust and flexible tool for usability practitioners[49]. In our study, we modified it to a game system and its usability, whereas the original version of SUS refers to a particular system. *Table 2* shows the revised version of the SUS questionnaires that are used in our usability testing of the Skiing Game.

Table 2. System Usability Scale (SUS) modified for this study

Questionnaires
1. I think that I would like to play this game frequently.
2. I found this game unnecessarily complex.
3. I thought this game was easy to play.
4. I think that I would need the support of a technical person to be able to play this game.
5. I found the various functions in this game were well integrated.
6. I thought there was too much inconsistency in this game.
7. I would imagine that most people would learn to play this game very quickly.
8. I found this game very cumbersome to play.
9. I felt very confident playing this game.
10. I needed to learn a lot of things before I could get going with this game.

Game Experience Questionnaires (GEQ)

In this study, we used GEQ to investigate participants' experiences during and after the gameplay. We used two GEQ modules: in-game and post-game to assess players' experiences in the game[50]. The GEQ in-game module is utilized to explore a player's game experience during a game-play session. It has seven components including Sensory and imaginative immersion, Flow, Competence, Positive affect, Negative affect, Tension, and Challenge[51,52]. According to Norman[45], GEQ is a reasonable and applicable questionnaire in exploring a player's experiences with a particular game system. The author also advocated that it has been widely and successfully used in many studies internationally[53].

Johnson, Wyeth, Sweetser, and Gardner[54] mentioned that 'Competence', 'Tension', 'Negative affect', and 'Positive affect' can be easily understood by their titles. 'Competence' refers to a player's skills in playing a game (e.g. I felt skillful). The component 'Tension' is about a player's level of frustration in playing a game (e.g. I feel frustrated). 'Positive affect' refers to a player's positive affection (e.g. I felt good), whereas 'Negative affect' means that a player feels negative while playing the game (e.g. I felt bored). The component 'Challenge' refers to a player's effort, challenge, and pressure in the game (e.g. I had to put a lot of effort into it). The component 'Sensory and imaginative immersion' refers to how interested a player is in a game's story (e.g. I was interested in the game's story). Finally, the component 'Flow'

is about how engrossed a player feels while playing a game (e.g. I felt completely absorbed). All GEQ in-game components and response options from the questionnaires are provided in *Table 3*.

Table 3. In-Game GEQ components and response options from the questionnaires

In-game GEQ components	Response option
Sensory and imaginative immersion	I was interested in the game's story. I found it impressive.
Flow	I forgot everything around me. I felt completely absorbed.
Competence	I felt successful. I felt skillful.
Positive affect	I felt content. I felt good.
Negative affect	I felt bored. I found it tiresome.
Tension	I felt frustrated. I feel irritable.
Challenge	I felt challenged. I had to put a lot of effort into it.

We also used the GEQ post-game questionnaire to assess how players felt after playing a particular game[55]. It has four components including 'Positive experience', 'Negative experience', 'Tiredness', and 'Returning to reality'. The 'Positive experience' component refers to a player's positive experiences after he or she has played a game such as satisfaction, victory, and power (e.g. I felt satisfied). The 'Negative experience' component is about a player's bad experiences after playing a particular game (e.g. I felt bad). The component 'Tiredness' refers to a player's exhaustion in playing a game (e.g. I felt exhausted). The 'Returning to reality' component is about a player's disorientation after he or she has played a game (e.g. I found it hard to get back to reality). For both GEQ in-game and post-game questionnaires, we used a 5-point Likert scale from Not at all (0) to Extremely (4). All GEQ post-game components and response options from the questionnaires are stated in *Table 4*.

Post-Gameplay interview questions

We implemented the post-gameplay interview questions, which were adapted from the Senior Technology Acceptance & Adoption Model[56]. There are four questionnaire items to investigate the elderly participants' perceptions after they have played a game:

(i) 'Perceived Usefulness' was used to understand the effectiveness and usefulness of playing digital games.

(ii) 'Perceived Ease-of-Use' was used to find out if playing the Skiing Game was easy for them.

(iii) 'Gerontechnology Self-Efficacy' was used to find out if the player could easily play after receiving the game instructions and to determine if the game instructions were adequate.

(iv) 'Gerontechnology Anxiety' was used to investigate if the player was afraid of making mistakes during the gameplay.

Figure 1. Skiing Game usability testing

Participants observation

In this usability testing, we observed the elderly participants' behavior, expression, emotions, and feedback. We used a video recorder to capture elderly participants' interaction experiences and the usability problems encountered by them. We also applied note taking technique in the situation when the individual elderly participant disliked to be recorded. *Figure 1* shows a picture being taken during their gameplay.

Results

In this section, we report the findings from the analysis of pre-study interview questions, SUS, In-game and Post-game GEQ, and post-study interview questions.

Pre-study interview

From the pre-study interview, we observed that 20 out of 21 elderly participants do regular exercises such as stretching, balance training, walking, cycling, and jogging. 11 out of 20 elderly participants perform physical exercises daily for 1-2 hours, whereas 9 participants exercise weekly for at least 2 hours. The elderly participants who exercise regularly stated that participation in regular physical exercises are important in old age, and they enjoy doing it. Only one elderly participant who is 85 years old had already stopped doing exercises, claiming that she was too old to do exercises.

Regarding prior experiences in playing digital games, 18 out of 21 elderly participants did not play digital games before. 10 out of 18 elderly participants mentioned that they were not interested in digital games while two elderly participants

Table 4. Post-Game GEQ components and response options from the questionnaires

Post-game GEQ components	Response option
Positive experience	I felt revived. It felt like a victory. I felt energized. I felt satisfied. I felt powerful. I felt proud.
Negative experience	I felt bad. I felt guilty. I found it a waste of time. I felt that I could have done more useful things. I felt regret. I felt ashamed.
Tiredness	I felt exhausted. I felt weary.
Returning to reality	I found it hard to get back to reality. I felt disoriented. I had a sense that I had returned from a journey.

claimed that it was a waste of time and the other two did not provide reasons. Two elderly participants revealed that they did not have a device to play digital games, whereas one participant did not like it. The last participant mentioned that digital games are meant for the younger people.
In this study, we observed that there were only three elderly participants who have played digital games before. They played Bejeweled, Sudoku, Solitaire, Chess, and Mahjong games. They used computer and mobile phones to play digital games. They commented that playing digital games is entertaining for them, as well as a good way to waste time in old age. They also recommended that digital games can improve their cognitive abilities and memory.

Attitudes towards physical exercises

Before the elderly participants played the game, we investigated their attitudes towards physical exercise. According to the findings from the analysis of data, we observed that all participants recommended that physical exercise is essential to good health (M=5.0). They believed that physical exercises can help to work of emotional tension and anxieties (M=4.9). All elderly participants advocated that physical exercises are important for maintaining health (M=5.0), and it is beneficial to the human body (M=5.0). Lastly, they recommended that regular physical exercise can make one feel better (M=5.0).

According to the following *Table 5*, we found that all elderly participants strongly agreed that participation in physical exercise is essential to good health. We also observed that 85.71% of participants strongly agreed on the fact that physical exercises can help them to work of tension and anxieties while 14.29% just agreed on it. Furthermore, all participants strongly advocated that doing physical exercises is important for a person to gain and maintain all-around health. All elderly participants also strongly agreed that it can be beneficial to the human body. Lastly, we observed that 95.24% of elderly participants strongly agreed that doing regular physical exercises can make them feel better and the other 4.76% just agreed on it.

SUS

After the elderly participants had played the game, they provided their feedback towards the usability of the Skiing game by responding to the SUS questionnaire. We analyzed their responses based on the original method by Brooke[44]. According to this method, each participant was given a score, which ranges from 0 to 100. Basically, a score lower than 68 was defined as 'Below Average', whereas greater than 68 is 'Above Average'[45,46]. As this score does not provide a specific meaning, we adopted the Adjective Rating Scale for SUS implemented by Bangor et al.[48]. This Adjective Rating Scale has seven adjective scales, including 'Worst imaginable', 'Awful', 'Poor', 'Ok', 'Good', 'Excellent', and 'Best imaginable'. *Table 6* shows the individual's SUS score and adjective scale towards the usability of the Skiing game. The following *Figure 2* shows the graphical representation of SUS scores and Adjective ranking.

According to *Table 7*, we observed that there is only one participant (4.76%) who rated the game 'Best imaginable'. Noticeably, there are a total of

Table 5. Elderly participants' attitudes towards physical exercise in 5-Point Likert scales

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Q1. Physical exercise is essential to good health.	0.00%	0.00%	0.00%	0.00%	100.00%
Q2. Physical exercise helps to work of emotional tension and anxieties.	0.00%	0.00%	0.00%	14.29%	85.71%
Q3. Physical exercise is important in helping a person to gain and maintain all-around health.	0.00%	0.00%	0.00%	0.00%	100.00%
Q4. Physical exercise is beneficial to the human body.	0.00%	0.00%	0.00%	0.00%	100.00%
Q5. Regular physical exercise makes one feel better.	0.00%	0.00%	0.00%	4.76%	95.24%

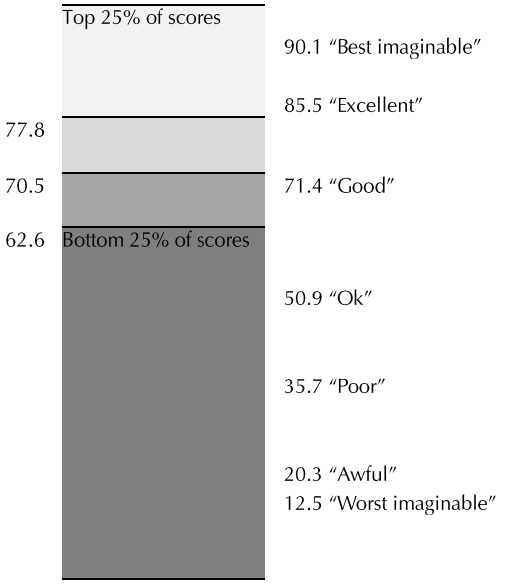

Figure 2. SUS scores and adjective rankings[57]

nine participants (42.86%) who rated the game 'Excellent'. Six elderly participants (28.57%) rated the game 'Good' while two participants (9.52%) for 'OK' and 'Poor' individually. Lastly, there is one participant (4.76%) who commented that the game was 'Worst imaginable'. For acceptability ranges of SUS, we observed that 16 out of 21 participants commented that the usability of the game was within the acceptable range while 2 participants rated as marginal. In contrast, 3 out of 21 participants revealed that the game was not acceptable.

We also analyzed the individual SUS item in 5-point Likert scale (from Strongly disagree to Strongly agree) (*Table 7*). We observed that more than 60% of participants responded that they would like to play this game frequently. We also found that more than 70% of them strongly disagreed that the game was unnecessarily complex, while 14.29% just disagreed. Furthermore, more than 60% of participants strongly agreed that the game was easy to play. Regarding the support from a technical person, 57.14% of participants commented that they did not need any support, whereas 19.5% commented that they needed support from a technical person. 57.14% of participants strongly agreed that the game was well-integrated with various functions, while 28.57% just agreed and 4.76% were neutral. Noticeably, more than 80% of total participants strongly disagreed that the game had inconsistencies. We observed that 76.19% of participants strongly agreed and 14.29% just agreed that the game was easy to learn. With regard to the gameplay, more than 75% of participants strongly disagreed that the game was cumbersome to play. Regarding the participants' confidence in playing the game, approximately 52% strongly agreed, whereas 33.34% strongly disagreed. Lastly, more than 50% of elderly participants strongly disagreed that they needed to learn a lot of things before playing the game.

In-game GEQ

We report the findings from the analysis of in-game GEQ questionnaire responded by the elderly participants. The analysis was conducted based on the calculation method by IJsselsteijn et al.[50]. According to *Table 8*, we observed that 'Positive affect' component had the highest score (M= 3.0). For this component, we observed that the participants felt content in the gameplay (M=2.8) and they felt good to play it (M=3.3). The component 'Flow' has the second highest score (M= 2.6). For this component, the participants responded that they forgot everything around them while playing the game (M= 2.3) and were moderately absorbed in the gameplay (M=2.9). The components 'Sensory and Imaginative' and 'Competence' had the same score (M= 2.3). For 'Sensory and imaginative', although they were fairly interested in the gameplay (M= 2.5), they were less impressive with the game (M=1.5). For competence, they felt successful (M=2.6) and skillful (M=0.9). Regarding the component 'Challenge', it had the second lowest score (M= 1.2). For this component, the game was less challenging for them (M= 1.8) and they did not put effort into the gameplay (M=1.1). The components 'Tension' and 'Negative affect' had the least score (M= 0.1) individually. For the component 'Tension', they were less frustrated (M=0.1) and irritated (M=0.4) respectively. Lastly, for the component 'Negative affect', the participants were not bored in the gameplay (M= 0) and they found the gameplay tiresome (M=0.3).

Table 6. SUS scores and adjective scales

SUS adjective rating (Score range)	Number of participants	Acceptability ranges	Percentage	Mean	SD
Best imaginable (90-100)	1	Acceptable	4.76%	100	0
Excellent (80-89)	9	Acceptable	42.86%	88.9	4.7
Good (63-79)	6	Acceptable	28.57%	78.3	5
OK (47-62)	2	Marginal	9.52%	68.8	1.8
Poor (25-46)	2	Not acceptable	9.52%	49	1.8
Worst imaginable (0-24)	1	Not acceptable	4.76%	17.5	0

Table 7. SUS scores in 5-point Likert scale

SUS Items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Q1. I think that I would like to play this game frequently.	14.29%	9.52%	16.67%	42.86%	23.81%
Q2. I found this game unnecessarily complex.	71.43%	14.29%	4.76%	4.76%	4.76%
Q3. I thought this game was easy to play.	4.76%	0.00%	14.29%	14.29%	66.67%
Q4. I think that I would need the support of a technical person to be able to play this game.	57.14%	14.29%	4.76%	4.76%	19.05%
Q5. I found the various functions in this game were well-integrated.	0.00%	9.52%	4.76%	28.57%	57.14%
Q6. I thought there was too much inconsistency in this game.	71.43%	23.81%	42.86%	4.76%	0.00%
Q7. I would imagine that most people would learn to play this game very quickly.	0.00%	0.00%	9.52%	14.29%	76.19%
Q8. I found this game very cumbersome to play.	52.38%	23.81%	0.00%	9.52%	14.29%
Q9. I felt very confident playing this game.	14.29%	19.05%	14.29%	19.05%	33.33%
Q10. I needed to learn a lot of things before I could get going with this game.	47.62%	23.81%	4.76%	9.52%	14.29%

According to the findings from the analysis of In-game GEQ individual items, we observed that most of the elderly participants (more than 60%) agreed that they felt content to play the game and 76% felt good in the gameplay. Regarding the flow in the game, 33.33% of participants strongly agreed that they forgot everything around them while 23.81% strongly disagreed. Furthermore, 47.62% strongly agreed and 23.81% just agreed on it. We also found that 42.86% strongly agreed that they were interested in the game, whereas 23.81 did not. Furthermore, 38.10% strongly agreed that the game was impressive, followed by 14.29% who strongly agreed on it. Regarding competence, 24.86% just agreed that they felt successful while more than 30% agreed that they were skillful, whereas more than 20% strongly disagreed and 33.33% were neutral. With regard to the component challenge, only 38.10% just agreed that they felt challenged, whereas more than 30% did not agree and 19.05% was neutral. Noticeably, more than 50% strongly disagreed they put effort into the gameplay. In addition, we observed that approximately 90% strongly did not agree that they were frustrated in the gameplay while all participants (100%) also strongly disagreed that they felt irritable. Lastly, all participants (100%) were not bored to play the game while more than 80% strongly disagreed that the game was tiresome.

Post-game GEQ

After the elderly participants had played the game, we asked their post-game experiences by using post-game GEQ questionnaire. Based on the findings from the analysis (*Table 9*), we observed that the participants had an average positive experience (M=2.0). We found that they were moderately satisfied with the game (M=2.5), followed by a victory (M=2.1) and being proud (M=2.1) respectively. Furthermore, the participants felt revived (M=2.0), energized (M=1.9), and powerful (M=1.6) respectively. In contrast, we observed that the elderly participants had almost no negative experiences (M= 0.1). They had a very low score in guilty (M=0.1) waste of time (M=0.2), while they did not feel bad, regret, and ashamed (M=0). Furthermore, we found that their tiredness had a noticeably low score (M=0.1). They felt weary (M= 0.1) and had no exhaustion (M=0). Lastly, regarding returning to reality, we observed that they also had a low score (M=0), including getting back to reality (M=0.2) and disorientation (M=0.9). We also found that they had a low score in returning from a journey (M=1.3).

We also analyzed the Post-game GEQ items in 5-point Likert scale (*Table 10*). We found that more than 30% elderly participants were neutral for their satisfaction and feeling powerful in the gameplay. We also observed that more than 35% of participants disagreed that they felt energized to play the game. In contrast, 28.57% of elderly participants agreed that they felt like a victory in the gameplay while the same percentage of participants remained neutral for being revived in the game. For being proud to play the game, 28.57% of participants strongly disagreed, whereas other 28.57% strongly agreed on it. Regarding the negative experiences, more than 80% of the participants strongly disagreed that they experienced negatively to play the game. Furthermore, concerning tiredness of the participants, more than 80% strongly disagreed that they had such experience. Lastly, 90% of the participants strongly disagreed that they found it hard to go back to

Table 8. In-game GEQ scores in 5- point Likert scale

GEQ Items	Mean	Standard Deviation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Positive affect	3	0.9					
I felt content	2.8	1.2	9.52%	0.00%	23.81%	33.33%	33.33%
I felt good	3.3	1.1	4.76%	0.00%	19.05%	14.29%	61.90%
Flow	2.6	1.2					
I forgot everything around me	2.3	1.6	23.81%	9.52%	14.29%	19.05%	33.33%
I felt completely absorbed	2.9	1.3	4.76%	19.05%	4.76%	23.81%	47.62%
Sensory and imaginative	2.3	1.3					
I was interested in the game's story	2.5	2.1	23.81%	0.00%	4.76%	42.86%	28.57%
I found it impressive	1.5	1.3	19.05%	14.29%	14.29%	38.10%	14.29%
Competence	2.3	1					
I felt successful	2.6	1.9	4.76%	4.76%	33.33%	42.86%	14.29%
I felt skillful	0.9	1.2	19.05%	9.52%	33.33%	33.33%	4.76%
Challenge	1.2	0.7					
I felt challenged	1.8	0.7	14.29%	28.57%	19.05%	38.10%	0.00%
I had to put a lot of effort into it	1.1	0.9	52.38%	33.33%	9.52%	4.76%	0.00%
Tension	0.1	0.2					
I felt frustrated	0.1	0	90.48%	4.76%	4.76%	0.00%	0.00%
I felt irritable	0.4	0	100.00%	0.00%	0.00%	0.00%	0.00%
Negative affect	0.1	0.3					
I felt bored	0	0	100.00%	0.00%	0.00%	0.00%	0.00%
I found it tiresome	0.3	0.8	80.95%	9.52%	4.76%	4.76%	0.00%

Table 9. Post-game GEQ scores in 5-point Likert scale

GEQ Items	Mean	Standard Deviation	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Positive experience	2	0.3					
I felt revived	2	1.4	23.81%	9.52%	28.57%	19.05%	19.05%
It felt like a victory	2.1	1.3	14.29%	19.05%	23.81%	28.57%	14.29%
I felt energised	1.9	1.1	4.76%	38.10%	33.33%	9.52%	14.29%
I felt satisfied	2.5	1.2	4.76%	14.29%	33.33%	23.81%	23.81%
I felt powerful	1.6	1.2	23.81%	19.05%	38.10%	9.52%	9.52%
I felt proud	2.1	1.6	28.57%	9.52%	9.52%	23.81%	28.57%
Negative experience	0.1	0.1					
I felt bad	0	0	95.24%	4.76%	0.00%	0.00%	0.00%
I felt guilty	0.1	0.5	85.71%	9.52%	4.76%	0.00%	0.00%
I found it a waste of time	0.1	0.4	90.48%	4.76%	4.76%	0.00%	0.00%
I felt that I could have done more useful things	0.2	0.6	80.95%	9.52%	9.52%	0.00%	0.00%
I felt regret	0	0	100.00%	0.00%	0.00%	0.00%	0.00%
I felt ashamed	0	0	95.24%	4.76%	0.00%	0.00%	0.00%
Tiredness	0.1	0.1					
I felt exhausted	0	0	95.24%	0.00%	4.76%	0.00%	0.00%
I felt weary	0.1	0.4	80.95%	19.05%	0.00%	0.00%	0.00%
Returning to reality	0.8	0.5					
I found it hard to get back to reality	0.2	0.8	90.48%	4.76%	0.00%	0.00%	4.76%
I felt disoriented	0.9	1	42.86%	38.10%	14.29%	0.00%	4.76%
I had a sense that I had returned from a journey	1.3	1.4	38.10%	33.33%	4.76%	9.52%	14.29%

reality while approximately 42% of them felt disoriented and 38% felt that they had returned from a journey after the gameplay.

Correlation between In-game and Post-game GEQ variables

We analyzed the correlation between positive and negative affect in In-game GEQ and positive and negative experience in Post-game GEQ. According to the findings from the analysis, we observed that there is a positive correlation between the positive affect and positive experience ($r=0.64$, $p<0.05$), while the other variables did not have correlations. *Table 11* shows correlations between In-game and Post-game GEQ variables.

Post-study interview

After the gameplay session, the elderly participants were asked about their opinions and feedback towards the Skiing game and digital game-based physical exercises. According to *Table 12*, we observed that 15 out of 21 elderly participants recommended that playing digital games can be an effective and effortless way of exercising, while 6 elderly participants did not agree on it. 20 elderly participants claimed that the Skiing game was easy to play, whereas one

Table 10. Correlations between In-game and Post-game GEQ variables

	Positive affect	Negative affect	Positive experience	Negative experience
Positive affect	1			
Negative affect	-0.11	1		
Positive experience	0.64*	0.01	1	
Negative experience	-0.69	-0.11	-0.49	1

participant disagreed. Regarding the in-game instruction, 17 elderly participants agreed that the adequate instructions were provided and they were easy to follow. However, 4 elderly participants did not support that statement. Finally, 20 elderly participants revealed that they were not afraid of making mistakes in the gameplay, whereas one participant was anxious about making mistakes.

Attitudes towards digital game-based exercise

After the gameplay session, the elderly participants were asked about their attitudes towards digital game-based exercise. Based on the findings from the analysis of data, the elderly participants claimed that digital game-based exercise is essential to good health (M=4.0) and game-based exercise is important to maintain all-around health (M=3.8), and the human body (M=3.4). Lastly, they mentioned that it can make one feel better (M=3.0). *Table 14* shows elderly participants' attitudes towards digital game-based exercise.

Based on the findings from the analysis of Post-game GEQ items in 5-point Likert scale (*Table 13*), we observed that more than 52% of elderly participants agreed that digital game-based exercise is essential to good health, whereas approximately 47% of them disagreed. More than 75% of elderly participants agreed on the fact that digital game-based exercises can work of their emotion, tension, and anxieties, whereas 14.29% did not agree on it. Noticeably, approximately 80% agreed that digital games can help a person improve and maintain his or her health while 4.76% was neutral and 14.29% strongly disagreed. Similarly, approximately 80% of elderly participants agreed that digital games can be beneficial to the human body while 19% did not agree on it. Lastly 33.33% strong agreed that digital game-based exercise can make one feel better while 14.29% just agreed. However, about 23% of elderly participants did not agree on it while 28.57% remained neutral. We also analyzed the difference between the elderly participants' attitudes towards physical exercises and digital game-based exercises by applying the Paired-Samples t-test. According to the findings from the analysis, we found that there was a significant difference between their attitudes towards physical exercises (M=4.9) and digital game-based exercises (M=3.6); $t(20) = -5.28$, $p < 0.05$. Furthermore, we also found that there was no correlation between the elderly participants' attitudes towards physical exercises and digital game-based exercises ($r = 0.004$, $n = 21$, $p < 0.05$).

Discussion

According to the findings from the analysis of the pre-study interview data, we observed that most of the elderly participants (20 out of 21) are active in physical exercises. They perform exercise activities daily or weekly. According to the pre-gameplay interview, we observed that their opinions towards participation in regular exercises are positive. For instance, they pointed out that engaging in regular physical exercises helps them remain active in old age. They also insisted that physical exercises improve their physical health as well as the social relationship with others. Based on these findings, we state that the elderly participants who were involved in our study are physically stable and active, and they participate in regular exercise routines.

The findings from the analysis of their responses towards the pre-study questionnaire highlight that most of them have highly positive attitudes towards physical exercises. They all recommended that doing physical exercises can help them improve health, reduce anxiety and tension, maintain all-around health, and makes them feel better. Furthermore, they are very much aware of the potential benefits of doing physical exercises. Based on this, we state that the elderly participants in our study have a very positive attitude towards physical exercises.

Table 11. Post-study interview questionnaire

Post-gameplay questions		Number of participants	
		Agree	Disagree
Perceived usefulness	Could playing digital games be an effective and effortless way of exercising?	15	6
Perceived ease-of-use	Was playing the game easy?	20	1
Gerontechnology self-efficacy	Were you able to play the game after receiving instructions? Would the user instructions have been adequate?	17	4
Gerontechnology anxiety	Were you afraid of making mistakes when playing the game?	1	20

Table 12. Elderly participants' attitudes towards digital game-based exercise

	Mean	Standard Deviation
Essential to good health	3	1.7
Helps to work of emotional tension and anxieties	3.9	1.4
Important in helping a person to gain and maintain health	3.8	1.3
Beneficial to the human body	4	1.5
Makes one feel better	3.4	1.4

Regarding their digital gameplay experiences, the findings highlight that most of the elderly participants (18 out of 21) in our study did not have prior experiences in playing digital games. We observed that they were not interested in digital games. Furthermore, they had misconceptions that digital games are not for elderly people, and it was a waste of time. Some elderly participants claimed that they did not like it and they did not have a device or gadget to play. Based on their comments, we state that the elderly participants in our study are non-gamers and they have no interest in it. More importantly, their attitudes towards digital games were relatively negative.

Based on the findings from the analysis of SUS, we observed that 16 out of 21 elderly participants provided a very positive feedback towards the usability of the Skiing game. The claimed that the game was easy to learn and play. It had clear in-game instructions, and adequate functions were integrated. The game context and gameplay were consistent. They mentioned that they had confident to play, and they would like to play it again more frequently. There were two elderly participants who rated the game as an average ('OK') and two participants who rated it negatively ('Poor'). One elderly participant rated it as ('Worst imaginable'). The elderly participants who provided negative feedback towards the game mentioned in the pre-study interview session that they had no interest in digital games. One of them had already stopped doing physical exercises due to her old age. Although there was a small number of participants who provided negative feedback towards the game, most of them supported that this game was easy to learn and play as well as user-friendly.

The findings from the analysis of In-game GEQ questionnaire, we observed that the elderly participants had a relatively high positive affection in playing the Skiing game, whereas they had a very low negative affection in the gameplay. The participants experienced a moderate success and absorption in the game. They were also relatively interested in the game as well as they thought that the game was not challenging for them. Apparently, they had almost no tension in the gameplay. Based on these findings, we state that the elderly participant's in-game experience in the Skiing game was moderately positive although most of them did not play digital games before.

With regard to the elderly participant's responses towards Post-game GEQ questionnaire, we observed that their positive experiences in playing the Skiing game were merely average. Except for the component 'Positive experience', the other components had a low mean score. Thus, we found that they have almost no negative experience, tiredness, and returning to reality. Based on this finding, we state that the elderly participants' post-game experience was moderately positive. We can take into consideration that the gameplay session was relatively short and most of them were non-gamers. Therefore, it might impact on the participants' experience in playing it. Regarding the correlation between In-game and Post-game elderly participants' experiences, we observed that their positive affection in the gameplay can affect on their post-game positive experiences.

According to the findings from the analysis of the post-study interview questions, we found that the majority of elderly participants (15 out of 21) recommended that digital game-based exercise can be an effective and effortless way of doing physical exercises. They expressed in the post-study interview session that they would like to try it again and they would like to play a variety of digital games. Some proposed their ideas of playing digital game-based

Table 13. Elderly participants' attitudes towards digital game-based exercise in 5-point Likert scale

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think digital game-based exercise is essential to good health.	33.33%	14.29%	0.00%	23.81%	28.57%
I think digital game-based exercise can help to work of emotional tension and anxieties.	14.29%	0.00%	9.52%	38.10%	38.10%
I think digital game-based exercise is important in helping a person gain and maintain all-around health.	14.29%	0.00%	4.76%	52.38%	28.57%
I think digital game-based exercise is beneficial to the human body.	19.05%	0.00%	0.00%	23.81%	57.14%
I think regular digital game-based exercise makes one feel better.	19.05%	4.76%	28.57%	14.29%	33.33%

exercises such as Bowling, Golf, Cycling, and Dancing. Most of them agreed that the Skiing game was an easy, simple, and effective way of doing exercise. We also observe that although most of them have had negative views on digital games, they have become interested in the digital gameplay as an alternative form of doing exercises. They expressed their enjoyment in the gameplay and desire to play in the future. Based on the findings from the post-study interview, we state that the most elderly participants supported that digital games can be an effective form of physical exercise for them.

The findings from the analysis of the elderly participants' attitudes towards digital game-based exercise show that after the gameplay, their attitudes have changed more positively towards playing digital games for physical exercises. Although they had a relatively negative attitude towards digital games before, they were quite positive that digital games are promising for improving and maintaining health. Furthermore, they commented that it can reduce their tension and the level of anxiety. They have a moderately positive view on digital games that it can be beneficial to human body and it can help a person feel better. Regarding the differences between the elderly participants' attitudes towards physical exercises and digital game-based exercises, we observed that they have more positive attitudes towards physical exercises. However, the findings also show that their attitudes towards digital game-based exercises are noticeably positive. Therefore, we can say that digital game-based exercises are also promising for promoting elderly people's physical exercises. We also found that there is no correlation between the elderly participants' attitudes towards physical and digital game-based exercises. It means that having positive attitudes towards traditional physical exercises does not have an influence on their attitudes towards digital game-based exercises.

Based on the observational study and interview sessions, we recommend usability and game design guidelines for designing digital game-based physical exercises for elderly people. For the game user interface, elderly people prefer simple and unclutter user interface so that they can play the game without distraction. We also observed that visual cues are important for elderly players so that they can easily understand how to succeed game tasks. In-game instructions are important for them to play. For interaction design, they prefer motion-based interaction, which is natural and easy for them. The elderly participants also pointed out that they liked to perform game actions that can be familiar to them (e.g. Skiing activity in this study). For game design, the elderly participants suggested that a variety of games and different gameplay will be more interesting. We found that repetitive game action is less interesting for them. We also observed that game calibration and customization are also important to meet the needs of elderly people's abilities in physical movements. Lastly, we observe that elderly people's safety in the gameplay is highly important because most of them expressed their concern for being fallen while playing.

In summary, we observed the following findings from this study. First, although the elderly participants had a moderately negative attitude towards digital games before they had played the game, they had changed their attitudes positively after they gameplay. Second, the elderly participants recommended that playing digital games can be an effective way of exercising for them. Third, the Skiing game is an easy and user-friendly for the elderly participants. More importantly, the usability and game design guidelines observed in this study can be useful and insightful for our future game development, as well as other practitioners in the related areas. Lastly, the elderly participants' overall in-game and post-game experiences were moderately positive although most of them had no prior experiences in playing digital games. In addition, we learned from the findings from GEQ analysis, creating positive experiences for elderly players in the game can positively impact on their post-game user experiences that can lead to their continuation and interest in playing digital games in the future. The findings from this usability study can be helpful and can provide some insights for researchers and practitioners into utilizing and adopting digital game technologies to promote elderly people's physical well-being in terms of physical exercises and rehabilitation.

For the key contributions of this study, firstly, the findings from this study support the existing literature that digital games are promising for elderly people's physical well-being in terms of physical exercises[12,13,15-17]. Secondly, user-friendly and easy digital games can change elderly people's negative attitudes and misconceptions about playing digital games in old age. Thirdly, the findings from this study show that digital games can be an alternative solution for elderly people to promote their physical exercises. Lastly, the usability and digital game design guidelines identified in this study can provide other designers in designing user-friendly digital games for elderly people.

Conclusion

In this study, we evaluated the user experiences and usability of digital game-based Skiing exercise with 21 Finnish elderly participants at one of

the elderly service homes in Finland. The main objective of this study is to investigate Finnish elderly participants' user experiences and the usability of the game for them. Furthermore, we aimed at investigating their attitudes towards physical exercises and digital game-based exercise. Then, we studied if digital games can be an alternative solution for their physical exercises. The findings show that most of the elderly participants in this study are physically active, and their attitudes towards physical exercise are highly positive. Although most of them did not have prior experiences in playing digital games, their feedback towards the usability of the Skiing game is quite positive. In addition, their in-game and post-game experiences were moderately positive. Noticeably, despite having negative attitudes towards digital games before, after the gameplay, their attitudes towards digital games have changed. They also recommended that playing digital games can be beneficial for their physical health. Based on the findings from this study, we conclude that digital games are promising and have the potentials to improve elderly people's physical exercise activities, and it can be used as an alternative solution to promote their physical well-being. The findings from this study can be helpful for people who are interested in using digital games for elderly people's physical well-being.

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