Chair-Stand Device for the Assessment of Elderly Patients in Risk of Frailty

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Abstract— **Frailty is an intermediate state in the ageing trajectory, preceding the onset of disability. It can be assessed via clinical, cognitive, nutritional, and physical performance components, whereas one component of physical assessment is measurement of lower limb strength. We propose a device for measuring lower limb strength based on the 30s sit-to-stand test (30s-STS) in an autonomous environment. The device is based on an ultrasound sensor that is mounted on the backrest of a chair and measures the distance to the back of the patient. A signal processing algorithm was developed with a dataset of healthy subjects and evaluated prospectively with geriatric patients. Results of evaluation show that measurement for geriatric patients is poorer than expected. Thus, we plan to re-train the algorithm with additional geriatric patients, and to study further the complexities of the 30s-STS analysing aspects such as the inter-observer-variability of reference annotations. The new algorithm will be evaluated as part of a clinical trial with 40 elderly patients at their dwelling. The clinical trial will also assess the acceptability of such a device in a home setting.**

Keywords- frailty; ultrasound sensor; mHealth.

I. INTRODUCTION

Frailty is conceptually defined as a state of older adults with increased vulnerability, resulting from age-associated declines in physiologic reserve and function across multiple organ systems, which compromises the ability to cope with stressors [1][2]. In contrast to permanent disability, frailty advance can be potentially reversed through appropriate interventions [3][4][5].

The project FrAilty Care and wEll funcTion (FACET) targets the development of tools that facilitate the detection of frailty advance, enabling intervention to prevent or delay the onset of frailty. FACET assessment strategy comprises clinical, cognitive, nutritional, functional and physical performance components. Among them, physical performance stands as a strong predictor of undesired clinical outcomes in elderly patients such as deaths, hospitalisation, disability [6], and falls [7]. The measurement of lower limb strength is one of the three basic physical assessment tools along with balance and gait speed assessment [8]. FACET project aims to measure both gait speed [9] and lower limb strength via specialized devices. The latter complements the former, since it directly measures lower limb power, a relevant factor leading to sarcopenia and higher risk of falls.

We present in this paper the device for lower limb strength measurement in the patient's dwelling, to be used together with a tablet, empowering the patients through self-assessment and a continuous and closer follow-up. In the next section the device and the algorithm used to interpret the measurements are described, along with the evaluation results and refinement steps taken accordingly. Section III includes a discussion of such results and, finally, Section IV presents the next steps in this line of research.

II. METHODS & RESULTS

The designed device offers the possibility of an automatic and unsupervised 30s-STS [10], counting the times elderly patients stand up and sit down from a chair in thirty seconds. It is attached to the backrest of a chair (see Figure 1), and it is equipped with an ultrasound sensor that continuously measures the distance between the device and the test subject with a sampling frequency of 10 Hz.

It is meant to be used by patients with the help of informal caregivers, to measure lower limb strength according to their geriatrist established plan, (i.e., once or twice a week). A training session is held at patient homes to ensure a safe usage, particularly focusing on avoidance of falling hazards.

A signal pre-processing and measuring algorithm (v1) was developed in MATLAB (The MathWorks, Nattick, MA, USA), and trained with the data from 30s-STS tests with 25 healthy young subjects in a controlled laboratory environment (dataset A). The mean number of stands per test was 11.2 with a standard deviation of 3.9. The pre-processing in v1 consisted of removal of outliers (distance > 70 cm) moving median filtering with a moving window length of 0.7 s detection of local maxima. Each detected peak was interpreted as a successful stand-up-event.

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Figure 1. Chair-Stand device as tested with data set B

When applied to dataset A, the first version of the algorithm was able to exactly count 88 % of the measurements (i.e., the calculated number of sit-to-stand events = reference number of sit-to-stand events as annotated via human counting). The mean absolute error was 0.16 stands and the mean relative error was 2.22 %.

This v1 of the algorithm was evaluated in a pre-clinical environment at the University Hospital of Getafe (HUG) with 30 volunteer geriatric patients and a trained nurse manually counting the stands in 30 s (dataset B). The mean number of stands was 9.2 ± 1.7 stands per test. The results of this prospective test showed a dramatically lower accuracy of the device in the assessment of potential real subjects. Only 7 % of measures were consistent with the manual measurements by the trained nurse. The mean absolute error was 2.57 stands and the mean relative error was 27.49%.

Based on dataset B, the algorithm was refined to a v2, trained retrospectively with dataset B. An adaptive threshold was defined based on the mean value of the moving median and minimum within a 4s window. The threshold for outlier detection was increased from 70 to 99cm. Successful stand-up-events were counted whenever a) the moving minimum of the signal with a window length of 0.7 s exceeded this threshold and b) the moving median within a 0.7 s window right after this timepoint exceeded 25 cm. Events that were closer than 1s to one another were not considered. V2 of the algorithm improved the accuracy of the measurements up to 40%. The mean absolute error was 1.10 stands and the mean relative error was 12.80 %.

III. Discussion

We found that the results achieved with the v1 of our algorithm were rather poor when applied to elderly patients. Due to the heterogeneous biomechanics of elderly patients while performing the test, the data differed remarkably as compared to healthy subjects. This fact, along with the poor adaptability of the algorithm to different chairs and subjects, were identified as potential sources of error in the measurement. V2 of the algorithm offered better results, but overfitting cannot be excluded.

In some cases, it is hard to tell whether a sit-to-stand event should be counted or not, i.e., whether the patient reached a complete upright position. Especially, the decision whether the final event was within the 30 s time interval is sometimes hard to make. Therefore, even our reference annotations (manual counts of sit to stand events) might show some uncertainties. Considering the study itself, we can identify as limitations the sample size and the current status of the device as a prototype.

For the system to be used in a clinical setting, it will be necessary to improve the accuracy by feeding the algorithm with additional measurements of real patients. The aim will be to make it at least as good as the average manual measurement by health professionals, which will also need to be measured. Nevertheless, for the system to be useful for monitoring frailty in a home setting, it is only necessary that the measurements are consistent within the same subject, to ensure decline in lower limb strength is detected early.

IV. Further Steps

In a next step, our algorithm will be evaluated in a prospective way with an additional test-set, which will be recorded from patients at the HUG. During this next step, it is planned that more than one person will manually count the sit-to-stand events, in order to quantify the inter-observer-variability of our reference annotations.

Next, the device will be used in a clinical trial with 40 elderly patients at their dwelling. The collected data will be analysed, inquiring the clinical relevance of a home-based chair stand test, and its ability to prevent frailty evolution to disability.

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