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Reproducibility and equivalence of GDLAM protocol mobile application for the evaluation of functional autonomy

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ABSTRACT

This study aimed to develop a mobile application (App) for the Latin American Group for the Development of the Elderly (GDLAM) protocol of functional autonomy in the Android environment and check its reproducibility. This study was divided into two stages: 1) creation and development of the GDLAM App, Android Studio software, and JAVA as a programming language; 2) evaluation of 63 volunteers for the GDLAM protocol using the traditional method and the App. The significance level was set at $p<0.05$. There were no statistical differences between the traditional GDLAM protocol and the App. However, the total time required to assess the GDLAM protocol using the App was significantly lower ($p <0.001$). In addition, the levels of agreement between assessments exhibited strong and very strong positive correlations with significance ($p <0.001$) for all variables. The study showed that the use of the GDLAM App is as efficient as the traditional functional autonomy protocol for the elderly, demonstrating that reproducibility is adequate, assessment time shorter, and results are obtained faster.

KEYWORDS: Mobile applications, Aged, Activities of daily living.

INTRODUCTION

The decrease in fertility and mortality rates (World Health Organization [WHO], 2015) has led to a significant increase in the number and proportion of older people in recent decades. This change has drawn attention to the care and needs of this emerging social stratum. Sports scientists have developed better training and assessment methods to improve seniors' functional autonomy and control the health-related variables (Dantas et al., 2014).

Although aging is a natural process, it causes declines in health-related variables (Filho et al., 2011; Jati et al., 2018; Vale et al., 2017). Thus, to perform the activities of daily living (ADL), it is essential to exert better control over these variables, mainly developing and preserving functional autonomy (FA) (Dantas et al., 2014; WHO, 2015).

The need for FA in the elderly goes beyond executing ADL, including walking around the house, dressing and combing one's hair. Regular physical activity also contributes to functional autonomy, good quality of life (QoL), preventing non-communicable chronic diseases, and decreasing the risk of falls (Borba-Pinheiro et al., 2016; Dantas et al., 2014). Multiple health-related variables are associated with muscular strength, flexibility, and aerobic power, which influence FA, QoL, and the performance of ADL (Azambuja et al., 2013; Passos e Borba-Pinheiro, 2016).

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There are several valid tests and protocols that systematize procedures in order to obtain quantitative results according to age group. These procedures require maximum attention to minimize errors while maintaining the proper execution method and reproducible results (Baechle e Groves, 1992; Dantas et al., 2014; Rikli e Jones, 2008).

The protocol developed by the Latin American Group for the Development of the Elderly (Grupo de Desenvolvimento Latino Americano para Maturidade – GDLAM) is a widely used methodological tool to evaluate FA. It consists of five motor tests that measure upper arm flexibility, dynamic and restored balance, time to walk 10 meters, muscle power, and agility. All test measures are in seconds. Based on these results, a mathematical model calculates the GDLAM index (GI) for autonomy and generates a functional classification (Dantas et al., 2014).

Technological tools may help accomplish tasks and activities such as motor tests (Ferreira, 2013). New scientific research technologies have grown steadily. These include mobile applications (Apps), important tools for optimizing results, and analyzing valid and reliable assessment techniques to help professionals and the general public (Tibes et al., 2014).

However, improvements in GDLAM protocol procedures are needed, such as minimizing errors and shortening the entire protocol's execution time to provide rapid results to individuals based on their classification and generate an automatic cloud database for researchers. The GDLAM protocol is still manually applied, and a mobile application could solve the above-mentioned problems. Thus, the present study aimed to develop a mobile application (App) for the GDLAM protocol in the Android environment and check its reproducibility.

METHOD

This methodological procedure involves two steps: 1 – the construction and development of the GDLAM FA App for Android; 2 – reproducibility and equivalence of the protocol through the App.

1st Phase: Construction and development of the GDLAM FA App for Android

The GDLAM FA App consists of five steps: requirements analysis, construct definition, computational representation, system coding, and system evaluation.

Requirements analysis

Requirements analysis consists of prior knowledge of what the App must accomplish with the specific variables, dynamics, functions, and calculations (Deitel et al, 2015). Requirements included a timer, the sequence of GDLAM FA protocol procedures, creation of a folder in the mobile phone's internal memory, and data recording on a Microsoft® Office Excel worksheet.

Knowledge definition

GDLAM protocol analysis determined which variables would be included in the App (Deitel et al., 2015). Thus, system developers needed detailed knowledge of each phase of the process, including testing, GI calculation, and classifying the results. The authors Dantas et al. (2014) described the GDLAM protocol for FA and found it to be valid.

Computational representation of knowledge

This phase consists of data classification, transformation into codes, and insertion to develop the application interface (Deitel et al., 2015).

Use cases were developed to describe how the GDLAM FA App would be used and the functionalities that would be included. These use cases follow a defined pattern, in which the reader/programmer follows the path established to construct the App (Deitel et al., 2015).

System coding

JAVA was the programming language, and Android Studio, the integrated environment for GDLAM FA App development (Deitel et al., 2015).

STEP 1: When initiate coding, it was necessary to include the permissions to the device resources, which, by default, are protected by the system. The App needs to ask for permission while it is running for the first time. This provides confidence to the users and optimizes the installation process. Thus, the App can access the device's storage, as well as read and write the data.

STEP 2: A simple and objective interface helps the user record test times. It has interactive play (start counting), return (resumes counting), and stop buttons (counting ends). Moreover, after selecting the stop button, the App generates a window as a message, where the user must indicate in which test the device should record the measured time.

STEP 3: In this step, programmers created a class that works only with the tests and receives their values as a parameter in milliseconds. The system includes them in the GI formula and relates these results to the subject's age. After providing the age and clicking on the check button, the user receives the rating immediately.

STEP 4: The system created a folder in the mobile phone's internal storage and a file denominated "GDLAM. xls". The App uses an open-source and ready-to-use application programming interface (Java Excel API) that allows developers to read, write, and modify the Microsoft® Office Excel spreadsheet (Deitel et al., 2015).

2nd Phase: Protocol reproducibility and equivalence through the App

Subjects

Through convenience sampling, sixty-three elderly women underwent the GDLAM testing protocol while attending two social assistance reference centers (CRAS) in the city of Tucuruí, Pará state, Brazil.

Selection Criteria

The following selection criteria were established for participation in data collection: women aged 60 years or older, enrolled in CRAS projects, exhibiting no physical problems that would preclude their performing any of the protocol tests, such as arthrosis, arthritis, herniated disc, and rheumatoid arthritis.

Research Ethics

All volunteers provided written informed consent according to Resolution No. 510/16, which governs research with human beings (Brazil, 2016). The study was approved by the Estácio de Sá University (Rio de Janeiro state) Research Ethics Committee in partnership with the University of the State of Pará, under protocol number 1.617.605.

Intervention procedures

Before protocol reproducibility was initiated through the App, weight, and height were measured to characterize the sample on an INMETRO-approved Welmy®CH110 anthropometric scale (Brazil) with a capacity of 150 kg with 100g intervals. Height was measured with the vertical anthropometer attached to the scale (WHO, 1995), and body mass index (BMI) was calculated according to the following equation (Brasil, 2014):

$$BMI = \frac{\text{Body mass}}{\text{height}^2}$$

Protocol reproducibility through the App was conducted as follows: two experienced raters and two assistants. Rater 1 collected data in the traditional manner, and rater 2 through the application. The function of assistant 1 was to: 1) filled in a Microsoft® Office Excel spreadsheet previously organized to receive the data collected by the rater who applied the protocol using the traditional method, where the GI formula was also placed, which showed the result automatically after filling the tests times, 2) performed the classification of the tests and the GI of the volunteers comparing the data with their age according to the reference table, 3) filled in the spreadsheet the classifications found. Assistant 2 recorded the time it took to perform the complete process since the tests were performed, data collection and storage, GI result and classifications of all tests, and GI, of both forms of execution (manual and App). The evaluators repeated the evaluation process twice, reaching an intraclass correlation coefficient (ICC) of 0.95 for all the tests and the GI of the GDLAM FA protocol. The mean of the two assessments for each one test was used to represent the data.

It is important to underline that for each test, the two raters started and finished the timer simultaneously, considering each one's reaction time. The tests were performed in the following sequence: from the lowest to the highest effort, with a three-minute interval between tests: putting and taking off a t-shirt (PTTs), rising from a sitting position (RSP), rising from the ventral decubitus position (RVDP), 10-meter walk (10MW), and sitting and rising and walking around a chair (SRWC).

Statistical analysis

Statistical analysis was conducted using IBM SPSS 20.1 software with a significance level of $p < 0.05$. Descriptive statistics was initially used with measures of central tendency and dispersion for the descriptive data. The Kolmogorov-Smirnov test of normality and Levene's test for homogeneity were carried out. The student's t-test for independent samples, Pearson's correlation coefficient, and the ICC were used for rational scale data. In addition, Cohen's kappa coefficient was used to measure nominal scale agreement between the classifications generated by the different GDLAM protocol application methods.

RESULTS

GDLAM FA App

The GDLAM FA App is an Android application that assists in assessing FA. The GDLAM FA protocol governs the type of App, which is available in Portuguese, Spanish, and English. The mobile phone system supports a language change, and the App automatically appears in the same language as the system configuration.

The step-by-step application is described below:

On the initial GDLAM FA App screen, the user clicks on the name of the test, and an explanatory screen appears, describing what the test evaluates, its procedures, and the reference. The user starts the stopwatch by clicking on a triangle and resets it by clicking the back icon and clicking on a square to stop recording.

The following message then appears: to which test want to assign the time recorded? The user must choose which of the five tests the time recorded should be attributed to, which is then displayed beside the selected test. The other tests follow the same procedure until the screen displays the five tests and their recorded times. To proceed, the user clicks on the green button to generate the index. However, if all the collections must be redone, the user clicks on the reboot icon, represented by a trash can.

After the green button is clicked to generate the index, another screen appears, where the users fill in the name and age of the individual evaluated and then click on the green check button, represented by a question mark.

Finally, the classification of each test and the index according to the recorded times and proper classification for the user's age are displayed. The App then automatically shows a message that the data have been saved in the Microsoft® Office Excel file generated by the program in the phone's memory. If the user still needs to perform the tests with other volunteers, they must click on the "new test button", represented by the plus sign (+).

Product reproducibility through the App

Table 1 shows the descriptive data with central tendency and dispersion measures to identify the subjects.

A total of 7.14% of the volunteers were underweight, 38.58% were normal weight, and 54.28% were overweight. Although BMI correlates with functional autonomy, the GDLAM protocol does not use this variable in the calculations.

Table 2 shows the comparative results between the traditional method and GDLAM FA App assessments. The test results exhibited no significant difference between the two application methods. However, each evaluation's total time showed a significant difference of 2 minutes ($p < 0.001$). The GDLAM FA App took less time than the manual protocol.

Figure 1 presents the Pearson's correlation results in scatterplots, where all analyses exhibited strong and significant correlations (r and $r^2 > 0.90$; $p < 0.001$) for 10MW, RSP, RVDP, PTTs, SRWC, and GI, in addition to total time spent using the traditional GDLAM method and the App.

Table 3 shows classifications obtained using the traditional GDLAM method and the App, demonstrating strong and very strong significant correlations for all variables. It also reveals "substantial agreement" for almost all the tests, except SRWC, which had an even better rating, that is, "almost perfect agreement", according to the classification (Landis e Koch, 1977).

Table 1. Physical characteristics of the study sample.

n = 63			
Variables	Mean ± SD	Maximum	Minimum
Age (years)	68.81 ± 6.38	83.0	60.0
Weight (kg)	63.6 ± 10.07	89.5	40.8
Height (m)	1.52 ± 0.06	1.70	1.41
BMI (kg/m^2)	27.41 ± 4.01	36.94	18.88

BMI – body mass index; SD – standard deviation.

DISCUSSION

There was a need to facilitate and optimize the sequence of the GDLAM FA protocol procedures. As a result, this application substitutes items such as a stopwatch, paper, and pencil, calculates indexes, and stores data on a spreadsheet, separately, thereby automating the collection and information gathering process. The entire process is concentrated into a single tool, the mobile phone, to help academics, teachers, and researchers.

Apps that facilitate health procedures and tasks are a current reality. Nussbaum et al. (2019) conducted a systematic review to determine how mobile Apps were used in the medical and rehabilitation fields and found 102 studies. One-third were used in intervention procedures, and the remainder to evaluate the App itself. They found that Apps used in exercise interventions or as a measurement tool may produce positive benefits. In this respect, the GDLAM FA App is simple, specific, and effective, in addition to reducing errors, accelerating classification, and providing enhanced data organization for researchers.

Specific applications to assess elderly performance were also found in the literature (Ferreira, 2013; Sampaio et al., 2017). Ferreira (2013) analyzed the single-leg standing and sit-to-stand exercises using the Falls Efficacy Scale and attaching a mobile device to the subjects' upper trunk. The results obtained with the App were positive when compared to other assessment methods. The Timed Up and Go (TUG) test was applied to evaluate 30 volunteers at different moments, such as rising from a sitting position, walking forward and turning and walking backward, and turning to sit down again. The sensors connected to the subject transmitted signals to an iPhone 4, which detected kinematic patterns. As such, the system was able to receive and analyze the different subphases of the test, performed by frail and non-frail seniors.

Sampaio et al. (2017) also used the TUG and Performance Oriented Mobility Assessment (POMA) tests, which assess balance and risk of falls in the elderly. They observed that the

Table 2. Comparative results between the two assessment methods.

Variables	GDLAM Manual		GDLAM App		*p-value*
	Mean ± SD	KS	Mean ± SD	KS	
10MW (s)	7.04 ± 0.87	0.200	7.02 ± 0.72	0.200	0.917
RSP (s)	10.46 ± 2.13	0.200	10.82 ± 2.30	0.200	0.342
RVDP (s)	3.62 ± 1.13	0.051	3.88 ± 1.00	0.061	0.154
PTTs (s)	12.91 ± 3.48	0.059	13.18 ± 3.23	0.063	0.645
SRWC (s)	49.41 ± 7.84	0.200	49.95 ± 8.30	0.200	0.690
GI (score)	29.37 ± 4.24	0.200	29.94 ± 4.17	0.200	0.426
Total time (min)	5.59 ± 0.91	0.184	3.89 ± 0.70	0.072	*< 0.001*

KS = Komolgorov-Smirnov normality test

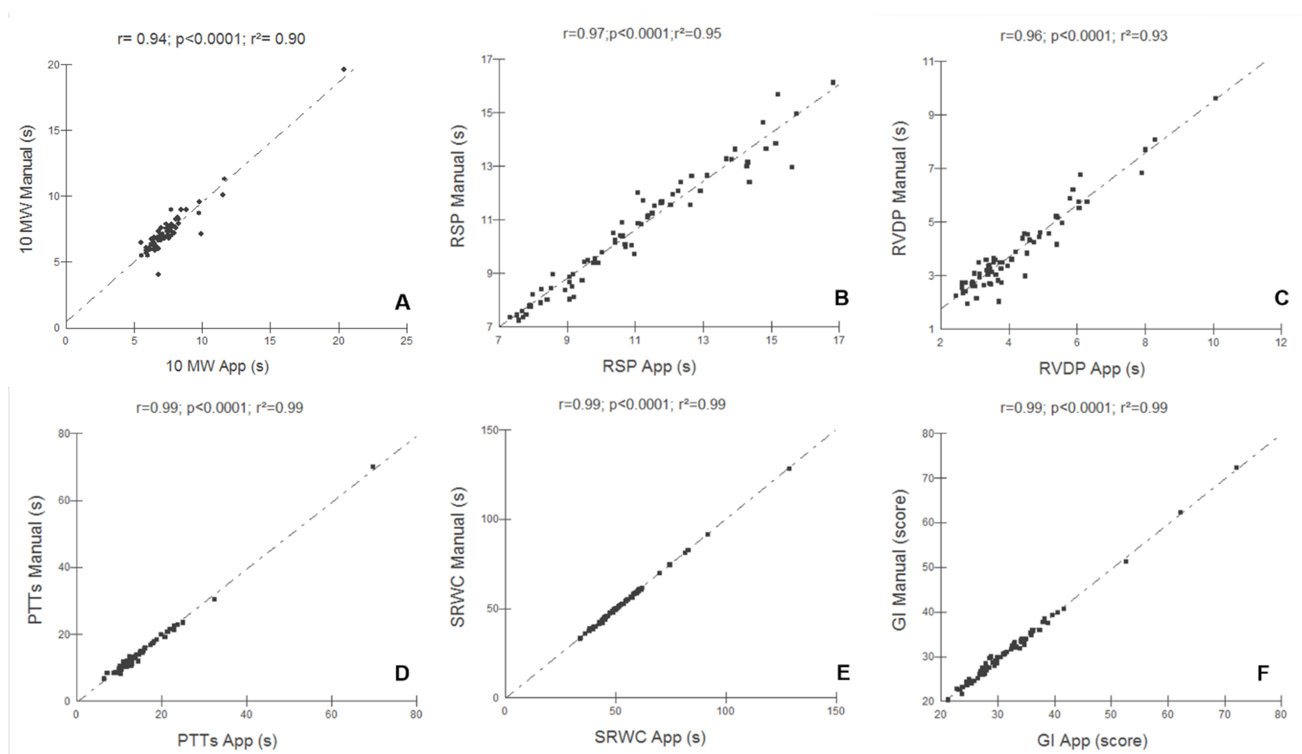

Figure 1. Scatterplot results of Pearson's correlation.

Table 3. Correlations between the two classifications of the two procedures.

Procedures	*R*	*Kappa*	*Classification*	*p-value*
10MW Manual vs. 10MW App	0.75	0.66	Substantial agreement	*< 0.001*
RSP Manual vs. RSP App	0.87	0.69	Substantial agreement	*< 0.001*
RVDP Manual vs. RVDP App	0.83	0.65	Substantial agreement	*< 0.001*
PTTs Manual vs. PTTs App	0.84	0.69	Substantial agreement	*< 0.001*
SRWC Manual vs. SRWC App	0.97	0.93	Almost perfect agreement	*< 0.001*
GI Manual vs. GI App	0.89	0.73	Substantial agreement	*< 0.001*

These GDLAM FA validity studies were published in issue 2492 of the Brazilian Journal of Industrial Property (INPI) of October 9, 2018, under process number BR512018051849-4. The GDLAM FA App is also available for free download on the Google Play Store platform.

application was able to detect oscillations during static balance, and differentiate the risk of falls, exhibiting good correlation with the traditional test. Their system showed efficiency similar to that observed in this study with the GDLAM FA App. No difference was found between manual and digital evaluations with the GDLAM FA App. Since Pearson's correlation was strong in all the tests, the GDLAM FA App demonstrated validity.

Reproducibility studies have also been conducted (Esteves, 2018; Marchi et al., 2016; Melquiades, 2018; Nogueira et al., 2018). Melquiades (2018) evaluated the intra-examiner reliability of shoulder measurements using the universal, digital, and Ratefast goniometer App, finding that, despite the widespread use of the universal goniometer, some studies report conflicting results regarding its reliability. In the present study, the digital goniometer (ICC: 0.41-0.73) and the App (ICC: 0.28-0.66) showed higher reliability and better reproducibility in relation to the universal device (ICC: 0.15-0.59).

In a case report, Nogueira et al. (2018) assessed an App used to plan total knee arthroplasty. This planning is typically done by evaluating a panoramic radiograph of the lower limbs. However, the difficulty with this assessment is the poor alignment of the peripheral components between the center of the femoral head, knee, and ankle (variation higher than 3º). Surgical planning of the case was carried out using the App and, as a control and safety measure, was also done manually, confirming that the App was reproducible, efficient, and safe for surgical planning of the case in question.

Marchi et al. (2016) compared the reproducibility and equivalence of using the Cobbmeter App with the manual measurement method to analyze the sagittal alignment of the spine, evaluating 20 spinal radiographs through the App, finding it to be a valid and reliable instrument.

Esteves (2018) aimed to determine the safety, effectiveness, and reproducibility of screening neurological patients through the App, assessing the medical records data and outcomes of 232 cases and found it to be safe, effective, and reproducible, in addition to having a positive impact on patient outcomes and requiring less screening time. Thus, it appears that in addition to these Apps being reproducible and safe, they also reduce screening time and are less susceptible to errors, as demonstrated in this study.

The applicability of the GDLAM FA App is also confirmed by the level of agreement between the two methods (manual and App). It was considered adequate and exhibited strong and very strong significant correlations ($p < 0.001$) for all variables, resulting in "substantial agreement" for almost all the tests and "almost perfect agreement" for the SRWC.

Tibes et al. (2014) conducted an integrated review of the literature searching for mobile Apps in Brazil and found that most studies assessed App importance. These Apps facilitate and optimize procedures, and are sustained by academic knowledge, reliable databases and validated protocols. Likewise, the App studied here aims to increase usage of a valid, easy-to-use, and accessible technological resource in order to increase public health interventions.

There is a need for Apps in several areas, and with the increasing use of cell phones, they can be used as a source of information or work tool, highlighting the rapid expansion of mHealth Apps that have proven to be safe, exhibit significant potential to improve information access, decrease the time spent on certain tasks, and increase the reliability of recorded data (WHO, 2018).

As such, the authors intend to make this tool available free of charge to health and research professionals who work with the FA of older adults in social programs and fitness centers. The GDLAM FA App aims to optimize a valid fitness test battery protocol, increase the speed of execution and data archiving, and provide immediate classification results.

CONCLUSION

The study showed that the GDLAM App is as efficient as the traditional functional autonomy protocol for the elderly, demonstrating adequate reproducibility, shorter evaluation time, and faster results.

It can also be applied during the data collection of larger groups in university extension programs, providing immediate test results. Thus, the App can be used to evaluate FA, due to its speed in showing results in different extension events, research, and day-to-day professional practice.

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