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Reliability and validity of the Grip-Ball dynamometer for grip-strength measurement

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Abstract—**Grip-strength measurement is a key element in the evaluation of numerous conditions including frailty. An innovative grip-strength evaluation tool, the Grip-Ball has been developed for remote assessment of grip-strength. The Grip-Ball is an airtight ball that can be inflated to different pressures, thus varying the stiffness of the ball and the grip-strength dynamics. Three different initial pressures of 100, 125, and 150 kPa were evaluated in respect to reliability and validity, when compared to the Jamar. Reliability was very high, with ICC values of 0.95, 0.98, and 0.99 for 100, 125, and 150 kPa, respectively. The new device was highly correlated with the force measured using the Jamar for all initial pressures (r= 0.88, 0.93, and 0.93 for 100, 125, and 150 kPa, respectively). The possibility of varying the initial pressure would enable the Grip-Ball to be used for standard grip-strength testing and rehabilitation, while still maintaining high reliability and validity.**

I. Introduction

The elderly population is increasing worldwide, with figures for France in 2005 estimated at 4.9 million for the number of "very old" elderly, aged over 75 years, equivalent to 8.2% of the French population. The French National Institute for Statistics and Economic studies (INSEE) has estimated that by 2050, this number will more than double to nearly 11 million, with the population aged over 85 years old quadrupling [1]. One of the problems related to the ageing populations is an increase in the incidence of health-related problems, such as frailty, which results from a decrease in the functional reserve of multiple physiological systems [2, 3]. One of the consequences of frailty is an increased risk of adverse events, such as falls [4-6]. The incidence of frailty in the elderly population has been estimated at 7-20% in those aged over 65 years, with such wide differences in estimates due primarily to differences in the diagnostic tools used [7, 8]. The incidence of frailty increases markedly as age increases, with an incidence of 20-26% reported in elderly over 80 years old, rising to over 32% for those aged over 90 years old [7, 8].

A key component of managing frailty is an early detection, thus enabling health professionals to intervene and delay the onset of frailty, or even start to reverse the process. In order to detect frailty it is essential to use appropriate screening tools, a number of which have been developed, such as the Study of Osteoporotic Fractures frailty measure, [9], the Edmonton Frail Scale [10], and the Fried frailty scale [7]. The Fried scale evaluates five criteria of physical frailty: unintentional weight loss, slow walking speed, general exhaustion, low physical activity, and grip strength. Low grip strength has been identified as one of the primary characteristics of frailty in other studies, such as those of Syddall et al., Kritz-Silverstein and Barrett-Connor, and Wu et al. [11-13].

The relationship between grip-strength and frailty, or indeed between grip strength and other clinical tests such as the Timed-up-and-go [14], Activities of Daily Living [15] or even nutritional status [16], makes grip strength measurement one of the key elements of any geriatric evaluation. Grip-strength is typically evaluated using one of a number of commercially-available dynamometers such as the Jamar (Sammons & Preston, Bolingbrook, IL, USA), the Lode (Lode dynamometer; Lode BV, Groningen, The Netherlands), the MIE digital pinch / grip (MIE Medical Research Ltd, Leeds, United Kingdom), and the Martin Vigorimeter (Martin Medizintechnik, Tuttlingen, Germany). The "gold-standard" grip-strength dynamometer, according to the American Society of Hand Therapists (ASHT) is the Jamar [17]. The Jamar is an isometric dynamometer, the latest version of which has a digital readout in pounds and kilograms, with a maximum force of 200 lb. (90 kg). The position of the Jamar handle is adjustable, with five positions, varying 34.9 to 85.7 mm in width, thus ensuring grip strength can be measured for varying hand sizes.

Although the Jamar is in widespread clinical use, the isometric nature of the device can lead to discomfort among certain users [18]. People who have undergone recent Carpal Tunnel Release (CTR) surgery are one such group [19]. An alternative device to the Jamar is the Martin Vigorimeter, which measures pressure rather than force. This device consists of a bulb that is attached via a tube to a manometer, with values displayed in kilopascals and bar. The maximal value of the Vigorimeter is 160 kPa (1.6 bar). The Vigorimeter has three different sizes of bulb, which can be used according to the circumference of the hand of the user. The Vigorimeter has been extensively validated against the Jamar, with Desrosiers et al. reporting correlations of 0.89 and 0.90 for the right and left hands, respectively [20].

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Despite the advantages of the Vigorimeter in terms of comfort, and the high correlation with the Jamar, the gold standard remains the Jamar. One reason for this is that the Vigorimeter does not provide grip force measurements, meaning that it cannot be used in frailty assessment. In addition, the Vigorimeter is not suited for self-assessment of frailty. To this end, a new grip strength dynamometer was developed. The Grip-Ball was developed in order to provide a measurement device that could be used to evaluate grip strength, as well as for use in home-based rehabilitation of the hand and forearm (Fig. 1). The Grip-Ball, which is described in more detail in [21], consists of a supple ball in which pressure and temperature sensors, as well as a data acquisition and communication system have been placed. Communication is performed via Bluetooth, thus ensuring interoperability with other local devices that could store or transfer the data (computer, tablet, mobile phone, etc.). The Grip-Ball transmits the pressure measured by the sensor inside the ball in real time.

Figure 1. The Grip-Ball.

In addition to the digital acquisition system in the Grip-Ball, the other main difference between the Grip-ball and the Vigorimeter is that the Grip-Ball is airtight and is equipped with a valve. In contrast to the Martin Vigorimeter, for which the bulb is always at atmospheric pressure, the Grip-Ball can be used to evaluate grip strength with different initial pressures. The internal pressure of the Grip-Ball can be modified using a standard pump. Any differences in initial pressure would lead to changes in the stiffness of the ball, modifying the corresponding dynamics of grip-strength measurement or rehabilitation exercises.

The Grip-Ball is currently undergoing a final development related to the miniaturization of the electronic components and an improved method of creating the envelope around them. During this development stage, one of the key concepts of the Grip-Ball was evaluated using a hybrid device. The possibility of varying the initial pressure of the Grip-Ball could result in differences in both reliability and validity of the device, due to changes in the corresponding dynamics of grip-strength measurement. The aim of the present study was to evaluate the reliability and validity of the Grip-Ball for a range of different internal pressures, and also to compare it to the Jamar.

II. Methods

A. Subjects

Sixteen subjects (10 men and 6 women) with no history of trauma in their forearms or hands, or with any prior or existing neurological or musculoskeletal disorders were tested. Descriptive data of subjects are presented in Table 1. 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.

TABLE I. Subject Characteristics

	Men (n=10)	Women (n=6)
age (y)	33.4 ± 10.2	25.8± 1.0
height (cm)	177.3 ± 7.5	162.3± 4.3
weight (kg)	82.0 ± 12.5	62.7 ± 10.7

Data are means ± SD

B. Grip-strength measurement

All testing in the present study was performed with a hybrid device consisting of a modified Vigorimeter attached to the Grip-ball electronics (Fig. 2). The system was closed, and was equipped with an interface enabling the bulb to be inflated to different pressures. This system has previously been compared to a standard Vigorimeter, and also to a Grip-Ball, with nearly identical values observed (r=0.997) between the two systems.

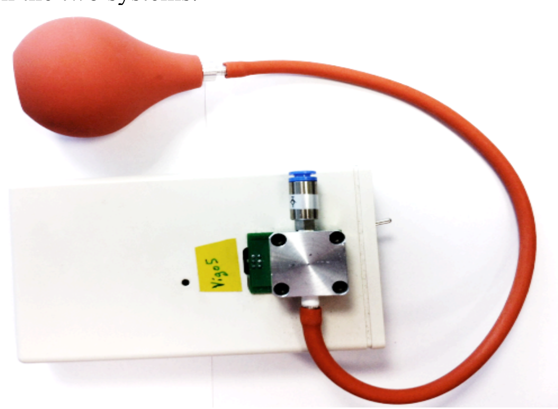

Figure 2. The modified Vigorimeter / Grip-Ball used for testing.

Testing was performed according to the recommendations of the ASHT, in two separate sessions. Subjects were placed in a chair facing the evaluator, with their feet flat on the floor, their back straight and placed against the back of the chair. Subject's arms were pressed against their body, with the shoulder abducted and the elbow flexed to 90°. All testing was carried out at room temperature. In the first session, grip strength was measured with the Jamar dynamometer placed at the second handle position. All tests were executed with the dominant hand and the maximal grip strength was measured three times with a two-minute rest between trials. The mean of the three trials was taken as the maximal grip force for the Jamar.

In the second session, grip strength was measured using the modified Vigorimeter described above. Subjects were tested using the medium-sized bulb, with all subjects asked to squeeze the bulb as hard as possible. Three different initial pressures were used for the trial (100, 125, and 150 kPa), with subjects required to perform three maximal tests for each pressure. The mean of the three trials for a given pressure was used for subsequent comparison with the Jamar in the validity analysis, while all three values were used in the reliability analysis.

C. *Data analysis*

The reliability of the grip strength measures was assessed using the Intra-class Correlation Coefficient (ICC 2,1) calculated for the three tests for each of the three initial pressures. The validity of the grip strength measurement performed with the modified Vigorimeter was evaluated by means of a comparison with the grip-force values obtained from the Jamar. The mean of the three trials for a given pressure was taken as maximal grip force. Linear regression was performed with the Jamar reading taken as the dependent variable and the Vigorimeter reading taken as the independent variable. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA). P values less than 0.05 were considered to be statistically significant.

III. Results

A. *Reliability*

The ICC values for the three initial pressures are presented in Table 2. All values exceeded 0.95, with no significant differences observed between initial pressures.

TABLE II. ICC VALUES FOR INITIAL PRESSURES

Pressure (kPa)	ICC	95% Confidence Interval
100	0.953	0.889 - 0.983
125	0.981	0.954 - 0.993
150	0.991	0.979 - 0.997

ICC are calculated using a two-way mixed effects model

B. *Validity*

Linear regression analyses were used to evaluate the relationship between the maximal forces recorded using the Jamar and the pressure recorded using the modified Vigorimeter. The regression analysis for an initial pressure of 100 kPa is presented in Fig. 3. The correlation between the Jamar and the Grip-Ball for an initial pressure of 100 kPa (atmospheric pressure) was r=0.88.

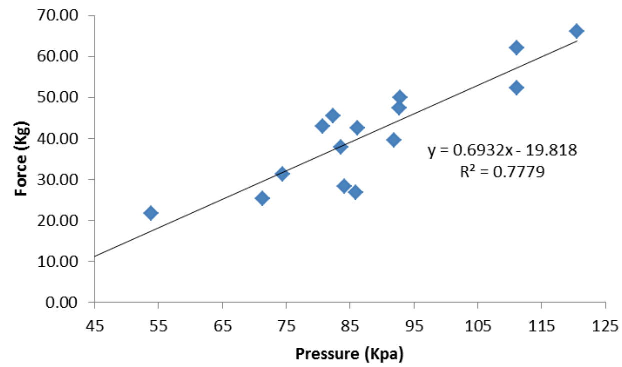

Figure 3. Linear regression analysis for an initial pressure of 100 kPa. Pressure data are differences between the initial pressure and maximum pressure.

Linear regression analysis for an initial pressure of 125 kPa is shown in Fig. 4. The correlation between the Jamar and the Grip-Ball for an initial pressure of 125 kPa was r=0.93.

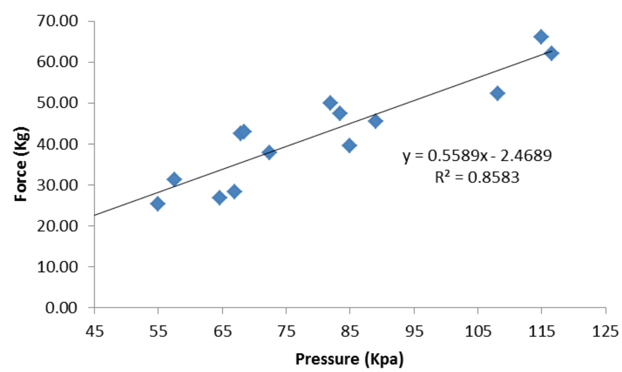

Figure 4. Linear regression analysis for an initial pressure of 125 kPa. Pressure data are differences between the initial pressure and maximum pressure.

Linear regression for an initial pressure of 150 kPa is shown in Fig. 5. The correlation between the Jamar and the Grip-Ball for this initial pressure was r=0.93.

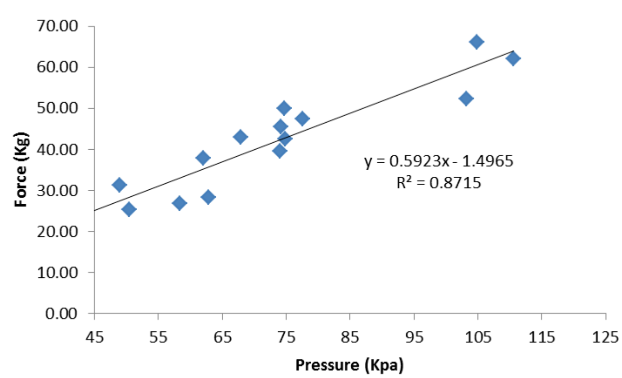

Figure 5. Linear regression analysis for an initial pressure of 150 kPa. Pressure data are differences between the initial pressure and maximum pressure.

IV. Discussion

The results of the reliability study are encouraging. The ICC values were extremely high for all three pressures, despite a relatively low number of subjects. Although no significant differences were found in respect to reliability between the three initial pressures (p=0.07 between the ICC for 100kPa and 150kPa), the highest ICC value was observed for the highest initial pressure of 150 kPa. In respect to the comparison between the hybrid device and the Jamar, similar correlations were found to those previously reported between the Jamar and the Vigorimeter. The R-squared values for the hybrid device ranged from 0.778 for an initial pressure of 100 kPa, through to 0.872 for 150 kPa. These values correspond to correlations of 0.88 and 0.93 for the 100 kPa and 150 kPa initial pressures, respectively. The observed correlations between the Jamar and the Vigorimeter were as high as 0.90 in the study of Desrosiers and colleagues [19].

The increase in both reliability and validity as initial pressure increased could be related to the stiffness of the bulb. When initial pressure increases, the bulb becomes harder and the device is well-suited for quasi-static strength tests. In contrast, at low initial pressures, the device could be used for dynamic strength testing.

In conclusion, the Grip-Ball is a reliable, valid device for grip-strength assessment. Future work with the final device will develop normative data for different populations, as well as develop a predictive model for grip force based on recorded pressure.

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