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Abstract

Introduction: Commercial platforms are widely used in research to assess and treat balance deficits in post-stroke patients. However, they do not provide the necessary specificity for the limitations and/or compensations that these patients may present. It is also difficult to extract the captured data, and there are concerns about the accuracy of this capture.

Objective: To validate a low-cost game platform called "Game Balance" for the analysis and training of balance in post-stroke patients.

Materials and Methods: This is a cross-sectional study with a quantitative approach. Eight (8) post-stroke patients of both genders were recruited from the Physiotherapy Clinic of FACISA (Santa Cruz/RN). This sample was evaluated using the following clinical scales: Mini-Mental State Examination (MMSE), Functional Ambulation Categories (FAC), The Modified Clinical Test of Sensory Interaction and Balance (mCTSIB), Modified Rankin Scale (mRS), and Fugl-Meyer Assessment Scale. The statistical analysis was performed using means or medians and standard deviation or quartiles, followed by correlation analysis using the Pearson coefficient based on the identification of data normality or non-normality using Statistical Package for the Social Sciences (SPSS) software, version 20.0, with a significance level of 5%.

Results: We had an n = 8, with a majority of males (62.5%), a mean age of 60.88 ± 11.67 years, and a majority of patients with ischemic stroke (62.5%) and left hemiparesis (75%) for a duration of 6.75 ± 4.33 years. Significant correlations were found between age and scores on "Game Balance" (Pearson's ρ = -0.743; p-value = 0.035), as well as between scores and activity time on the platform (Pearson's ρ = -0.738; p-value = 0.037), and between limb balance on the platform and the Rankin scale (Pearson's ρ = -0.745; p-value = 0.034).

Conclusions: The platform achieved the proposed objective, with some relationships between the variables of the device and the physical conditions of the selected population. The results of this research serve as a basis for future studies aiming to establish the effectiveness of this therapeutic approach in the rehabilitation of post-stroke sequelae.

INTRODUCTION

Stroke occurs when blood flow to the brain is interrupted, either due to a ruptured blood vessel (hemorrhagic stroke) or a blockage caused by a clot (ischemic stroke), resulting in cerebral paralysis in the region that experiences the lack of circulation. In Brazil, stroke is considered the leading cause of death, and there is an increased incidence of hospitalizations in young adults in the Northeast region (ADAMI et al., 2016). Impairment of the lower limbs can occur when the afferent and efferent pathways of specific areas are affected, and this impairment has a significant correlation with limitations in balance and walking ability (KIPER et al., 2020; WANG et al., 2017). Post-stroke patients demonstrate poorer performance in clinical balance tests compared to healthy older adults (LI et al., 2021).
Postural balance is the individual’s ability to maintain their Center of Pressure (CoP) within their base of support (feet). Approximately 83% of post-stroke survivors exhibit balance alterations related to physical impairments, disability, and low quality of life, which together can lead to high fall rates (LI et al., 2019). It is known that the rehabilitation process for post-stroke patients is often extensive and monotonous, mainly due to the need for multiple repetitions, leading to low adherence. This aspect has been used as a justification for the use of virtual reality in the rehabilitation process of these patients (VERMA et al., 2017; NOVELETTO et al., 2018; MASSETTI et al., 2018).

Among commercial games, the most commonly used is the Nintendo Wii (ALARCÓN-ALDANA et al., 2020; MASSETTI et al., 2018; CLARK et al., 2018; GUMAA et al., 2021). This console features a non-immersive system that uses a screen to display the environment (MIGUEL-RUBIO et al., 2020). In terms of clinical applicability, non-immersive interventions become more attractive and easy to use. However, they do present some limitations. For example, a study concluded that Nintendo Wii games could not be specifically used for rehabilitation because the feedback provided by the Wii (game score) differed from the physical performance visually assessed by the therapist (DEUTSCH et al., 2011). Additionally, a review pointed out technical limitations in this platform that may influence its validity, such as poor signal-to-noise ratio and inconsistent sampling rate (CLARK et al., 2017). These limitations make it difficult to calculate the variation of the Center of Pressure (CoP) on the platform, requiring a data acquisition protocol, signal filtering methods, and selection of outcome variables to minimize potential errors. These limitations reinforce the need for the development of a dedicated platform for research purposes.

Therefore, the construction and use of these technologies should include a precise motion capture system (ALARCÓN-ALDANA et al., 2020) with a high sampling rate. It is also important to calibrate them for individuals with disabilities (MASSETTI et al., 2018). Furthermore, studies involving different populations are needed to reach firm conclusions regarding the validity of using games for assessing balance, postural oscillation, as well as reaction time, speed, and accuracy of postural movements in these individuals (GUMMA et al., 2021). In this context, the main objective of this research was to validate a low-cost game platform called "Game Balance" using functional tests for the analysis and training of balance in post-stroke patients.

**RESULTS**

Ten post-stroke patients were recruited; however, two were excluded, one due to a MMSE score below 24 and another due to a FAC score below 3, resulting in a total of eight individuals, as characterized in Table 1.
Table 1
Distribution and percentages of socio-demographic variables in post-stroke patients, as well as their performance in the employed scales.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Participants (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>5 [62,5%]</td>
</tr>
<tr>
<td>Men (n [%])</td>
<td>3 [37,5%]</td>
</tr>
<tr>
<td>Women (n [%])</td>
<td></td>
</tr>
<tr>
<td>Age (mean ± SD)</td>
<td>60,88 ± 11,67 years</td>
</tr>
<tr>
<td>Stroke time (mean ± SD)</td>
<td>6,75 ± 4,33 years</td>
</tr>
<tr>
<td>Stroke type</td>
<td>5 [62,5]</td>
</tr>
<tr>
<td>Ischemic (n [%])</td>
<td>3 [37,5%]</td>
</tr>
<tr>
<td>Hemorrhagic (n [%])</td>
<td></td>
</tr>
<tr>
<td>Compromised Hemibody</td>
<td>2 [25%]</td>
</tr>
<tr>
<td>Right (n [%])</td>
<td>6 [75%]</td>
</tr>
<tr>
<td>Left (n [%])</td>
<td></td>
</tr>
<tr>
<td>FAC (median [Q1:Q3])</td>
<td>5 [4:5]</td>
</tr>
<tr>
<td>Rankin (median [Q1:Q3])</td>
<td>1,5 [1:2,75]</td>
</tr>
<tr>
<td>MMSE (median [Q1:Q3])</td>
<td>27,5 [24:28] points</td>
</tr>
<tr>
<td>mCTSIB</td>
<td>30 [30:30] seconds</td>
</tr>
<tr>
<td>OASI (median [Q1:Q3])</td>
<td>14 [11,5:30] seconds</td>
</tr>
<tr>
<td>OFSI (median [Q1:Q3])</td>
<td></td>
</tr>
<tr>
<td>Fugl-Meyer</td>
<td>38,5 ± 7,15 points</td>
</tr>
<tr>
<td>Total (mean ± SD)</td>
<td>28 ± 5,24 points</td>
</tr>
<tr>
<td>LL (mean ± SD)</td>
<td>10,5 ± 2,51 points</td>
</tr>
<tr>
<td>Balance (mean ± SD)</td>
<td></td>
</tr>
<tr>
<td>Game Balance</td>
<td>36,5 ± 3,46 points</td>
</tr>
<tr>
<td>Score (mean ± SD)</td>
<td>126 ± 3,3 seconds</td>
</tr>
<tr>
<td>Time (mean ± SD)</td>
<td>48,88 ± 5,82%</td>
</tr>
<tr>
<td>Balance (mean ± SD)</td>
<td></td>
</tr>
</tbody>
</table>
Legend: SD - standard deviation; Q1 - first quartile; Q3 - third quartile; FAC - Functional Ambulation Categories; MMSE - Mini-Mental State Examination; mCTSIB - modified Clinical Test of Sensory Interaction and Balance; LL - Lower Limbs. Data presented with mean and standard deviation were normally distributed, while those with abnormalities were presented with median and quartiles.

The majority of the sample did not smoke (87.5%) or consume alcohol (87.5%), and only 25% were sedentary. They also used an average of 3.37 medications and had an average of 1.37 stroke episodes, predominantly affecting the right cerebral hemisphere (75%).

A correlation test using Pearson's coefficient and Spearman's coefficient was also conducted to identify any correlations between variables and the patients' performance in the game, as shown in the table below.
### Table 2
Analysis of correlation with performance variables in Game Balance (n = 8)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Game Balance (score)</th>
<th>Game Balance (time)</th>
<th>Game Balance (balance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.743*</td>
<td>0.587</td>
<td>-0.470</td>
</tr>
<tr>
<td>Pearson's ρ</td>
<td>0.035*</td>
<td>0.126</td>
<td>0.240</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke time</td>
<td>-0.429</td>
<td>0.357</td>
<td>-0.156</td>
</tr>
<tr>
<td>Pearson's ρ</td>
<td>0.289</td>
<td>0.385</td>
<td>0.713</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FAC</td>
<td>0.495</td>
<td>-0.110</td>
<td>0.401</td>
</tr>
<tr>
<td>Speraman's ρ</td>
<td>0.212</td>
<td>0.795</td>
<td>0.325</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mCTSIB OFSI</td>
<td>-0.024</td>
<td>0.415</td>
<td>0.147</td>
</tr>
<tr>
<td>Spearman's ρ</td>
<td>0.954</td>
<td>0.307</td>
<td>0.728</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fugl-Meyer</td>
<td>0.252</td>
<td>-0.024</td>
<td>0.265</td>
</tr>
<tr>
<td>Pearson's ρ</td>
<td>0.548</td>
<td>0.955</td>
<td>0.526</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rankin</td>
<td>0.217</td>
<td>-0.204</td>
<td>-0.745*</td>
</tr>
<tr>
<td>Spearman's ρ</td>
<td>0.606</td>
<td>0.627</td>
<td>0.034*</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Game Balance (score)</td>
<td>1</td>
<td>-0.738*</td>
<td>0.371</td>
</tr>
<tr>
<td>Pearson's ρ</td>
<td></td>
<td>0.037*</td>
<td></td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Game Balance (time)</td>
<td>-0.738*</td>
<td>1</td>
<td>-0.024</td>
</tr>
<tr>
<td>Pearson's ρ</td>
<td>0.037*</td>
<td></td>
<td>0.955</td>
</tr>
<tr>
<td>p value</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

This study aimed to validate a game platform and compare the performance of post-stroke patients in the platform with functional scales and tests. As observed in Table 2, there is a strong negative correlation between the points scored by patients in the platform and their age, indicating that younger patients tend to score more points in the game. A study by GOLLA et al. 2018 found that older patients benefit more from the use of the platform, as their initially poor performance improved with training. However, they highlighted that their participants did not reflect the population of stroke survivors with higher functional limitations. Therefore, the findings regarding the feasibility of the intervention could not encompass the different levels of disabilities caused by the sequelae of the disease.

We also found a negative correlation between points scored and the time taken by patients to complete the course with the avatar. This suggests that response time, i.e., perception and movement of the avatar, influences the ability to collect more points. This response time will change as users gain more experience with the platform, as shown in a study by VERMA et al. 2017, which identified that the sample that spent less time on the platform collected more points. This highlights how the repetitive practice facilitated by these games allows patients to become familiarized and improve their performance in the game.

The scoring aspect is important as an evaluation parameter because it provides immediate feedback to the patient about their performance. Studies have shown that patients often state that they are improving as they are able to increase their score (NOVELETTO et al., 2018). Additionally, a moderate positive correlation was identified between the game score and the patients' performance on balance tests, indicating that the point system could be used as a complement to evaluate balance in this population.

Regarding weight distribution on the platform, measured by the variable "balance," we observed a strong negative correlation with the Rankin scale, which measures the patients' need for assistance during ambulation. We know that the gait phases involve swing and weight distribution between both lower limbs, and this correlation suggests that the more independent a patient is during ambulation, the better their weight distribution on the platform. This is supported by improvement in gait observed in a study by SONG et al. 2015 following training on a game platform, where patients who were evaluated as having worse gait were also classified as worse on the Rankin scale. Another study by SANA et al. 2023 also identified improved gait using the Time Up and Go Test (TUGT), with 56.7% of the sample in that study scoring 3 (moderate disability) or higher on the Rankin scale. We could thus infer that those with poorer
scores on the Rankin scale would benefit more from these devices. However, further studies specifically targeting this population are necessary to confirm this.

Interestingly, the variables that were expected to be significant were weight distribution (balance) and the mCTSIB test, but when we reviewed the literature (SACKLEY et al 1993; MANSFIELD et al 2013; KAMPHUIS et al 2013), it indicated a weight distribution imbalance of 61–80% between the paretic and non-paretic limbs in post-stroke patients. Our sample had an average of 48.88%, close to 50% and even better than the pilot project (44.5%), indicating a good weight distribution in our sample. A study by YATAR et al. 2015 treated the balance of post-stroke patients, where one group received conventional balance training and the other used a game platform. Although weight distribution improved in the game group, there were no significant differences between the groups, which they attributed to the minimal difference in weight distribution between the groups (52% and 55%, respectively). A review by LI et al. 2016 also found no changes in weight distribution after training. Both studies highlight limitations such as the short follow-up period and the lack of heterogeneity in the sample, as most studies have a mean age between 44 and 66 years, a small sample size (less than 30 participants), and none examined the efficacy of therapy in subacute cases where the learning process is greater. Therefore, more virtual reality studies are needed in the early stages of stroke to confirm the benefits already found for this population in other studies (KARASU et al 2018; SANA et al 2023; BOWER et al 2014).

Not only was good weight distribution observed on the platform, but the average scores on the functional tests were also very close to the maximum score. This leads us to reflect on the functional level of the sample in this study, what their physical limitations are, and whether they interfere with balance to the extent that they are evident in the tests or the developed platform. This point was also discussed in a study by GOLLA et al. 2018, which presented participants with a good average performance on functional tests, and they concluded that the patient’s functional status directly influences the usability and applicability of the platform, as well as the benefits they will derive from it.

To our knowledge, this is the first study to validate a game platform with functional clinical tests specifically aimed at post-stroke patients, making it difficult to find studies with similar variables and objectives. Most studies utilize commercial platforms (ALARCÓN-ALDANA et al 2020; MASSETTI et al 2018; CLARK et al 2018; GUMMA et al 2021) and balance scales such as the Dynamic Gait Index (DGI), TUGT, and the Berg Balance Scale parameters (YATAR et al 2015 NOVELETTO et al 2018; LI et al 2019). When stroke scales are used, they are solely for sample characterization and are not employed in the statistical analysis. Other limitations include the long time since stroke onset (6.75 years) and a small sample size of patients meeting the inclusion criteria.

**CONCLUSION**

In conclusion, the development of a game platform aimed at post-stroke balance rehabilitation makes training more targeted and provides more visible feedback and self-perception of progress for patients. It was possible to establish some relationships between the device variables and the physical conditions of
the selected population. However, the results of this pilot research should be viewed with caution and serve as a foundation for future studies aiming to establish the efficacy of this therapeutic approach in rehabilitating post-stroke sequelae.

METHODOLOGY

1 - Study Design

This study is an observational, clinical, cross-sectional study with a quantitative approach that tested and compared a low-cost game platform developed for balance training in post-stroke patients with functional tests. The inclusion criteria involved individuals clinically diagnosed with stroke of any etiology, in the chronic phase (< 6 months), accompanied by lower limb hemiparesis, without vestibular disorders or associated orthopedic and/or neurological pathologies (e.g., Parkinson's disease) that could hinder the study. Participants also needed to have preserved cognitive capacity for understanding and executing commands, as assessed by the Mini-Mental State Examination (MMSE), and normal or corrected-to-normal vision. Individuals who did not complete any of the study stages or had a Functional Ambulation Categories (FAC) score below three, as described below, were excluded from the study. Convenience and intentional non-probabilistic sampling were used to recruit participants through contact with stroke patients registered and undergoing physiotherapy follow-up at the Physiotherapy Clinic of FACISA (Santa Cruz/RN).

2 - Description of the "Game Balance" Game Platform for Hemiplegic Patients

The "Game Balance" game platform was developed to be presented at FEBRACE 2021 (DOS SANTOS et al., 2021). As a way to be tested in practice, the partnership between UFRN and IFRN initiated this project. The game was conceived based on the context of post-stroke patients treated at the Physiotherapy Outpatient Clinic of the Integrated Clinic of Facisa/UFRN, located in Santa Cruz-RN, Brazil, using elements from their daily lives and real environment, aiming to engage them through ludic elements (narrative, graphical interfaces, sounds, control system, scoring, etc.) that facilitate immersion and player representation.

This platform was developed to allow the evaluation and training of balance in post-stroke patients and has the following features: (a) construction of a mechanical base that offers precision in describing body weight and static and dynamic balance of the user; (b) development of a game that promotes user engagement during sessions of static/dynamic balance rehabilitation; (c) user-friendly design for easy instrument handling, data visualization, and extraction of variables produced during assessment or training; and (d) provision of user's clinical/therapeutic history visualization at the end of the game.

The mechanical base has the function of supporting the platform containing the load sensors and electronic circuits responsible for extracting, processing, and sending the user's weight information based
on their mechanical distribution on the platform. There are four load sensors on each platform, positioned at the upper right, upper left, lower right, and lower left axes of the mechanical base (Fig. 1). After the data capture by the sensors, it is sent to hardware installed in each platform, where it is processed and transformed into values that express the user's horizontal balance (weight distribution between the right and left hemibody) and vertical intensity (weight distribution anteroposteriorly on the user's feet).

There are two mechanical bases, constructed with tempered glass (one for each foot), and on their lower surface, the fixtures for the load sensors/cells and other electronic equipment are attached. To provide stability for users, eight load sensors were used, four on each foot base.

The load sensors used have a capacity to support 50kg each and dimensions of approximately 34mm in width and length and 7mm in thickness. This device detects the amount of force exerted on it by altering its internal resistance. The resistance variation is proportional to the force applied to the device and can be measured using the Wheatstone bridge. The AutoCAD software is used to construct the fixture models, which are 3D-printed using a 3D printer.

The platform also includes a hardware component (microprocessor (ESP32)) connected to four HX711 modules, which are connected to each set of load sensors/cells (Fig. 2).

The HX711 module, responsible for connecting the sensors to the platform hardware, is an analog-to-digital converter used to measure the values of the load cell and determine the forces applied to the platform at that support point. The platform hardware consists of an ESP32 microcontroller, responsible for processing the control signal data, as well as communicating with the target platform. The microcontroller receives information from the four HX711 modules, filters and shapes the signal, and then transforms it into commands based on the platform's balance equations. These commands are sent to the game control via Bluetooth interface.

After the data is processed on the platform hardware (establishing balance and vertical intensity), it is sent to the game software via Bluetooth connection to control the movements of the game's main character, for example, moving the character right or left (lateral displacement) and accelerating or decelerating the character (anteroposterior displacement) (Figs. 2).

The game was developed in Unity 3D and exported to Windows 10, Mac OS X, and Linux computer platforms, with the intention of facilitating game implementation in most market computer systems, such as desktop computers, laptops, tablets, smartphones, and Raspberry Pi. Furthermore, the concepts of a Short Game Design Document (SGDD), which governs the forms of interaction between the game and the player, the game objectives, as well as the limitations of the community that will use it (i.e., post-stroke patients), were considered. The game has four levels of difficulty (1, 2, 3, and 4), progressing from the first level (where the distances between the corn spikes are greater and the course is easier to navigate) to the last level (where the distances between the corn spikes are smaller, and the user faces more difficulty in
navigating the course). Only level 1 was used in this research to standardize the performance analysis of the sample.

3 - Experimental Protocol

The protocol, with a maximum duration of one hour, involved collecting sociodemographic and clinical data (gender, age, lifestyle habits, current medications, stroke history), performing functional tests, and evaluating performance on the game platform developed for this research.

3.1 - Functional Tests

3.1.1 Mini-Mental State Examination (MMSE)

The Mini-Mental State Examination (MMSE) was used to screen the cognitive level of the participants. It consists of a set of thirty questions divided into seven categories: temporal orientation, spatial orientation, three-word registration, attention and calculation, recall memory, language, and visual constructive capacity. According to a study conducted in the Brazilian population, individuals with no education are considered to have a score below eighteen points, while individuals with prior education are considered to have a score below twenty-four points (LOURENÇO et al., 2006).

3.1.2 Functional Ambulation Categories (FAC)

The FAC is a functional walking test that assesses the individual's ambulation capacity. It uses a six-category scale to evaluate the state of ambulation, determining the level of human support the patient requires while walking, regardless of whether or not they use an assistive device for walking. The patient is required to walk approximately three meters and will be classified as follows: zero - non-functional ambulator; one - ambulator dependent on physical assistance level II (continuous manual contact); two - ambulator dependent on physical assistance level I (light continuous or intermittent touch); three - ambulator dependent on supervision; four - independent ambulator on flat surfaces; and five - independent ambulator on any surface (HOLDEN et al., 1984).

3.1.3 Modified Rankin Scale (mRS)

With seven classifications, this scale clinically measures the patient's global disability and the need for assistance from third parties (CINCURA et al., 2009). The classifications are as follows: zero - no symptoms; one - symptoms without disability, no need for assistance with daily tasks and activities; two - slight disability, no assistance required for personal needs; three - moderate disability, ambulates without assistance; four - moderate to severe disability, requires assistance for ambulation; five - bedridden and in need of constant attention, severe disability; and six - death.

3.1.4 Fugl-Meyer Assessment Scale
This scale measures motor and sensory impairment following a stroke. Based on scores, it evaluates six aspects of the patient: range of motion, pain, sensation, motor function of the upper and lower extremities, balance, coordination, and speed, on an ordinal scale of three points: zero (cannot be performed), one (partially performed), and two (fully performed), with a total of two hundred and twenty-six points. The motor function assessment includes measurements of movement, coordination, and reflex activity of the hip, knee, and ankle. The coordination and speed of the lower extremities are also evaluated, totaling a maximum score of thirty-four points. The balance assessment involves sitting, standing, and unipedal support, with a maximum score of fourteen points. In this study, a maximum score of forty-eight points was used, and the closer the patient's score is to this maximum score, the less impaired they are (MAKI et al., 2006).

3.1.5 The modified Clinical Test of Sensory Interaction and Balance (mCTSIB)

The CTSIB is a clinical assessment method for sensory integration. The individual undergoes six different sensory conditions, gradually increasing the difficulty by altering visual, somatosensory, and vestibular information. This allows for the analysis of how the individual deals with the absence or conflicts of information (SHUMWAY-COOK, HORAK, 1986). The test involves placing the subject in an upright position with feet together and arms at their sides, aiming to maintain the position for 30 seconds under each condition. Each condition is performed three times, and the average time from the three attempts is recorded. In this study, a modification will be made (SCAGLIONI-SOLANO et al., 2014), and only four conditions will be performed: condition one - eyes open on a firm surface (EOFS) with all senses present; condition two - eyes closed on a firm surface (ECFS), i.e., no visual information is available; condition three - eyes open on a foam surface (EOFS) providing inaccurate information to the proprioceptive system; and finally, condition four - eyes closed on a foam surface (ECFS) with inaccurate information to the proprioceptive system and the absence of the visual system.

3.2 - Measures and Evaluation Protocol of the "Game Balance" Game Platform

The laboratory measurements of the "Game Balance" game platform were obtained from the data generated by the platform itself. The following outcome measures were used: (a) weight distribution percentage (Balance) in the two hemibodies (determined by the patient's weight distribution on the two plates - the closer to 50% bilaterally, the better the balance); (b) Points acquired during the game (Points). The user was instructed to collect the corn cobs with the Avatar (chicken). The higher the number of points, the better the user's ability to shift their weight to the right or left or maintain the midline. In order for the user to shift the Avatar to the left, they had to shift at least 51% of their body weight to the left. Similarly, to shift to the right, they had to shift at least 51% to the right. To keep the Avatar on the midline, they had to maintain 50% of their body weight on both sides; (c) Training time (Time), the time the user took to complete that level (the shorter the time, the better the user's ability to complete the game's stages).
The participants were instructed about the objective of the game (collecting corn) and that their movements would be reproduced by the avatar (chicken). These movements should only involve tilting the body to the right or left to move the chicken sideways, without the need to remove their foot from the platform or walk on it. They were also informed about the duration of the game and the obstacles that may appear. They had a practice session to familiarize themselves with the game, followed by three game sessions to collect the data for averaging.

4 - Statistical Analysis

Descriptive measures such as measures of central tendency (mean and median) and dispersion (standard deviation and quartiles) were used to describe the participants' characteristics. This was followed by inferential statistical analysis using the Pearson correlation test, after assessing the normality of the data using the Kolmogorov-Smirnov test. The tests were analyzed using the Statistical Package for the Social Sciences (SPSS) software version 20.0, with a significance level of 5%.

Declarations

1- Ethical Approval

The research project was submitted for approval to the Research Ethics Committee (CEP) of the Faculdade de Ciências da Saúde do Trairi - FACISA/UFRN, through the national interface Plataforma Brasil, in accordance with Resolution 466/12 of the National Health Council and the Declaration of Helsinki for research involving human subjects. The project was approved under the opinion number 4,847,237. Before being admitted to the study, all volunteers signed an informed consent form (ICF).

2- Competing interests

None declared

3- Authors' contributions

We would like to acknowledge the individuals who made significant contributions to this article. A, the author, conducted the data analysis and generated the entire content. D, as the editor, reviewed and refined the text. C, the developer, created the gaming platform and prepared the accompanying visuals. B assisted A in data collection.

4- Funding

Not applicable

5- Availability of data and materials
Any data from this research can be accessed through the authors' email: maria.julia.018@ufrn.edu.br; eniowalker@gmail.com;

References


Figures

Figure 1
Illustrative image of the 3D mechanical base and its four sensors (source: author, 2020).

Figure 2

Diagram of the platform connections with the game.