WaterBall: The Exergaming Design for Rehabilitation of the Elderly

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ABSTRACT

This study applied the concept of closed chain exercise to WaterBall, which combines rehabilitation exercises with a digital game. By using WaterBall, the elderly can enjoy the benefits of both entertainment and rehabilitation. In addition, WaterBall provides multi-touch control, is easy to use, and have the potential to improve physical activity in older adults The elderly can play the game intuitively. WaterBall Exergaming was used by 52 residents of an elderly community, and they reported that WaterBall offers exercise and fitness, enhances the efficiency of exercises, and provides entertainment and interaction.

1   INTRODUCTION

With the progress of medical technologies, people are living longer, but age-related physical degeneration still affects the quality of life. Rikli and Jones suggested that elderly tend to sit for long periods of time, but regular exercise can improve their physical functioning and reduce mortality [1]. Exercises can enhance cardiopulmonary function, flexibility, and the sense of balance. Vertical or horizontal instantaneous moving or exercises that require endurance or twisting of the body are helpful for the sense of balance. Walking, jogging, aerobic dancing, sitting and standing, and calisthenics are suitable for the elderly [2]. Moreover, the American College of Sport Medicine has suggested that regular exercises can improve cognitive function, reduce depression, improve sleeping quality, and enhance the quality of life. Therefore, exercises are not only recreational activities, but also means of rehabilitation. By exercising, people can recover and maintain physical health. Many studies have indicated that rehabilitation exercises or movement therapy can improve physical functions and reduce disability [3-6].

Exergaming can enhance physical abilities. In 1998, Konami [7] introduced Dance Dance Revolution (DDR). By playing the game, users have sufficient physical exercises; thus, it became central to Exergaming. DanceTown [8], designed for the elderly, is similar to DDR. Users stand on a square dancing mat and follow the arrows on the screen to music. The movement is similar to dancing. EyeToy [9] is a video game for the PlayStation 2, released in 2003. The EyeToy combines computer vision and gesture recognition to process images taken by the camera. This technology allows players to interact with games using motion, colour detection and also sound. SSD has developed the XaviXPORT system [10] which is transmitted by infrared rays, instead of cable lines. Each game is played with an auxiliary device, such as step pad, boxing gloves, baseball bat, tennis racket, golf club, or bowling ball. Thus, users can play the game intuitively. In 2006, Wii [11] launched a new trend by introducing human-machine interaction of virtual reality, sport and fitness. The game not only is entertaining, but also allows users to move their bodies [12-13]. PlayStation Move Motion Controller of SONY PS3 uses a handheld sensor for control [14]. Microsoft introduced XBox-Kinect [15] which does not require any auxiliary device to be worn on the body. Users can control the game by gestures or body movement. Exergaming includes Dance Dance Revolution, EyeToy, XAVIX, Wii and Xbox-Kinect. They have been proven to increase physical activity levels [16-19]. Exergaming has also been applied to rehabilitation therapy. For instance, application of experiential Wii to rehabilitation has been regarded as a therapeutic system of basic rehabilitation training and entertainment to maintain health. It can increase the effect of sports rehabilitation and improve physical functions, movement, and mental heatlh[20-22]. Betker et al. developed a rehabilitation sports game controlled by COP (center of pressure). The game was designed for people who had trouble with their balance. The results showed that the training could improve balance control and reduce the probability of falling [23-24]. Rahman studied children with Down syndrome who had used Wii-Fit, and found that Wii-Fit training could increase their balance. It was even more effective than traditional physical therapy [25]. Exergaming is mostly entertaining. The game is applied to rehabilitation therapy and the interaction will increase the patientsÑinterest in long-term rehabilitation [26-27]. However, awkward postures and positions, inappropriate operation may be harmful and be susceptible to overuse injuries. Thus, Wiitis, cases of improper or overuse of Wii, has become another research topic [27-30].When designing Exergaming for the elderly, besides the entertainment effect, the physical capabilities of the elderly ease of use, and acceptance were considered.

2   EXERGAMING: WATERBALL DESIGN AND DEVELOPMENT

This study designs an exergaming activity for the elderly: WaterBall. The design concept, operational model, and exercise model application, rule of game, hardware and software are described below.

(1) Interactive situation simulation

WaterBall is based on the form of Îtable Ï, which is very familiar to the elderly. It replaces the mouse and keyboard with touch and a real object (push plate). Elderly people can easily use it. The WaterBall interface is indicated by the pond which includes stones (the Îgoa Ï) and tortoise shell (the Îball Ï), scores. In the game, wave of the pond will change with different levels of push. The game simulates real waves (Fig. 1).
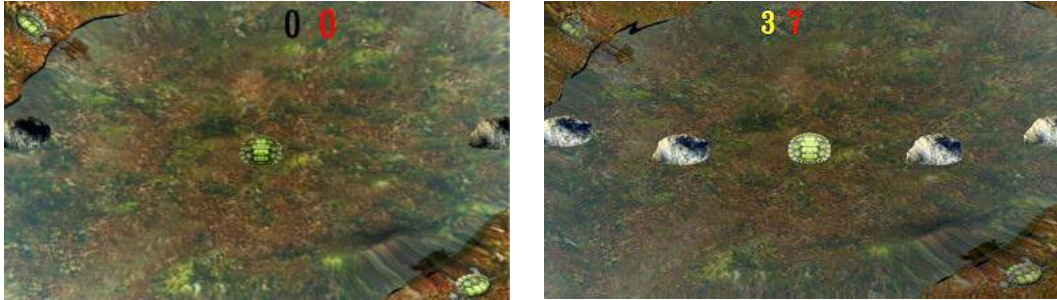
Fig. 1: Picture of WaterBall.

(2) Ease of use and instinctive operation

WaterBall is based on intuitive operation. Users can directly touch the screen by hands and real objects (such as push plate), instead of using mouse cursor and keyboard. Such design would be more acceptable to the elderly. Users can rely on a gentle touch without devices. By using the touch control and push plate, users can simulate attack and defense by moving their hands and arms.

(3) Closed chain exercise model

Steindler suggested that "Kinetic Chain" is a type of clinical rehabilitation and exercise training. The kinetic chain can be open or closed [28]. Open kinetic chain exercises (OKC) are exercises that are the far end of limbs and that can be freely moved in space (e.g., hand waving or feet swaying in gait cycle). Open kinetic chain exercises are typically non-weight bearing, with the free movement occurring the elbows or knee joint. Open chain involves speed, and emphasizes free activity; however, it is unstable. The opposite of OKC are closed kinetic chain exercised (CKC). Closed kinetic chain exercises are physical exercises performed where the hand (for arm movement) or foot (for leg movement) is fixed and cannot move. In other words, the hand/foot movement remains in constant contact with the surface, usually the ground or the base of a machine, such as push-up exercise, squatting, or climbing stairs. When exercising, several sets of muscles will concentrate at the same time. Fig. 2 shows the closed kinetic chain exercises. The hands are fixed and support physical weight [29]. Steindler indicated that closed kinetic chain exercise is safer, with more stability and less acceleration. Moreover, closed chain exercises have some advantages in terms of athletic training and rehabilitation. In contrast to open chain exercises, closed kinetic chain motions for training are more functional and sport-specific. Since closed chain can press and enhance the joints, it can contribute to increase muscle strength and facilitate proprioceptive functions [30–32]. However, people tend to become bored with prolonged repetitive exercises, and thus, rehabilitation training may fail. Boredom and inattention have been shown to limit the efficacy of rehabilitation exercise. Therefore, this study will help elderly users to perform closed kinetic chain motions while playing the digital game, thus increasing their interest and their exercise efficiency.

WaterBall is similar to an air-hocky game[1]. WaterBall Exergaming (Fig. 1and Fig. 3) allows the elderly users to push tortoise shell (ball) (on touch screen) to stone (goal) (on touch screen) by push

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[1] Air-hocky is a game between two players on a table. Players earn points by hitting the plate of table hockey to attack the other's goal. The plate moves quickly. Thus, it requires eye-hand coordination. When playing the game, the players must place their hands on the table to push the ball. The hand supports the weight of the body. The action is a closed chain exercise.

plate to earn points. WaterBall is the gaming platform. It consists of a large touch module (including a 52-inch large touch screen) and control panel. is the laboratory simulation of WaterBall. Before the game, users place one hand on the table, and hold the push plate with the other hand. When the game starts, the hand holding the push plate pushes the ball or stops the other side's ball. The game stretches and moves the upper arms. Different muscle groups will concentrate at the same time, thus meeting the purpose of closed chain exercise model. The game is entertaining and interactive.
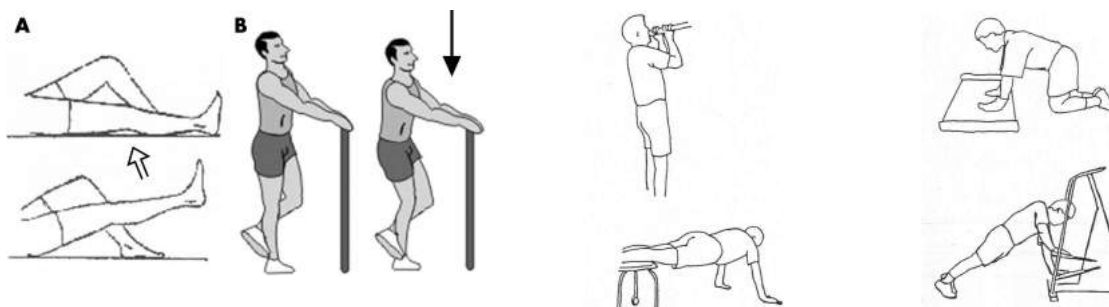

Fig. 2: Closed chain exercise [33–34].

Fig. 3: WaterBall simulation in laboratory.

(4) Introduction and rules of WaterBall

WaterBall is the game of competition (Fig. 1). The push plate on the table is used to push the ball. The tortoise shell in the center of the screen is the ball. The upper screen indicates the scores of two parties. the stones on two sides are the goals. Players push the ball to the other's stones with the push plate to earn points. The push plate can push the ball to attack the other's goal, and stop the ball from the other side. The players'force and direction of arm waving will influence the speed and direction of the ball. When the ball hits the wall or is stopped and rebounds, there will be sound reminder. Score gaining will be the same. At the start of the game, the ball will be in the center of the screen, and either party can start the ball. The players push the tortoise shell to the other's goal with the push plate. They should avoid the other's attack or their own faults. After earning points, the ball will return to the starting position in the center, and either player can play the ball. The player who earns 7 points first wins the game. At the end of the game, the screen will be still and the ball will remain in the center. The game will be started again by choosing the ball.

(5) Hardware and system

WaterBall is the gaming platform. It consists of a large touch module (including a 52-inch large touch screen) and control panel. The hardware and system of WaterBall are described below:

- **Touch panel: Traditional electric resistance and electric capacity touch screens cannot be large, and are expensive. Thus, an optics model that has a broader sensing scope and supports**

multi-touch is used. With the intuitive operation of touch screen, the players can reduce the adaption time and resistance. Therefore, the touch panel is developed by 52-inch LCD and infrared rays optics touch module.

- RFID: It is for identification. RFID cards (e.g., access card of the community and Easy Card) are widely used and easy to obtain. Traditional identification requires accounts and codes, thus, it is difficult for the elderly. By using RFID, users can register simply by placing the card on the table.
- Cloud Server: With a Cloud Server, all data are saved in Cloud, thus reducing computing time and data in the control unit. Cloud Server is used to record the frequency and time of use, in addition to playing time and figures of horizontal hand moving in order to observe usersÑ exercise and interaction.
- Writing platform XNA: The XNA platform provides complete program API to construct 3D world. There is a complete multi-media interface that can significantly reduce the program writing time. Its 3D touch interface can make the game appealing to elderly players.
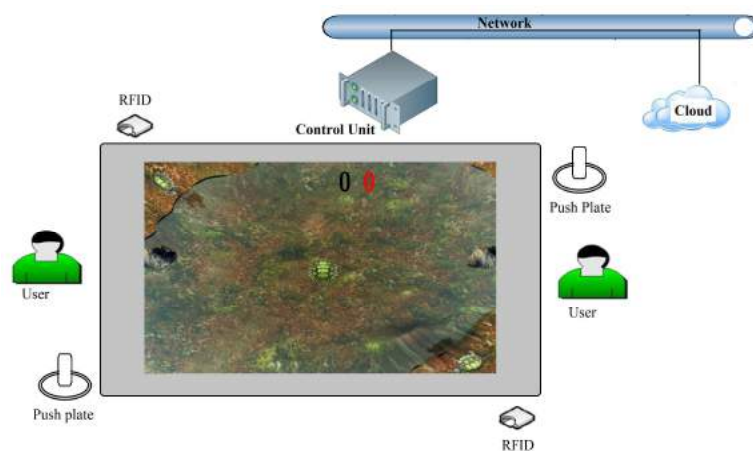-

Fig. 4: WaterBall system framework.

3   WATERBALLUSERS' ACCEPTANCE AND USE TEST

The user test was conducted in an elderly community. There were 52 participants: 17 males and 35 females. They ranged in age from 64 to 91 years old, with an average age of 79. After the participants used WaterBall system, a 30-minute interview was conducted to learn about their acceptance of the game. The results were analyzed in terms of ease of use, usability of physical consumption, and interaction and entertainment.

			52 Participants
Gender		**Age (years)**	
Male	17 (32.7%)	<70	7 (13.4%)
Female	35 (67.3%)	71–80	18 (34.7%)
		91–90	23 (44.2%)
		>90	4 (7.7%)

Tab. 1: 52 participantsÑ information.

(1) Ease of use

All 52 participants reported that the game is easy to play; even two participants over the age of 90 could play the game. Most of the participants described WaterBall as simple, and they were able to play it without having to learn and practice in advance. The touch screen is based on instinctive use, and WaterBall is similar to table hockey or table tennis. Thus, the users can easily move or stop their opponent's ball. They expressed a strong intention to use, and suggested more types of WaterBall system.

(2) Usability of physical consumption

According to participants, the game is exciting and allows them to move their bodies. It is therefore suitable for the elderly (Fig. 5, Fig. 6, Fig. 7 and Fig. 8). When playing WaterBall, the player will place one hand on the table, and push or stop the ball or with the other. It is a closed chain exercise model. Participants suggested that WaterBall not only enhances their reaction training, but also allows them to have physical exercise. Some participants asked to play 2 to 3 games, and invited others to play. According to many participants, although WaterBall is simple, it makes players sweat without making them uncomfortable. For instance, one participant suggested that when playing WaterBall, he (she) sweats, thus achieving the purpose of exercising.

Fig. 5: WaterBall playing of the elderly.

Fig. 6: Upper limb stretching in the game of WaterBall.

Fig. 7: WaterBall meets closed chain.

Fig. 8: Interaction among the elderly in the community.

(3) Interaction and entertainment

Participants suggested that besides moving the body, WaterBall trains the mental reaction and eye-hand coordination. Since there are winners and losers, in the test, the players encouraged each other, shared skills to with new players, enjoyed the game, and expected to challenge other players. For instance, one participant preferred playing computer games, and suggested that by playing WaterBall, he did not have to click the mouse in front of a screen. He expected the development of more games similar to WaterBall. During the game, many participants became talkative. In addition, since WaterBall allows players to interact, some participants invited their friends to join the game. They claimed that they would play WaterBall with their children, grandchildren or other relatives.

4   CONCLUSION

WaterBall is a type of rehabilitation Exergaming for the elderly, and it meets closed Kinetic Chain exercise. It is entertaining, and has increases the exercise motives and channels. The game combines entertainment and rehabilitation, thus increases the interest of rehabilitation exercise, and its efficiency. In addition, the users are interested in digital technology; thus, WaterBall combines real and virtual operation with the intuitive use of touch screen. It can reduce adaption time and resistance. Moreover, the game is easy to learn and to play, and it encourages interaction among users.

REFERENCES

[1]   R. E. Rikli and C. J. Jones, Assessing Physical Performance in Independent Older Adults: Issues and Guidelines., Journal of Aging and Physical Activity, 5, 1997. DOI: 10.1016/S0765-1597(00)80005-2.

[2]   G. C. Burdea, Virtual Rehabilitation – Benefits and Challenges, Methods of Information in Medicine, 42, 519–523 2003. DOI: 10.1267/METH03050519.

[3]   H. Shimada, et al., Specific effects of balance and gait exercises on physical function among the frail elderly, Clinical Rehabilitation, 17, 472–479, 2003. DOI: 10.1191/0269215503cr638oa.

[4]   S. Eyigor, et al., Effects of a group-based exercise program on the physical performance, muscle strength and quality of life in older women, Archives of Gerontology and Geriatrics, 45, 259–271, 2007. DOI: 10.1016/j.archger.2006.12.001.

[5]   J. F. Bean, et al., Benefits of exercise for community-dwelling older adults, Archives of Physical Medicine and Rehabilitation, 85, 31–42, 2004. DOI: 10.1016/j.apmr.2004.03.010.

[6]   American Physical Therapy Association, Interactive Guide to Physical Therapist Practice: American Physical Therapy Association, 2003. DOI: 10.2522/ptguide.978-1-931369-64-0.

[7]   Konami. (1969, Feb 22, 2011). Dance Dance Revolution. Available: http://www.konami.net/

[8]   Exergame Fitness. (1998, Feb 22, 2011). DanceTown. Available: http://www.exergamefitness.com/

[9]   Sony Computer Entertainment. (1993, Feb 22, 2011). EyeToy. Available: http://www.jp.playstation.com/scej/title/eyetoy/

[10]   SSD Company Limited. (2004, 22 Feb, 2011). XaviX®PORT. Available: http://www.xavix.com/

[11]   Nintendo. (2006, Feb 22, 2011). Wii. Available: http://wii.com/

[12]   M. Katzourin, et al., Swordplay: Innovating Game Development through VR, Computer Graphics and Applications, IEEE, 26, 15–19, 2006. DOI: 10.1109/MCG.2006.137.

[13] L. Graves, et al., The contribution of upper limb and total body movement to adolescentsÑenergy expenditure whilst playing Nintendo Wii, European Journal of Applied Physiology, 104, 617–623, 2008. DOI: 10.1007/s00421–008–0813–8.

[14] Sony Computer Entertainment. (2011, Feb 22, 2011). PlayStation®Move. Available: http://us.playstation.com/ps3/playstation-move/

[15] Microsoft. (2011, 22, Feb.). Xbox–Kinect. Available: http://www.xbox.com/en-US/

[16] L. Lanningham–Foster, et al., Energy Expenditure of Sedentary Screen Time Compared With Active Screen Time for Children, Pediatrics, 118, 1831–1835, 2006. DOI: 10.1542/peds.2006–1087.

[17] R. R. Mellecker and A. M. McManus, Energy Expenditure and Cardiovascular Responses to Seated and Active Gaming in Children, Arch Pediatr Adolesc Med, 162, 886–891, 2008. DOI: 10.1001/archpedi.162.9.886.

[18] K. Sell, et al., Energy expenditure during physically interactive video game playing in male college students with different playing experience, Journal of American College Health, 56(5), 505–11, 2008. DOI: 10.3200/JACH.56.5.505–512.

[19] L. Straker and R. A. Abbott, Effect of screen–based media on energy expenditure and heart rate in 9– to 12–year–old children, Pediatric Exercise Science, 19, 459–471, 2007.

[20] A. Steinbauer and C. Mitchell, Virtual reality used as an effective rehabilitation tool for increasing motor function in people with physical disabilities: A systematic literature review: The College of St. Scholastica, 2009.

[21] G. Saposnik, et al., Effectiveness of Virtual Reality Exercises in STroke Rehabilitation (EVREST): Rationale, Design, and Protocol of a Pilot Randomized Clinical Trial Assessing the Wii Gaming System, International Journal of Stroke, 5, 47–51, 2010. DOI: 10.1111/j.1747–4949.2009.00404.x.

[22] R. Homma, Effects of the Wii on the physical and psychosocial condition of older adults in a senior residential facility, M.S., Rehabilitation Science, State University of New York at Buffalo, New York, United States, 2009.

[23] A. Betker, et al., Video GameÌBased Exercises for Balance Rehabilitation: A Single–Subject Design, Archives of Physical Medicine and Rehabilitation, 87, 1141–1149, 2006. DOI: 10.1016/j.apmr.2006.04.010.

[24] A. L. Betker, et al., Game–based Exercises for Dynamic Short–Sitting Balance Rehabilitation of People With Chronic Spinal Cord and Traumatic Brain Injuries, Physical Therapy, 87, 1389–1398, 2007. DOI: 10.2522/ptj.20060229.

[25] S. A. R. A. Rahman, Efficacy of Virtual Reality–Based Therapy on Balance in Children with Down Syndrome, World Applied Sciences Journal, 10, 254–261, 2010.

[26] A. Cogan, et al., Pong game as a rehabilitation device. , in Fourth Annual Conference on Systems and Devices for the Disabled, University ofWashington School of Medicine, Seattle,WA, 1977, 187–188.

[27] D. Nelson, et al., The effects of an occupationally embedded exercise on bilaterally assisted supination in persons with hemiplegia, American Journal of Occupational Therapy, 50, 639–646, 1996.

[28] A. Steindler, Kinesiology of the Human Body.: Charles C. Thomas, 1955.

[29] G. Davies and S. Dickoff–Hoffman, Neuromuscular testing and rehabilitation of the shoulder complex, 18, 2, 449–458, Journal of Orthopaedic & Sports Physical Therapy.

[30] K. E. Wilk, et al., Closed and open kinetic chain exercise for the upper extremity, Journal of Sport Rehabilitation, 5, 88–102, 1996.

[31] M. L. Voight, et al., The effects of muscle fatigue on and the relationship of arm dominance to shoulder proprioception, Journal of orthopaedic and sports physical therapy, 23, 348–352, 1996.

[32] W. B. Kibler, Shoulder rehabilitation: principles and practice, Medicine & Science in Sports & Exercise, 30, 40–50, 1998.

[33] A. H. Bakhtiary and E. Fatemi, Open versus closed kinetic chain exercises for patellar chondromalacia, British Journal of Sports Medicine, 42, 99–102, 2008 2008. DOI: 10.1136/bjsm.2007.038109.

[34] Hands on Care. (2010, 22, Feb.). Specializing in Shoulder, Elbow, Wrist and Hand Therapy. Available: http://www.hocinc.us/rotator_cuff.htm