Measurement of the Reaction Time in the 30-S Chair Stand Test using the Accelerometer Sensor Available in off-the-Shelf Mobile Devices

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Abstract: The 30-s Chair Stand Test (CST) is commonly used with elderly people for assessing the lower limbs strength, which can provide sufficient information regarding the general mobility and fall risk. The mobile devices are widely used for the acquisition of the different physical and physiological data from the sensors available, including the accelerometer. In this way, the aim of the present study consisted on the development of an automatic method for the measurement of the reaction time (RT) based on the 30-s CST using a mobile device. Besides that, the data acquisition through an accelerometer allows the assessment of different variables, such as the maximum values of the acceleration, the instant velocity, the maximum force and the peak power, that may contribute to a better understanding of the physical demands during the 30-s CST performance. The results presented in this study demonstrated that the calculation of the RT and the different variables during the 30-s CST performance is possible, opening new possibilities for the development of scientific projects, namely those that encompasses the motor and cognitive training of elderly people.

1 INTRODUCTION

The ageing process involves several transformations within the human body, including a decline of the skeletal muscle tissue, described as sarcopenia (Walston, 2012), and a decrease in the cognitive function. Thus, contributing to a slower processing speed and motor performance (Bautmans et al., 2011), and an increased reaction time (RT), both in elderly people with and without cognitive impairments (Arnold et al., 2015).

According to Wong, Haith, and Krakauer (2015) the RT means the time from the stimulus onset to the beginning of the motor action. It includes the time to capture the stimulus, process the information and initiate a motor response (Bautmans et al., 2011). It is current practice to evaluate the RT through a visual and/or an acoustic stimulus either from a computer software (Jain, Bansal, Kumar, & Singh, 2015) or mobile devices (Mulligan, Arsintescu, & Flynn-Evans, 2016). The latter are equipped with several sensors, *e.g.*, Global Positioning System (GPS) receiver, gyroscope, accelerometer, magnetometer, and microphone, which enable the acquisition of different types of data, including those related to physical activities.

Following previous work regarding the development of methods for the acquisition of physical and physiological parameters using off-the-shelf mobile devices, a method for the measurement of the jump flight time was previously developed by Pires, Garcia, and Canavarro Teixeira (2015), as well as a method for the recognition of Activities of

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Daily Living (ADL) and their environments (I. Pires, N. Garcia, N. Pombo, & F. Flórez-Revuelta, 2016; Pires, Garcia, & Flórez-Revuelta, 2015; I. M. Pires, N. M. Garcia, N. Pombo, & F. Flórez-Revuelta, 2016).

The development of systems aimed to monitoring the lifestyle is an emerging topic, included in the Ambient Assisted Living (AAL) and Enhanced Living Environments (ELE) systems (Botia, Villa, & Palma, 2012; Dobre, Mavromoustakis, Garcia, Goleva, & Mastorakis, 2016; Garcia, Rodrigues, Elias, & Dias, 2014).

The evaluation of the physical fitness in elderly people is usually done through the Senior Fitness Test (SFT), which is a battery of 7 tests developed by Rikli and Jones (2001). One of the tests, the 30-s Chair Stand Test (CST) is used to assess the lower body strength, enabling also to detect changes in mobility and fall risk (Pereira et al., 2012). In the literature, there are several studies that used the accelerometer in the 30-s CST to assess the physical condition of elderly people (Millor et al., 2017; Regterschot et al., 2014). . The accelerometer sensor allows the measurement of different real-life situations and includes the concept of the development of a personal digital life coach, which can be adapted to monitoring the physical activity of elderly people (Garcia, 2016). This sensor have been successfully implemented in different tests and age groups, like the Time-Up and Go (Reis, Felizardo, Pombo, and Garcia, 2016) and the Heel-Rise Test (Pires, Andrade, Garcia, Crisóstomo, and Florez-Revuelta, 2015).

Nevertheless, to the best of our knowledge, the measurement of the RT in the 30-s CST using the accelerometer sensor available in off-the-shelf mobile devices is not yet implemented. Thus, the aim of our study is to develop an automatic method to measure the RT based on an acoustic stimulus in elderly subjects, performing the 30-s CST. Besides that, it is our intention to validate this protocol for a future use on studies related to the effects of high-speed resistance training on the velocity of the body movement and the RT in elderly people.

This paragraph ends the introductory section. Section 2 presents the methodology of this study. The results are shown in the section 3 and discussed in section 4. Finally, the conclusions are presented in section 5.

2 METHODS

2.1 Study Design

For the measurement of the RT in the 30-s CST, we developed an application for mobile phones that acquires the accelerometer data during the movement. A subject (68kg; 1.70m) volunteered to be assessed on the 30-s CST using the mobile device in the front pocket of the jeans for further calculation of the RT. The subject repeated the test 3 times.

It is important to note that in future experimental studies, this test protocol will be applied with elderly people.

The present study is structured in three stages:

1. The development of a mobile application for capturing the sensors' signal, with the transmission of an acoustic signal (beep) to initiate the 30-s CST.
2. The implementation of the 30-s CST to evaluate the RT and the respective ability based on an acoustic signal.
3. The analysis of different variables (i.e., velocity, force, power) based on the accelerometer data.

2.2 Description of the Modified 30-S CST

This test was originally designed by Jones, Rikli, and Beam (1999). The test procedure consists in the following:

In a sit position on a chair (next to a wall) with the back straight and the arms crossed over the chest, after a verbal permission (“1, 2, 3, go”), the subjects had to stand up and sit down from a chair as many times as possible within 30 s. In the present study, the modification consisted in the introduction of an acoustic signal (a beep), instead of a verbal signal to initiate the test.

2.3 Data Acquisition

In the present study the off-the-shelf mobile device used was a Huawei Y530-U00. This device has an accelerometer sensor incorporated that acquires data at 60 Hz frequency (Huawey, 2013). The data acquisition was performed with a mobile application, whose function is to save the outputs of the accelerometer sensor into a text file for further processing. The data were acquired with the off-the-shelf mobile device placed in the front pocket of the pants for the correct acquisition of the accelerometer outputs.

The data acquisition was started by pressing a start button in the application with the subject sit and not moving. After 10 s of the start, an acoustic signal indicates that the subject should start the test and data continues to be acquired for more 30 s.

2.4 Data Analysis

2.4.1 Data Processing

After the data acquisition process, the text files stored in the mobile devices were processed in a computer.

The accelerometer measures the three components of the acceleration, but since it was not possible to ensure that the device position remained unchanged through the test duration, it was decided to compute the total acceleration from the three components.

In order to have the gravity acceleration value when the subject is not moving, the following correction was introduced (Bennett, Jafari, & Gans, 2014):

$$a_{corr} = a_{meas} - a_{ref} + 9.81 \quad (1)$$

where a_{corr} is the corrected acceleration, a_{meas} is the acceleration measured, and a_{ref} is a reference value equal to the average value of the acceleration measured in the 5 s previous to the acoustic signal (i.e., starting of the test). This reference value was needed since the signal presents small oscillations even when there is no movement.

2.4.2 Calculation of the Sensor-based 30-S CST Variables

After the data processing, and based on the magnitude of the acceleration signal, the following variables, presented in the Figure 1, were assessed:

1. *Reaction Time* (RT)*:* the time between the acoustic signal and the initiation of the movement;
2. *Movement Time* (MT)*:* the time from the beginning of the motor action to the end of the movement *(i.e.,* return to the sit position);
3. *Total Time* (TT)*:* the time from the acoustic signal to the return to the sit position.

In the present study the focus is on the RT evaluation and therefore the analysis will be mostly based only on the first stand up and sit down movement of the several repetitive movements that occur during the 30-s CST.

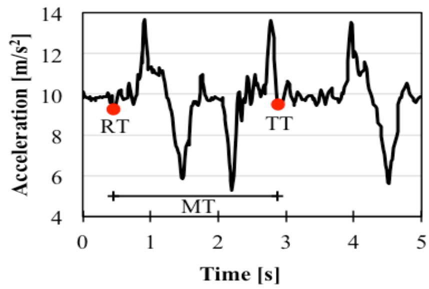

Figure 1: Signal Plot of the acceleration during the stand-up phase from a sit position on the chair.

It is important to note that in future studies, for example related to the influence of high-speed resistance training programs on the RT in elderly people, other variables can be assessed through the accelerometer data, such as:

1. Maximum absolute acceleration;
2. Maximum absolute velocity
3. Mean velocity;
4. Maximum absolute Force;
5. Maximum absolute Peak power.

As a demonstration, we calculated those variables, which can be seen in the results section.

The velocity was obtained by numerical integration of the acceleration, for example using the trapezoidal rule (Davis and Rabinowitz, 2007).

$$V_2 = \frac{a_2 + a_1}{2} \times (t_2 - t_1) + V_1 \quad (2)$$

where V is the velocity, a is the acceleration, t is the time, and subscripts 1 and 2 correspond to previous and actual time, respectively. The force was calculated with Newton's second law $F = m \cdot a_{rel}$ (Keller, 1987), where the relative acceleration is $a_{rel} = a_{corr} - 9.81$ (Tao, 1967). The power is simply $P = F \times V$ (Tihanyi, Apor, and Fekete, 1982).

3 RESULTS

3.1 Prototype

The mobile application developed for this study has an easily usage adapted for elderly people, designed for different ages, as presented in the Figure 2. The usage of the mobile application consists only in pressuring a large button enabling and stopping the data acquisition. At this stage of the project, the mobile application only performs the data acquisition of the accelerometer data, but, in the future, the calculation of the RT and the other variables should be calculated at real time within the mobile application. The files created by the mobile application are stored in the mobile device for further processing and validation.

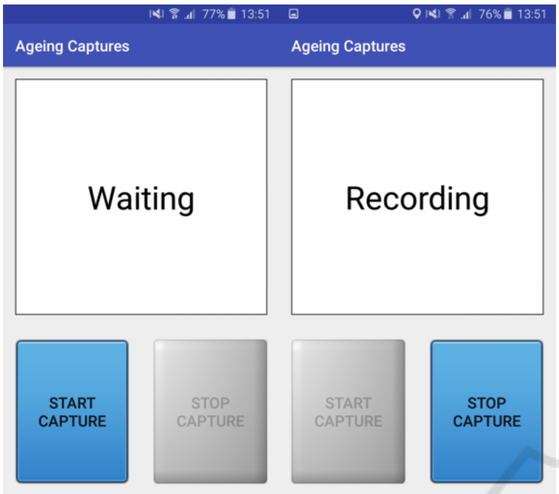

Figure 2: Prototype of the mobile application developed.

3.2 Validation

The relative acceleration is presented in Figure 3. The instant velocity is represented in the Figure 4. The maximum force produced during the stand up phase was also calculated, taking into account that the weight of the subject was 68 kg (Figure 5). Finally, the maximum peak power value for the first instant was also determined (Figure 6).

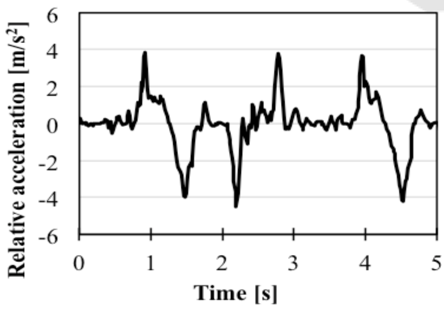

Figure 3: Time-evolution of the relative acceleration.

The calculation of the proposed variables in this study is proved possible with the data represented in the Figures 1, 3, 4, 5 and 6. As example, the values of the calculated variables were:

1. RT: 0.460 s;
2. TT: 2.881 s;
3. MT: 2.421 s;
4. Maximum acceleration: 13.66 m/s^2;
5. Maximum velocity: 0.702 m/s;
6. Maximum Force: 929 N;
7. Maximum Peak Power: 495 W.

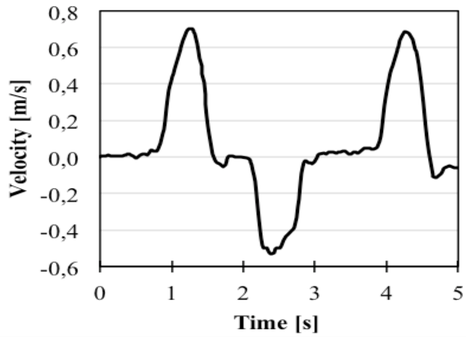

Figure 4: Time-evolution of the velocity.

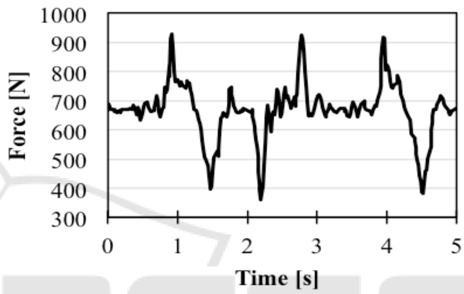

Figure 5: Time-evolution of the force.

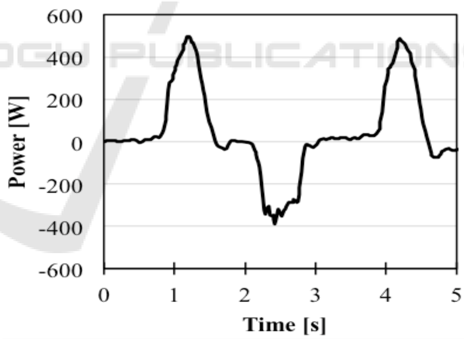

Figure 6: Time-evolution of the power.

4 DISCUSSION

Following the results highlighted in the previous section, the RT of the subject used as an example was 0.460 s. This value is higher than the RT values referred in the literature (around 0.2 s, Wong et al. (2015)). Two possible explanations can be stated: i) in the present study an acoustic signal was used instead of a visual stimulus; and ii) the 30-s CST involves to stand up from a chair, which requires the overcoming of a much higher inertia than, for example, the one of a rapidly touch of a button.

The maximum velocity (0.702 m/s) seems a reasonable value by comparison with the value of 0.52 ± 0.13 m/s obtained by Regterschot et al. (2014) with elderly people in the sit-to-stand test. Moreover, the time-evolution of the velocity (Figure 4) clearly shows a pattern that should be expected for a stand-up and sit-down movement. Namely, it is seen a first peak with positive velocity corresponding to the stand-up phase, followed by a small plateau with velocity zero, corresponding to the moment when the subject is standing vertically, afterwards the velocity is negative, corresponding to the sit-down phase. The process is continued with the repetition of the stand-up and sit-down movement.

The maximum peak power (495 W) is also in the range of values reported Regterschot et al. (2014) (423.4 ± 141.1 W) with elderly people.

The measurement of the RT and other variables using the data acquired with the mobile device was successful, although several constraints should be mentioned, such as the reduced memory, low power processing and low battery capabilities, as well as the positioning of the mobile device during the data acquisition process. In addition to the above-mentioned limitations, the RT may also vary with several conditions including healthy state, age and physical condition (Bautmans et al., 2011).

Due to the lack of studies in the literature that use the accelerometer sensors for the measurement of the RT, the comparison of our method with others is not possible. However, based on the present results of this study and the study of Regterschot et al. (2014), the use of the accelerometer data for the measurement of several variables during the performance on the 30-s CST seems reliable.

5 CONCLUSIONS

The present study highlights a novel approach on the measurement of the RT in the 30-s CST. The results obtained through an easy use mobile application can be extrapolated to different research areas, including the computer science and sports science, and studied according to the main interests of the researchers.

The results of this study must be interpreted as preliminary, since further validation is still needed (like using different mobile devices and comparing the values with other measurement methodologies). Nevertheless, the results presented here are quite promising and constitute an advance on the measurement of neuromuscular variables.

In conclusion, this study is a start of a project related to the cognitive function of elderly people, consisting the evaluation of the 30-s CST with a simple mobile device. However, for future work, our method should be validated with more elderly people.

It is also our intention to integrate this test protocol on a scientific study, whose principal aim will consist in the analysis of the influence of a high-speed resistance training program on the RT and the velocity of the movement of institutionalized elderly people with and without cognitive disorders.

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