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DYNAMIC STRENGTH ASSESSMENT IN AN OLDER-OLD FRAIL POPULATION: TO A CLINICAL TOOL DEVELOPMENT

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Abstract: *Around 10% of people aged 65-75 years and half of all people aged over 80 years suffer from frailty. This syndrome is costly for medical care and also makes affected people and their relatives to have a dismissed quality of life. One of the major predictor is a decline in lower function and the subsequent reduction of mobility and independence. Therefore, measures of lower body strength and endurance could make clinicians be aware of these problems and monitor the corresponding actions. In general, maximal dynamic strength is obtained through a leg press machine. However, this kind of measuring instruments are not practical in clinical settings. Inertial units are an alternative due to its reduced size and prize. In the case of lower body strength, kinematic parameters of chair transitions are strongly associated with maximal dynamic strength. In particular, significant associations have been found for sit-to-stand duration (r=-0.76) and power (r=0,82 in the case of maximum peak of power for sit-to-stand). This confirms that significant information could be obtained in and easy and affordable manner by using inertial sensors. So, clinicians and physiotherapists could benefit of this tool to undergo the corresponding actions to promote independent living in later years of life.*

1 INTRODUCTION

Promoting a healthy aging is becoming a major challenge [1], [2]. According to the United Nations, population aged 80y or over is projected to increase globally more than threefold between 2017 and 2050. Disability rates among those people have also increased substantially, as a result of an accumulation of health risks across a lifespan of disease, injury and chronic diseases. In particular, 25% of individuals aged 65y and over have mobility limitations [3]. These problems make it more difficult those people to cope with daily living activities and to remain active and independent. Muscle strength decline is one of the main factors related to functional capacity in the oldest old [4]. However, there is not an established age at which mobility drawbacks occur due to the influence of other factors in muscle function.

Expert working groups recommend to evaluate older adult muscle health in terms of mass, strength and functional performance [5]. Surveys on functional status in older people normally include performance-based tests to stratify the risk of muscle weakness [6]. Lower body strength (i.e. quadriceps strength) is thought to undergo a preferential age-related decline relative to the upper body [7]. Previous studies showed that gait pattern disorders may be explained by a deterioration of the lower limb muscles [8]. Moreover, muscle strength is crucial for a successful chair rise, an essential task for independent living [9] [10]. However, functional performance tests are mainly focused on a single parameter (i.e walking time, number of sit-to-stand, SiStSi, repetitions) and do not provide any information on the specific aspects of the test subtasks. In the case of the sit-to-stand, SiSt, transition, studies of the biomechanics have found that this is a complex movement which involves not only lower limb strength but also balance, sensorimotor and psychological factors [11].

Advances in technology make it possible to use inertial units to obtain acceleration and angular velocity in 3 directions and, therefore, provide valuable information about functional test (i.e. SiSt and stand-to-sit, StSi, transitions, step time, variability, etc.) [12], [13]. Frail population can be identified based on these kinematic measurements as demonstrated by numerous studies [14], [15]. However, muscle-related parameters (i.e. muscle size and quality) are poorly investigated despite of its significant role in older adults functional performance [16][1]. The general aim of this paper is to assess muscle health in a population of oldest old and stablish correlations between maximal dynamic strength, measured with a leg press machine, and information from functional test such as the 30-s chair stand test (CST). In particular, both clinically-used scores (i.e. number of SiStSi cycles) as well as kinematic parameters (i.e. SiSt and/or StSi duration and SiSt power). Our final purpose is to provide clinicians with an easy-to-use and easy-to-understand tool that can help them to undergo the corresponding actions to promote independent living in later years of life.

2 MATERIALS AND METHODS

2.1 Experimental design

This study was designed to evaluate the associations between thigh muscle quality and strength of the thigh and the ability to sit and/or stand from a chair measured by a functional test (i.e. 30-s CST) with the goal of assess muscle health in the oldest old. Leg-strength tests were conducted to obtain strength and power values; as well as functional test, evaluated in terms of tests-scores and kinematic parameters. This study is a part of a larger project with the purpose of determining functional and morphological changes that are induced by exercise intervention.

2.2 Study participants

In this study participate eight institutionalized oldest among the elderly patients (>90 years) in the Pamplona area in Spain. Inclusion criteria was to be in a frail status, according to the Fried criteria of frailty which was determined by the presence of 3 or more of the following components: slowness, weakness, weight loss, exhaustion, and low physical activity [17]. Individuals who showed 2 or fewer of these characteristics (pre-frail and robust) were excluded.

Other exclusion criteria were the diagnosis of dementia, disability (defined as a Barthel Index lower than 60 and inability to walk independently without the assistance of another person), recent cardiac arrest, unstable coronary syndrome, active cardiac failure, cardiac block, or any unstable medical condition.

The eight elderly subjects who volunteered to participate in the study met the necessary requirements and their physical characteristics are presented in Table 1. Finally, participants or they legal guardians completed an ethical consent form. This study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of the Public University of Navarra, Spain.

2.3 Functional tests procedures

Participants were asked to perform the 30-s CST functional tests. This test consists on executing as much SiStSi cycles as possible within 30s. They started on the sit-down positon on standard chair (seat height of 40 cm, without armrests but with backrest) and the single requirement was not to use their arms to complete the whole movement. Measurements were obtained in the same place and ambient conditions for every participant.

	Frail participants, n=8
Age, y	92.3 ± 2.1
Women/men	5/3
Body mass, kg	57.3 ± 11.4
Height, cm	157.3 ± 9.9
Body mass index, kg/cm^2	23.25 ± 2.1

Table 1: Subjects characteristics.

A unique inertial unit MTx (XSENS; Xsens Technologies B.V., Enschede, Netherlands) was attached over L3 region of the subject’s lumbar spine to provide kinematic data for both tests. This placement was chosen because of its proximity to the body’s center of mass (CoM) in the standing position. The MTx device is a portable, non-annoying and cheap tool that can provide, often in real time, direct and accurate measurements of motion and position. In particular, MTx itself combines 9 individuals Micro-Electronic-Mechanical Systems (MEMS) to provide drift-free 3-dimensional (3D) orientation as well as kinematic data such as 3D acceleration and 3D rate of turn.

2.4 Kinematic parameters

An automatic analysis was performed to obtain an accurate count of the number of repetitions, removing failed attempts, which is the current 30-s CST outcome. Moreover, a set of the most interesting kinematic parameters for the SiSt and/or StSi transitions that involves the 30-s CST were also extracted from the inertial unit. This procedure was implemented as a three-stage algorithm and further details can be found elsewhere [15]. In this case, time duration, range-of-motion, and maximum/minimum power exertion of the different phases (i.e. impulse, SiSt and StSi) were obtained.

2.5 Maximal dynamic strength and muscle power output of the legs

Maximal dynamic strength was assessed using the 1-repetition maximum test (1RPM) on the bilateral leg press exercise. The procedure starts with a specific warmed up. Then, the maximal load of each participant or 1RPM value was determined with no more than 5 attempts, with 3-minutes recovery between attempts. Using these value, participants performed three repetitions at maximal intentional velocity and intensities of 30% and 60% of 1 RPM (PW30 and PW60) to obtain their maximal power output at these loading intensities. Finally, the test consists of two attempts at each intensity level, with a 2-minute recovery between attempts. As a result, the maximal power exerted to the bar was recorded by connecting a velocity transducer to the weigh plates (T-Force System; Ergotech, Murcia, Spain). Strong verbal encouragements were given to participants for all performance test with the aim to encourage them to perform each test action as maximally and as quickly as possible.

2.7 Statistical analysis

Descriptive results are reported as the mean ± SD. The Pearson product-moment correlation test was used to investigate possible associations between muscle variables, leg-strength measures, and 30-s CST kinematic parameters. Significance was accepted at $p<0.05$. MATLAB and Statistic Toolbox Release 2013b software (The MathWorks, Inc., Natick, MA) was used for the data analysis.

		Mean ± SD
Chair parameters		
Nº Cycles	NC	5.29 ± 2.75
Time duration$_{SiSt}$ (s)	TD_SiSt	1.73 ± 0.74
Time duration$_{StSi}$ (s)	TD_StSi	1.45 ± 0.37
Time duration$_{SiStSi}$ (s)	TD_SiStSi	5.79 ± 2.62
AP range of motion$_{SiSt}$ (º)	AP_RM_SiSt	27.21 ± 15.42
Max Power$_{SiSt}$ (W)	MaxP_SiSt	39.03 ± 33.77
Min Power$_{StSi}$ (W)	MinP_StSi	-120 ± 73.60
Leg strength and power, W		
1-repetition maximum test	1RPM	62.85 ± 27.51
Max. intentional velocity at 30%	PW30	63.04 ± 63.31
Max. intentional velocity at 60%	PW60	146.80 ± 68.75

Table 2: Gait and chair parameters, Leg Strength and Power.

3 RESULTS

Kinematic parameters were listed (mean ± SD), functional test scores and, leg strength are summarized on Table 2.

The results of correlations between leg strength and chair performance based on both test scores and kinematic values are shown on Table 3. A significant negative correlation was found between transitions duration and power; the time required to stand-up from the chair correlated negatively with 1RPM ($r=-0,76$; $p<.05$), as shown on Figure 1. Another interesting result was that also significant positive correlation was found between maximal peak power while SiSt and both PW30 ($r=0,82$; $r<.05$) and PW60 ($r=0,79$; $r<.05$). Additionally, negative correlation was found between minimal peak power executed while StSi and PW30 ($r=0,82$; $r<.05$) and PW60 ($r=-0,80$; $r<.05$). Not significant results but a clear negative tendency was found between both SiSt transition and SiStSi cycle duration and power measured by PW60 ($r=-0.72$; $p=0.07$ and $r=-0.69$; $p=0.08$). Finally, any significant correlation was found between parameters related to the transition strategy (i.e. anterior-posterior orientation) and power exertion and neither for time duration of the StSi transition and power exertion.

Leg Power	30-s CTS score	30-s CST kinematic parameters					
	NC	TD_SiSt	TD_StSi	TD_SiStSi	O_AP_SiSt	MaxP_SiSt	MinP_SiSt
1RM	0.34	-0.76**	-0.16	-0.48	-0.63	0.43	-0.29
PW30	0.19	-0.30	-0.14	-0.31	-0.27	0.82**	-0.80**
PW60	0.53	-0.72*	-0.33	-0.69*	-0.66	0.79**	-0.63

Table 3: Pearson Correlation Coefficients (r) of Leg Power With 30-s CST score and kinematic parameters.

* Means that there is a tendency in the result (0.05<p<1)

** Means that there is a significant result (p<0.05)

7 DISCUSSION

The 30-s CST output, measured as the number of completed cycles, has been used as a proxy indicator of lower limb strength in older adults [18]–[20]. However, recent studies revealed that the SiSt task is a multidimensional functional movement involving more just than lower limb body strength [11], [21]. Therefore, other variables such as sensorimotor, balance and psychological parameters should be taken into account. This idea support one of the principal findings of this study which revealed no relationship between lower-extremities power and the 30-s CST number of completed cycles. This may contrast somehow previous studies [11], [22], where the 30-s CST outcome has been used as a measure of lower power. However, this difference could be due to oldest old particular performance of the 30-s CST, involving the previously mentioned major influence of other variables than power.

The main objective of this study is to provide valuable information from lower limb muscle performance based on the 30-s CST. Elderly population tend to suffer an age-related decline in muscle properties and function and, as a consequence, mobility limitations [23]. Therefore, a decreased muscle strength makes it necessary a high demand on the postural balance system [24], [25] reducing the ability to rise and sit down to a chair, something essential daily functional activities. Several studies highlighted that longer SiSt and StSi times in elderly strongly predict falls risk and functional dependence [26]–[28]. Similarly, highly significant associations has been found for those durations and health/functional status[29]. Our study extends the important role of transition duration since significant negative correlations between them and lower muscle power in accordance with previous authors [10], [30], [31]. In particular, elderly with greatest muscle power typically perform chair rise faster (r=-0.76), demonstrating better stability and ability to perform this movement. Not a significant but a tendency relationship was also found for the SiST transition and the whole SiStSi cycle with PW60. These results reinforced the idea that the weaker the muscle, the more time is needed to perform the chair rise and also the whole SiStSi cycle during a 30-s CST. It is probably due to the fear of falling since many falls were produced in terms of transition performance (i.e. SiSt, StSi, initiating walking) [32], [28]. Interestingly, it should be signaled that any significant relationship was found for lower limb power and StSi duration. Therefore, StSi does not require as much postural control as the SiSt, for the elderly old population [33].

Another interesting result from our study is that there are other parameters that presents significant correlations with leg power measures. This confirms the general idea about the complexity of chair transitions movements where more detailed information than merely a duration measure is needed [34]. In our case, significant correlations have been found between vertical SiSt and/or StSi vertical power, estimated from the acceleration measured by the inertial sensors, and lower leg power parameters. Regarding SiSt movement, maximal peak power correlated positively with both PW30 (r=0,82; r<.05) and PW60 (r=0,79; r<.05), as previously signaled in [35], [36]. Additionally, we have also found a significant negative correlation between minimal peak power and PW30 (r=0,82; r<.05) and PW60 (r=-0,80; r<.05), for the StSi movement. Both results demonstrate that power exerted in both transitions can be measured in terms of the 30-s CST instead of using the 1-RMS method which is complex and attached to laboratory conditions. This leads to a new method for evaluating lower limb muscle power in the clinical setting of preventive nursing care for older adults.

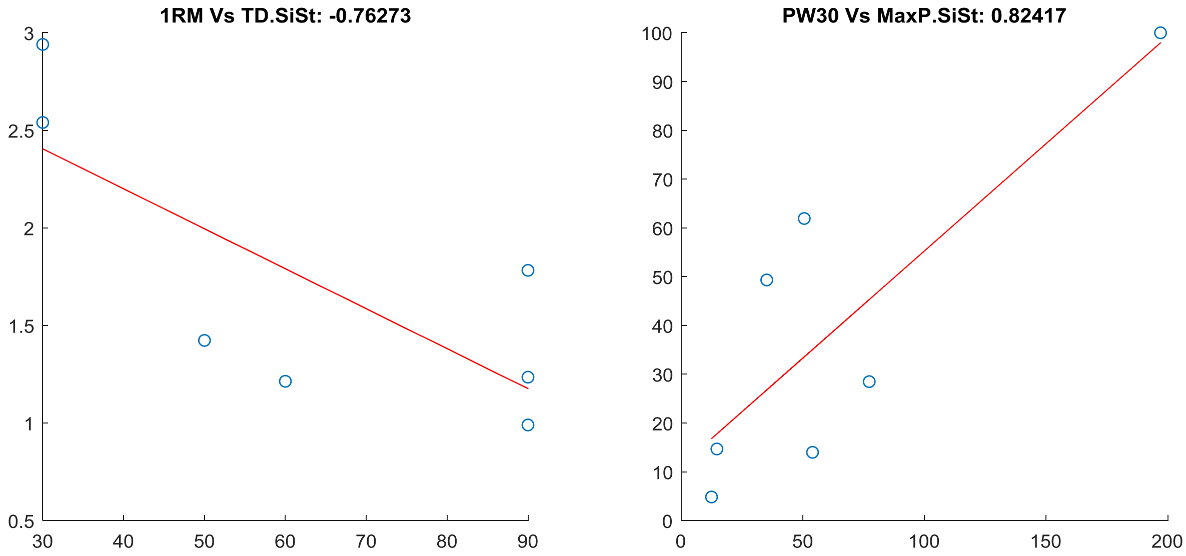

Figure 1: 1RMS vs SiSt duration and PW30 vs SiSt max. power values

Summarizing, both SiSt duration and power peaks during chair transitions provide valuable information about lower limb power in an oldest old frail population. The use of inertial sensor provides another perspective of information, clarifying the mechanism of a correct SiStSi cycle and lower limb power involved. Such a detailed characterization of both SiSt and StSi transition patterns opens the perspective for a broader range of clinical applications. For instance, elderly persons transitioning to frailty who have increasing difficulties and use compensatory strategies to achieve a successful transition could be provided by an exercise intervention. Moreover, it should be noted that these results could have a significant impact on the prevention of the adverse outcomes in the elderly population. Further studies should be conducted to better understand the importance of specific exercise programs to enhance lower limb muscle capacity, to improve the ability to stand from a chair and consequently prevent mobility problems and the subsequent adverse outcomes such as falls, hospitalization and death.

8 CONCLUSIONS

The use of inertial sensors with functional tests such as the 30-s CST provides additional information on the global pattern of transitions. Regarding lower limb power, significant correlations were found for SiSt transition duration as well as SiSt and StSi vertical peak power with leg power measures such as 1RM and PW30. Those results highlights the relevance of lower limb power when executing a safety chair transition. Moreover, provides clinicians with objective parameters to monitor frailty subjects and monitor specific exercise programs to enhance lower limb muscle capacity. This actions not only will improve elderly quality of life but also prevent falls and subsequent adverse outcomes such as hospitalization and death.

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