Does the Use of a Serious Game and the Grip-Ball Decrease Discomfort in Older People When Assessing Maximal Grip-Strength?

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Abstract— **Grip strength testing is a common tool in healthcare evaluation due its predictive ability for a range of concerns including nutritional status, fall risk, and frailty. With respect to frailty, grip strength is one of the Fried criteria, which is the most widely used frailty assessment tool. One problem with maximal grip strength testing is that values might underestimate maximal force due to problems with motivation or discomfort associated with the maximal test. An innovative serious game using the Grip-ball dynamometer was designed to measure grip strength in comparison to the frailty threshold of Fried. Discomfort levels were assessed using a visual-analogue scale for the Serious Game, the Grip-ball in a standard test, and the Jamar dynamometer, which is the gold standard for grip-strength testing. Discomfort was significantly higher for the Jamar, which had a 95% confidence interval of 6.2-7.5, in comparison to 1.5-2.4 for the Grip-ball and 0.7-1.3 for the Serious Game. The Serious Game was able to identify individuals who were not able to produce sufficient grip force to pass the Fried threshold for frailty, while improving comfort levels for the users when compared to a Jamar dynamometer.**

Keywords— **Grip-ball, frailty, discomfort, evaluation, serious games·**

I. Introduction

It is widely accepted that it is better for older people to remain living in their own homes. Older people in most European countries prefer to remain independent as long as possible. Community dwelling has a number of benefits for older people, such as living in a familiar environment, maintaining social links, and continuing to perform typical activities of daily life. However, it is important to be able to functional decline that could lead to frailty in independent older people as early as possible to enable appropriate rehabilitation to be provided, and thus decrease the risk of a loss of independence.

Fried and colleagues [1] developed a test to identify physical frailty using five criteria: weight loss, exhaustion, decreased physical activity, slow walking speed, and low grip strength. Two of these criteria, walking speed and grip strength, can be calculated objectively, while if frailty is monitored over time, weight loss and physical activity assessment can also be measured objectively. The ARPEGE project developed technological devices to measure all four of these criteria [2]. In this paper, one of the devices in the ARPEGE frailty evaluation pack, the Grip-ball, was chosen to test this hypothesis. The Grip-ball was designed to measure grip strength, which is also a commonly used measure in healthcare evaluation protocols. Grip-strength has been used to successfully predict a range of different medical outcomes nutritional status [3].

Maximal grip strength testing can pose numerous problems due to motivation required to perform a maximal test. In many cases, the force measured might be less than maximal capacity. One way to increase motivation could be by using serious games, which are a new addition to gerontechnology applications. Serious games are often adopted in health projects for older people, and might increase motivation in the user, making it more likely that the maximal value recorded would be close to the true maximal capacity of the person tested.

Another issue in respect to grip strength is discomfort. The gold standard in grip-strength assessment is the Jamar (Sammons & Preston, Bolingbrook, IL, USA), which is a hydraulic dynamometer [4]. The Jamar can cause discomfort among older subjects and people with arthritis [5]. A more comfortable dynamometer is the Vigorimeter® (Martin Medizintechnik, Tuttlingen, Germany), which consists of a supple bulb attached to a manometer. The Grip-ball, is similar, using a supple ball that can be squeezed to produce a grip strength recording that has been validated in previous work to measure grip-strength [6].

The aim of this paper is to see whether the use of the grip-ball and a serious game can be used to measure maximal grip strength in older people, while keeping discomfort levels to a minimum.

II. METHODS

A. The Grip-ball

Existing grip strength dynamometers such as the Jamar® and the Vigorimeter® have some limitations, such as the absence of remote communication or limited user-friendliness. The Grip-ball was developed as a user-friendlier device that also has the advantage of being able to

The original version of this chapter was inadvertently published with an incorrect chapter pagination 903–906 and DOI 10.1007/978-3-319-32703-7_176. The page range and the DOI has been re-assigned. The correct page range is 909–912 and the DOI is 10.1007/978-3-319-32703-7_177. The erratum to this chapter is available at DOI: 10.1007/978-3-319-32703-7_260

E. Kyriacou et al. (eds.), *XIV Mediterranean Conference on Medical and Biological Engineering and Computing 2016*,
IFMBE Proceedings 57,
DOI: 10.1007/978-3-319-32703-7_177

be inflated to different initial pressures, leading to stiffness that varies as a function of the initial pressure (Fig. 1a). Testing in the present study was performed using a hybrid device, the Vigoriball, which consisted of a modified Vigorimeter, which included the Grip-ball electronics (Fig. 1b) [7]. The Vigoriball has a pneumatic connection that enables the bulb to be inflated at different pressures. For the present study only atmospheric pressure was used. A validity study for the Vigoriball can be found in [6].

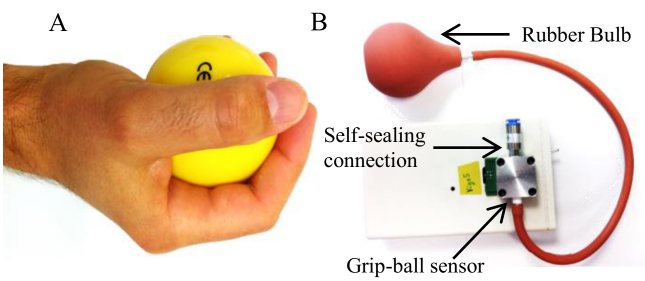

Fig. 1 (A) Grip-ball on the left and (B) the hybrid version on the right

B. Serious Games

In serious games the entertainment provided by the application is not the primary objective. They can be designed to use an enjoyable interface to hide their true purpose, such as assessing health or physical function. They can also include games that were initially designed only for entertainment, but for which a secondary purpose can be applied, such as rehabilitation. Serious games can be of any genre, can use any game technology, and can be developed for any platform. For the purposes of this work, serious games are defined as games that allow the player to achieve a specific purpose using the entertainment and engagement component provided by the experience of the game. Serious games can also form an innovative approach to the education of medical professionals, and surgical specialties are eager to apply them for a range of training purposes.

C. Force-tracking task

The Grip-ball measures the pressure exerted by the hand in mbar, however Fried's cutoff value for frailty was calculated in kg [1]. Accordingly, a model was used to convert force into pressure [8].

$$P_A = \frac{F}{4.855*10^{-3} P_i - 2.020*10^{-2}} \quad (1)$$

Where P_i is the atmospheric pressure, with force (F) expressed in kg and pressure (P_A) expressed in mbar. The Fried cut-off criteria for grip strength are shown in Table 1, with values for both kg and mbar shown, based on the formula (1).

An example of a possible profile for the force tracking system is shown in Fig. 2. The x-axis represents the time from takeoff to landing, while the y-axis represents the pressure applied by users when squeezing the rubber ball.

Table 1 Thresholds of grip-strength for frailty [1]

Subject group	Threshold (kg)	ΔP mbar
Men		
BMI ≤ 24	29	623
BMI 24.1 – 26.0	30	645
BMI 26.1 – 28.0	30	645
BMI > 28.0	32	688
Women		
BMI ≤ 23	17	365
BMI 23.1 – 26.0	17.3	372
BMI 26.1 – 29.0	18	387
BMI > 29.0	21	451

In this example, the third point was set to the Fried criteria for the user, with this force level automatically calculated based on the BMI and the gender of the user. In the protocol, the software randomly choose one of three points after the first point (one of points 2-4), and set this point to Fried's threshold for the user.

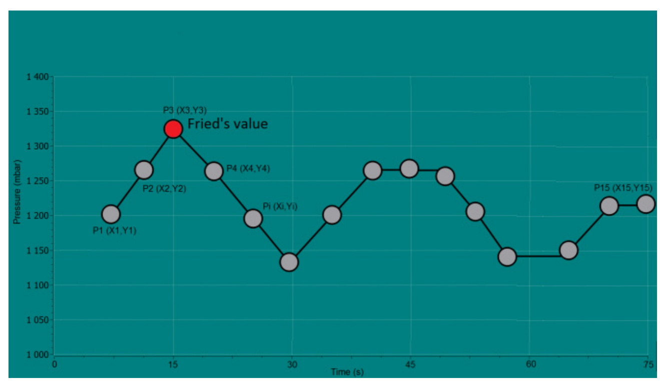

Fig. 2 Typical profile of the force-tracking task

D. Serious game interface

In the game interface, each point ($P_i(x_i, y_i)$) of the force tracking template, as shown in Fig. 2, was represented by an ellipse centered on P_i. An aircraft represented the user's force, while a hoop suspended beneath a hot-air balloon represented each ellipse (Fig. 3.). The aim of the game, which was explained to the user, was to fly the aircraft through the hoops as accurately as possible. The height of the aircraft corresponds to the grip force exerted by the user. The harder the user squeezes the Grip-ball, the higher the aircraft flies. The speed at which the aircraft flies can be chosen by the user themselves, with three choices of speed available.

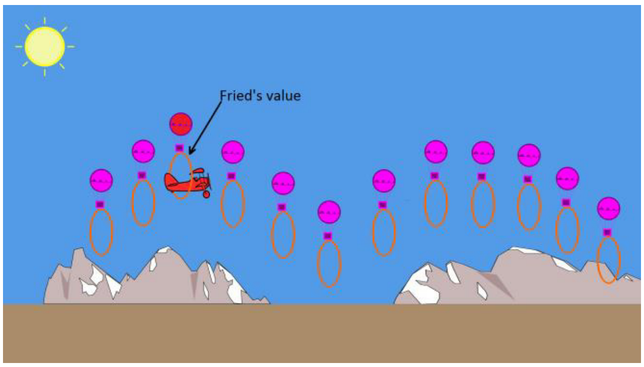

Fig. 3 Serious game user interface

This serious game could be deployed is a variety of settings, including a users own home, or a hospital or clinic. The minimal computational requirements to run the game are basic, meaning that any tablet, smartphone, or desktop computer could be used. This low-tech specification had to be balanced with the need to provide a professional look and feel for the game, so that players would feel attracted to the game. The game was developed in the object oriented Qt-creator, using the C++ compiler from the GNU Compiler Collection.

E. Protocol

Subjects were given a detailed description of the objectives and requirements of the study prior to the experiment, while an informed consent was read and signed by each subject before testing. Self-reported age, height, and weight were recorded for each subject on a score sheet, as well as their dominant hand. Subjects were seated on a chair facing the evaluator with their dominant forearm resting on the arm of the chair and their elbow flexed at 90 deg. Each of the three systems was tested in a randomized order, with subjects evaluating the discomfort associated with each device immediately after using it. Handle position two was used for all tests with the Jamar. The force exerted was recorded on the score sheet. The 6-cm diameter Grip-ball was used, with this diameter corresponding to position two of the Jamar. In the two maximal tests, subjects were instructed to exert their maximum force for three seconds. For the serious game, subjects were instructed to fly the aircraft through the hoops as accurately as possible. For both Grip-ball tests data was recorded on a tablet PC, with data collected in mbar. Discomfort was measured using a visual analogue scale (VAS) from 0-10, with 0 corresponding to an absence of discomfort and 10 corresponding to the greatest discomfort imaginable.

F. Statistical analysis

Statistical analyses were performed using IBM SPSS version 21 (IBM Corporation, Armonk, NY, USA). Data were tested for normality using the Kolmogorov-Smirnov test. In the absence of normality, a Friedman test was used to compare discomfort between devices. The bias-corrected and accelerated (BCa) bootstrap method was used to produce unbiased estimates of 95% confidence intervals for the non-normal data [9].

III. RESULTS

Thirty-three subjects were tested, with no subjects having any prior history of trauma in either their forearms or their hands, and no prior or existing neurological or musculoskeletal disorders. Characteristics of the subjects are presented in Table 2. Four subjects were classified as frail according to the Fired criteria, with agreement between the three devices.

Table 2 Subject characteristics

Subjects	Age (y)	Weight (kg)	Height (m)
Females (n=21)	73.9 ± 9.0	61.2 ± 11.0	1.61 ± 0.10
Males (n=12)	71.1 ± 8.2	75.0 ± 7.2	1.67 ± 0.09

Scores for the VAS were non-normal for both the Grip-ball and the game (Table 3). There was a significant difference in the mean rank of the three devices with respect to discomfort level (Chi-square statistic 58.07, p=0.000). The boot-strapped estimates of the 95% confidence limits for discomfort were 6.2-7.5 for the Jamar, 1.5-2.4 for the Grip-ball, and 0.7-1.3 for the Serious Game.

Table 3 Discomfort levels for the three devices

Device	Mean ± SD	Mean Rank §	KS Test	Sig (2-tailed)
Jamar	6.8 ± 1.9	3.0	0.12	0.200
Grip-ball	1.9 ± 1.5	1.8	0.21	0.001
Serious game	1.0 ± 0.8	1.2	0.29	0.000

§Mean rank calculated using the Friedman test

IV. DISCUSSION AND CONCLUSIONS

The discomfort levels of the three devices differed markedly, with the Jamar being by far the most uncomfortable to use. Even though the maximal test with the Grip-ball and the serious game used the same device, the maximal test was perceived as being less comfortable than the game. This was probably due to the different force levels used in the two tests. On average, the maximal force measured exceeded the threshold for frailty by 33%, meaning that the serious game required an average maximal force of 67% of subjects' maximal values. In the standard frailty assessment of Fried, maximal grip strength is measured using a dynamometer, which can be unpleasant and sometimes painful for an older person[5]. In contrast, for the serious game, users were only required to exert the threshold force corresponding to their gender and BMI, and this only once during the game. When users were unable to exert sufficient force to pass the threshold, the game stored this as a failed attempt. This means that the serious game was able to provide a more comfortable alternative to a maximum grip strength test.

This type of serious game could also be suited to other populations, such as people with hand injuries. The supple nature of the Grip-ball combined with the possibility of varying the initial pressure, means that users could perform regular training with the Grip-ball by playing the serious game. This might be more enjoyable than standard rehabilitation exercises in which repetitive movements could be boring for the users, possibly making them more decrease the number of exercises performed. Motivating patients to engage actively in rehabilitation exercises is a major problem faced by therapists. If rehabilitation could be changed into something more interactive and entertaining, subjects might be more motivated on playing games, in comparison to standard exercises.

Future work could include the development of a serious game to progressively increase force requirements, eventually leading to a maximal force contraction. In a previous study, verbal encouragement and visual feedback were shown to increase maximum force by 5% and 6%, respectively [10]. The addition of feedback could also be assessed and compared to a standard maximal test. Other improvements could be considered with respect to the shape of the template used for the game, such as following a triangular or sinusoidal pattern. Different degrees of difficulty could also be added, while the system could also be adapted for online use via a web browser with a Java applet.

In conclusion, the serious game developed was able to identify individuals who were not able to produce sufficient grip force to pass the Fried threshold for frailty, while improving comfort levels for the users when compared to a Jamar dynamometer.

ACKNOWLEDGMENT

This work was supported by the Champagne-Ardenne Regional Council (CRCA) and the European Regional Development Fund under the Collaborative Research Program (ARPEGE Project, grant reference numbers CRCA E201012437 and FEDERE201013375). The authors would like to thank Micheal Mordefroy for his assistance with the development of the serious game software.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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