Proposal of a Computerized System Based on Game Therapy to Reduce Postural Sway

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Proposal of a computerized system based on gametherapy to reduce postural sway

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Abstract– **For balance training, one of the methods used is gametherapy, which consists in the use of games for a better motivation of the patients. Thus, the objective of this work was to develop three games for balance training that explore laterollateral and anteroposterior movements, as well as the combination of both. The games were developed and tested with a force platform with controlled inclination, which is used to control the game avatars. To test the platform's functionality, weights were placed on the equipment, and the response of the sensors was verified. The games were evaluated by two distinct groups of professionals: the first composed of 5 system/game developers, and the second by 5 physiotherapists. To this end, two questionnaires were developed based on regulatory standards for software development and quality and on the System Usability Scale (SUS). In the functionality test, the sensors responded by increasing their values according to the region of the platform being pressed. The responses obtained in the SUS questionnaire presented a score of 81 in the evaluation of the physiotherapists and 83 in the evaluation of the system developers. Both values classify the system as good, according to the SUS scale. Games can be a very useful tool with great potential for use in balance training and rehabilitation. The developed system may bring a significant improvement in treatments, as well as help the health professionals by increasing the possibilities of applied techniques, thus reaching a longer permanence of the patient during treatment, with the motivation to use the games.**

Keywords- **Balance, Software tests, Gametherapy, Unity.**

I. Introduction

Postural control can be defined as a complex motor skill arising from the interaction of multiple sensorimotor processes [1]. The neuromuscular responses aim to ensure that the body's center of gravity (CG) is maintained within the support base (area formed by the lower limbs) [2,3]. Thus, over time, postural training methods have been developed aiming at improving orthostatic balance [4]. For balance training, unstable platforms such as the wobble board are commonly used [5]. Either by strengthening the lower limb stabilizing muscles, by improving proprioception, or by improving the muscle activation capacity [6].

One of the resources to improve balance training is the implementation of virtual reality. This system is capable of simulating balance training activities, increasing mobility and reducing the fear of falls [7]. On this way, [8,9] define that balance training based on computerized games can improve patient motivation, raising the training capacity.

In the [10] study a wii balance board was used to control the games. However, on the wii balance board the patient cannot be tested in tilting situations, which is more indicated [9]. In another study [11] a Kinect controlled game was developed along with a force platform. However, in this work the force platform is only used for data collection and not for controlling the game. Other authors [9] made a manually tilted platform with three games. However, the tilt of this platform is manual and limited to angles multiple of 5.

Therefore, a game system controlled by a force platform with biaxial rotation could better adapt to the exercises and the needs of each patient. This way, the training can be done in several angles, generating a personalization with different degrees of difficulty. Thus, the objective of this work was to develop a gametherapy proposal based on the application of three virtual games, where each one of them allows the training of a different type of movement, being the first focused on the laterolateral movement, the second focused on the anteroposterior movement, and the third focused on the combination of both movements. The games developed have an interaction interface through the movement of the player on a force platform.

II. Material and methods

A. Equipment

To control the avatars of the developed games, a biaxial force platform with controlled inclination is used [12]. It has the ability to change its inclination through four step motors controlled by a microcontroller, allowing its use in various inclinations (FIG. 1a). This platform has eight load cells fixed on its surface (FIG. 1b). Its sensors allow the movement or control of the game as soon as they are pressed.

FIG. 1. a) Biaxial force platform with controlled inclination; b) Positioning of the load cells that allows the control of the avatars.

In order to test the functionality of the force platform, we first used two alters with eight kilograms each. They were placed in the front region of the platform, one between sensors 1 and 2, and the other between sensors 5 and 6. Then it was observed if these sensors increased their value read by the microcontroller's analog ports, in order to test the avatar's response, either moving forward or upward depending on the game to be played. The same was done by placing the loads between sensors 3 and 4, 7 and 8. For the right side, the loads were placed between the four sensors, being 5, 6, 7 and 8. Finally, the same test was performed for the left side with the loads between sensors 1, 2, 3 and 4, thus registering their values. By increasing the values of each sensor depending on the region pressed, it is possible to determine the control of the avatars. Through this, the patient can be trained by inducing him/her to perform laterolateral or anteroposterior movements. The following flowchart shows how the avatar control is performed (FIG 2).

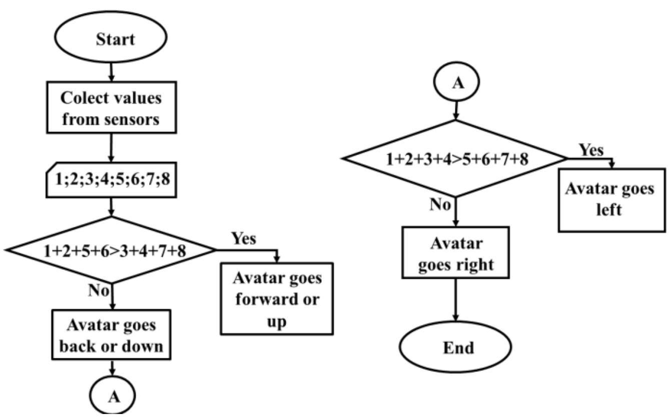

FIG. 2 Flowchart showing the difference between the sensors for moving avatars.

B. Game development

For this study, the Unity multiplatform 3D game engine was used. Through this tool, three games were developed, each responsible for the training of different movements: Balance Block Breaker (FIG. 3a), for training laterolateral movements; Balance Bird (FIG. 3b), for training anteroposterior movements; and Balance Maze (FIG. 3c), for training laterolateral and anteroposterior movements.

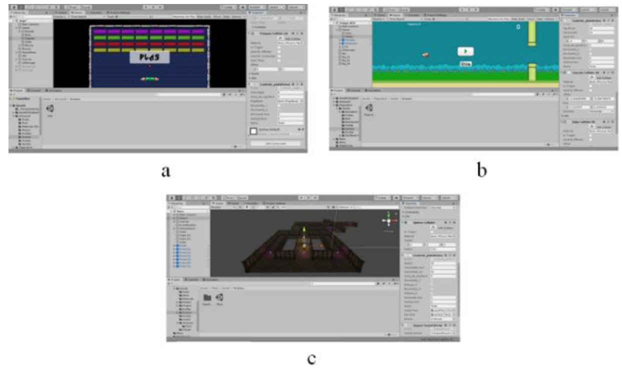

FIG. 3. Unity game development screens; a) Balance Block Breaker game development screen; b) Balance Bird game development screen; c) Balance Maze game development screen

C. Game 1 – Balance Block Breaker

In Balance Block Breaker, the objective is to bounce a ball off a series of blocks located at the top of the screen using a board at the bottom. The board is controlled by a laterolateral movement on a force platform.

D. Game 2 – Balance Bird

The goal of Balance Bird is to control a bird that moves at a constant speed, in order to pass through obstacles located in front of it, the more obstacles it passes, the more points it receives. The control is done through anteroposterior movement.

E. Game 3 – Balance Maze

In the game Balance Maze, an avatar in the ball form is controlled on a 3D plane inside a maze. The goal of the game is to collect crystals scattered throughout the labyrinth, for each crystal collected, the player gets one point. When all available crystals are collected, the game is finished and the score and game time are recorded in the player's profile. The movements of the ball are free for all axes, so the player must combine anteroposterior and laterolateral movements to control the ball and complete the maze.

F. Game validation

According to the literature [13], to test the quality of a computerized system 5 evaluators are necessary, because about 85% of the errors are listed and after this number the same problems will tend to be observed. In this sense, to evaluate the quality of the system proposed in this study, 10 evaluators were invited, divided into 2 groups according to their backgrounds. Group 1 was composed of 5 physiotherapists, aiming at evaluating whether the system proposes movements that may contribute to balance improvement. Group 2 was composed of 5 developers aiming to evaluate the system's usability. This multidisciplinary approach aimed to obtain opinions from several angles of the system application.

This evaluation was done using specific questionnaires based on the training of the evaluators. Following the NBR ISO/IEC 9126-1 [14] to validate the games, the principles of using questionnaires proposed by John Brooke [15], called SUS (System Usability Scale), were adopted. SUS presents excellent consistency of results for tests with relatively small sample sizes [16].

However, due to the difficulty of performing the tests in person, we recorded a video of the system working for each game. For this, four different views of the force platform were filmed (FIG. 4a). Camera 1 filmed the front view (FIG. 4b), camera 2 filmed the side view (FIG. 4c), camera 3 filmed the oblique view (FIG. 4d), and camera 4 filmed a rear view (FIG. 4e). The videos were then edited to present all four views at the same time and sent to the experts along with the questionnaire.

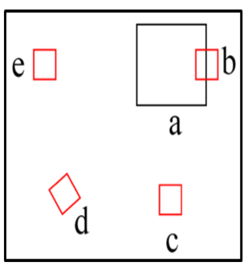

FIG. 4. Concept map of feature recording. a) Biaxial force platform; b) Frontal camera; c) Side camera; d) Oblique camera; e) Rear camera

III. Results

The developed games establish a serial communication with the biaxial force platform. When starting the game, the platform is tilted to the desired angle, which can be between 0 and 20 degrees. This tilt can be forward, backward, right, or left. Through this, balance training is conducted with games.

The avatars are controlled according to where the force platform is pressed. The following table shows the values of the admensional reading of the microcontroller's analog ports, obtained in the platform functionality test.

Table 1 Value of the sensors when pressed

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
No load	0	0	0	0	0	0	0	0	Avatar standing still
load between 1;2;3;4	2	2	0	0	2	2	0	0	Avatar goes left
load between 5;6;7;8	0	0	2	2	0	0	2	2	Avatar goes to the right
load between 1 and 2; 5 and 6	0	0	0	0	2	2	3	3	Avatar goes up or forward
load between 3 and 4; 7 and 8	2	2	2	4	0	0	0	0	Avatar goes down or goes back

In the game Balance Block Breaker (FIG. 5a), for the control of its avatar, the movement in the X axis is considered, inducing the player's movement in laterolateral. In the Balance Bird game (FIG. 5b), for the control of its avatar, the movement in the Y axis is considered, inducing the player's movement in anteroposterior. In the Balance Maze game (FIG. 5c), to control the avatar, both axes are combined, leaving the player more free, combining anteroposterior and laterolateral training.

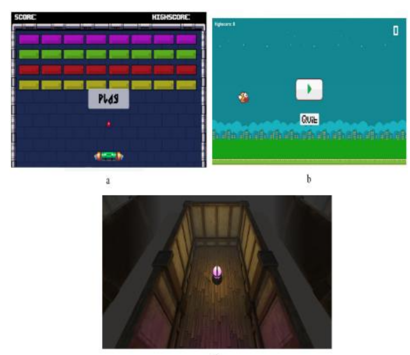

FIG. 5. Developed balance training games. a) Balance Block Breaker; b) Balance Bird; c) Balance Maze

Due to the pandemic state, the device validation was done through videos (FIG. 5). In line with the Ministry of Health and in order to avoid contamination with the COVID-19 virus, everyone involved was properly protected.

FIG. 6. Balance Block Breaker game recording

Through the SUS scale, the following results were obtained:

Table 2. Average per questions in the SUS assessment questionnaire

	SUS assessment results for physiotherapy experts	
Item	Question	Average
1	The movements made in the proposed games areappropriate for balance training.	4,8
2	The games weren't able to motivate the user's interest for a use.	2,0
3	The games presented in any way may harm or damage the player's health.	1,6
4	Gametherapy is not able to provide an improvement in balance training.	1,0
5	They would often use the proposed gametherapy system in their therapies.	4,8
6	The use of game therapy is not able to motivate balance training	1,2
7	You were satisfied with the functioning of the proposed gametherapy system.	4,6
8	Wouldn't need technical help to use the proposed system.	3,0
9	You were satisfied with the application of the safety structure to prevent accidents.	4,8
10	You would not subject your patient to training using the proposed system	1,0
	SUS assessment results for development experts	
Item	Question	Average
1	The game is able to attract user interest to interact	5,0
2	The game is not able to provide easy operation and control to the user.	2,2
3	The game is able to provide the results accurately and effects correctly as intended	4,0
4	The game lacks the ability to perform functions to accomplish tasks and goals.	1,0
5	The game is able to prevent software or interface malfunctions.	3,4
6	The game is not able to recover data if there is a crash while running the software.	2,6
7	The game is easy to collect data.	5,0
8	The game is unable to process and respond while performing its basic functions.	1,2
9	The game has stability, due to possible changes in the software.	3,8
10	Without the need for other actions, the game does not have adaptability to different environments.	1,8

The results obtained from the evaluation of the physical therapists reached an average of 81 points on the SUS scale. And the results obtained by the System Developers evaluation reached an average of 83 points by the SUS scale. According to the literature [17], the results of both groups are classified as a B. The literature [18] further states that the average SUS scale is 70.14 points, and that tests with scores above 70 but below 90 can be considered good. Thus, one can legitimize the evaluation of professionals in the correlated areas of study

IV. Discussion

In this study, 3 digital games were developed using the Unity game engine [19]. The games were associated with a force platform, and offer conditions for the individual to experience obstacles and difficulties of the real world in a safe way. Likewise, the study [20] used Unity in the development of its game for balance training in the elderly and the work [21] used a force platform to train balance in the elderly in a controlled and safe way.

Games can be considered a tool for balance training, helping health professionals [20]. They can bring more concentration to the individuals who are using them, providing a playful and more attractive environment when compared to conventional training methods, also being used for rehabilitation [11].

The present study developed games for balance training, and they were combined with a force platform with controlled inclination that is used to control the Avatars of the games. Thus, several protocols can be performed, using the inclined platform at different angles, inducing the patient to maintain his balance by performing anteroposterior and laterolateral movements.

These movements can bring results of improvement to the individual, since for this the sensorial and motor system is trained. One of the factors that influence postural balance is the stabilization of the ankle joint [21]. Through it, the movement of plantar flexion and dorsiflexion is performed, and it also influences the anteroposterior and laterolateral. Some muscles are also part of this system, such as the medial gastrocnemius and anterior tibial [22]. All of this can influence postural balance [23].

As the individual needs to move to control the games, this makes them dynamic, and may also train compensatory postural adjustment and anticipatory postural adjustment. The fact that the games have a scoring system and a time register allows the evaluation of the individual's evolution during the gametherapy sessions.

Each game is designed to suit a specific type of movement, unlike commercial games that cannot be changed and are inaccessible to some participants [24].

During the SUS evaluation, a combination of specialists in software development and in physiotherapy brought about a broad evaluation of the system from different points of view. The results showed that it was simple, userfriendly, easy to use and totally safe, without the need for great interference in usability. According to the literature [25], the SUS scale is a robust means of evaluation, being used in a variety of systems and/or devices.

V. Conclusions

According to the proposed objectives, the presented project can offer a useful tool to the health area, especially to the rehabilitation area, helping professionals who deal with balance in the therapeutic processes.

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Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

References

1. Fernie GR, Gryfe CI, Holliday PJ, Llewellyn A. The relationship of postural sway in standing to the incidence of falls in geriatric subjects. *Age Ageing*. 1982;11(1):11-16. doi:10.1093/ageing/11.1.11
2. Zatsiorsky VM. *Kinetics of Human Motion*.; 2002. http://books.google.com/books?id=wp3zt7oF8a0C&pgis=1
3. Winter DA. *Biomechanics and Motor Control of Human Movement: Fourth Edition*.; 2009. doi:10.1002/9780470549148
4. Chiaramonte R, Bonfiglio M, Leonforte P, Coltraro GL, Guerrera CS, Vecchio M. Proprioceptive and Dual-Task Training: The Key of Stroke Rehabilitation, A Systematic Review. J Funct Morphol Kinesiol. 2022 Jul 7;7(3):53. doi: 10.3390/jfmk7030053. PMID: 35893327; PMCID: PMC9326539.
5. da Silva, A.R.F., Lazzareschi, L., de Paula Bischof, K. et al. Distribution of mass and center of pressure in dynamic balance presented by an instrumented wobble board. Res. Biomed. Eng. 36, 501–510 (2020). https://doi.org/10.1007/s42600-020-00092-6
6. DiStefano LJ, Clark MA, Padua DA. Evidence supporting balance training in healthy individuals: A brief review. J Cardiopulm Rehabil Prev. 2010;30(2):139-140. doi:10.1097/HCR.0b013e3181d6c875
7. Bateni H. Changes in balance in older adults based on use of physical therapy vs the Wii Fit gaming system: A preliminary study. Physiother (United Kingdom). 2012;98(3):211-216. doi:10.1016/j.physio.2011.02.004
8. ACMS. *ACSM's Guidelines for Exercise Testing and Prescription*.; 2010.
9. Amritha N, Mahima MM, Namitha K, et al. Design and development of balance training platform and games for people with balance impairments. *2016 Int Conf Adv Comput Commun Informatics, ICACCI 2016*. Published online 2016:960-966. doi:10.1109/ICACCI.2016.7732169
10. Lange B, Flynn S, Proffitt R, Chang CY, Rizzo A. Development of an interactive game-based rehabilitation tool for dynamic balance training. *Top Stroke Rehabil*. 2010;17(5):345-352. doi:10.1310/tsr1705-345
11. Postolache O, Girão PS, López A, Ferrero FJ, Dias Pereira JM, Postolache G. Postural balance analysis using force platform for K-theragame users. *2016 IEEE Int Symp Med Meas Appl MeMeA 2016 - Proc*. Published online 2016. doi:10.1109/MeMeA.2016.7533705
12. Ishizaki, M. T., da Silva, A. R. F., de Almeida Moura, L., dos Reis, P. C., Lazzareschi, L., da Silva Boschi, S. R. M., ... & da Silva, A. P. (2022). Development of a dynamic balance analysis and training system through posturography in a bipodal force platform with biaxial rotation. Research on Biomedical Engineering, 1-17.
13. Nielsen J. Why You Only Need to Test with 5 Users. Jakob Nielsens Alertbox. doi:http://www.useit.com/alertbox/20000319.html
14. ABNT. NBR ISO/IEC 14598-1 Tecnologia de informação - Avaliação de produto de software - Parte 1: Visão geral. Published online 2001:1-14.
15. Brooke J. This document : More Project information and further documents : SUS - A quick and dirty usability scale. *Psychol Mark*. 1986;27(10):1-8.
16. Tullis TS, Stetson JN. A Comparison of Questionnaires for Assessing Website Usability ABSTRACT : Introduction. *Usability Prof Assoc Conf*. Published online 2004:1-12. http://home.comcast.net/~tomtullis/publications/UPA2004TullisStetson.pdf

17. Bangor A, Staff T, Kortum P, Miller J, Staff T. Determining what individual SUS scores mean: adding an adjective rating scale. *J usability Stud*. 2009;4(3):114-123.
18. Bangor A, Kortum PT, Miller JT. An empirical evaluation of the system usability scale. *Int J Hum Comput Interact*. 2008;24(6):574-594. doi:10.1080/10447310802205776
19. UNITY3D. Published 2021. Accessed February 25, 2021. https://store.unity.com/products/unity-pro?gclid=CIm178878gCFciBkQodLhMMIQ%3E
20. Eggenberger P, Wolf M, Schumann M, de Bruin ED. Exergame and balance training modulate prefrontal brain activity during walking and enhance executive function in older adults. *Front Aging Neurosci*. 2016;8(APR):1-16. doi:10.3389/fnagi.2016.00066
21. Terada, M., Harkey, M. S., Wells, A. M., Pietrosimone, B. G., & Gribble, P. A. (2014). The influence of ankle dorsiflexion and self-reported patient outcomes on dynamic postural control in participants with chronic ankle instability. Gait & posture, 40(1), 193-197.
22. Galdino, T. R., & Kneubuehler, P. A. (2018). Análise comparativa do movimento de extensão de joelho na cadeira extensora, associado à dorsiflexão ou flexão plantar do tornozelo durante treinamento de hipertrofia em mulheres. RBPFEX-Revista Brasileira De Prescrição E Fisiologia Do Exercício, 12(73), 130-139.
23. Spink, M. J., Fotoohabadi, M. R., & Menz, H. B. (2010). Foot and ankle strength assessment using hand-held dynamometry: reliability and age-related differences. Gerontology, 56(6), 525-532.
24. Whyatt C, Merriman NA, Young WR, Newell FN, Craig C. A Wii Bit of Fun: A Novel Platform to Deliver Effective Balance Training to Older Adults. *Games Health J*. 2015;4(6):423-433. doi:10.1089/g4h.2015.0006
25. Katsanos C, Tselios N, Xenos M. Perceived usability evaluation of learning management systems: A first step towards standardization of the system usability scale in Greek. *Proc 2012 16th Panhellenic Conf Informatics, PCI 2012*. Published online 2012:302-307. doi:10.1109/PCi.2012.38

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