Can Sit-to-walk Assessment Maximize Instrumented Timed Up & Go Test Output?

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Abstract: Daily human activities commonly include standing from a seated position. In research this transition is investigated, among others, as a part of a functional Timed Up & Go test. Spatio-temporal parameters are widely used to assess the sit-to-walk transition. Usually, the parameters calculated for the sit-to-walk signal is in its entirety. Another approach primarily splits the transition into phases and then calculates parameters for individual phases separately. The objective of this work is to examine whether splitting the Timed Up & Go test into subphases provides additional value for transition assessment. In order to compare both approaches, we utilized angular rate parameters (duration, peak value, mean, variance) and analyzed their reliability. The reliability proved to be dependent on the subject group and transition phase. In addition, we compared transition parameters from the entire transition and individual phases between the two subject groups. The mean only differentiated between the subject groups in individual phases, but not is entire transition. To summarize, splitting the transition into phases turned out to be beneficial for sit-to-walk transition assessment.

1 INTRODUCTION

Standing from a seated position is a commonly performed daily activity. The sit-to-stand movement is a part of functional tests such as Timed Up & Go test. The Timed Up & Go (TUG) test is a modified timed version of the "Get-Up and Go" Test (Mathias et al., 1986). TUG involves rising from a chair, walking 3 m, turning 180°, walking back to the chair, and sitting down again. Usually, a TUG is measured as the total time it takes to perform the test.

The increasing utilization of inertial measurement units during the last decade increases the ability to separate individual TUG subcomponents (Salarian et al., 2010; Greene et al., 2010; Zakaria et al., 2015; Smith et al., 2016; Craig et al., 2017; Newman et al., 2018), i.e. sit-to-walk, walking forward, 180 degree turn, walking back to the chair and turn-to-sit, and consequently their individual assessment.

Recent studies employed two approaches to the sit-to-walk (StW) assessment. The first approach analyzed the entire StW at once. Salarian et al. (Salarian et al., 2010) tested four StW parameters (duration, peak angular velocity, mean angular velocity, and the range of trunk movement) in Parkinson disease patients and older adults. They did not reveal any difference between the tested subject groups. Also, Weiss et al. (Weiss et al., 2013) did not observe a difference in the transition measures (duration, acceleration amplitude range, median and standard deviation) of PD patients and older adult groups. Galán et al. (Galán-Mercant and Cuesta-Vargas, 2014) showed a difference in duration and acceleration-based parameters (minimal, maximal, and mean value) between frail and non-frail older adults. The second approach, Zakaria et al. (Zakaria et al., 2015) modified the StW assessment so that they divided the transition into two phases: sit-bend and bend-stand. Then, they assessed the duration, acceleration and angular rate measures (peak values, RMS) in elderly subjects with low and high risk of falls. No differences were observed in the transition phase measures for both groups. Although a number of studies utilized the instrumented TUG, only a few of them included StW assessment (Salarian et al., 2010; Weiss et al., 2013; Zakaria et al., 2015; Galán-Mercant and Cuesta-Vargas, 2014). Moreover, Millor et al. (Millor et al., 2014) noted that the angular kinematics of StW transitions in the TUG test did

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not yield meaningful information. None of the previous studies assessed or compared both approaches, i.e. the assessment of the entire StW and individual phases at the same time.

Reliable outcomes are crucial for the interpretation of results and the subsequent adoption in clinical practice (Smith et al., 2016). Salarian et al. (Salarian et al., 2010) examined a TUG inter-session reliability including the sit-to-walk transition of elderly subjects and patients with Parkinson's disease (PD). Their work did not provide reliability per subject groups, rather the analysed reliability of the mixed group. The results showed the poor reliability of all analysed parameters (ICC<0.5). Newman et al. (Newman et al., 2018) also assessed the intra-session reliability of a TUG including the StW transition among children with traumatic brain injury and controls. Although the reliability of the sit-to-walk parameters was assessed previously none of the previous works studied the reliability of the sit-to-walk transition with a focus on its phases.

The aim of this study is to analyse the division of the StW transition into two phases. Specifically, to examine the additional value of splitting the transition into subphases when compared to the transition assessment at once. For this purpose, we compared parameters computed for an entire StW transition and its individual phases. Then, we assessed the reliability of all computed parameters and compared the distinctiveness between the two subject groups, namely older adults and Parkinson disease patients.

2 METHODS

2.1 Participants and Protocol

Two groups of participants were enrolled in this study. The first group included 35 early untreated Parkinson disease (PD) patients (24 males, 11 females), mean age 58.6 (+-13.4). The second group, control group (CG), included 36 volunteers (32 males, 4 females), mean age 64.3 (+-9.5). All PD patients and CG were evaluated twice within one session (TUG_1, TUG_2). All subjects accomplished an extended Timed Up & Go Test (ETUG) (Wall et al., 2000). Each subject was measured while she/he rose from a chair during the ETUG, walked 10 meters, turned, walked back, and sat down again. The study was approved by the Ethics Committee of the General University Hospital in Prague, Czech Republic, and therefore performed in accordance with the ethical standards established in the 1964 Declaration of Helsinki.

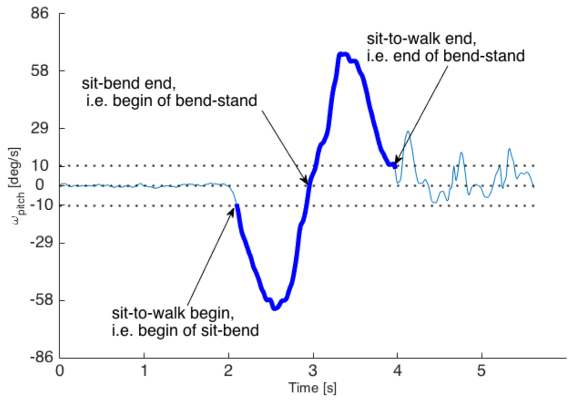

Figure 1: Plot showing pitch angular rate of one subject. Bold - sit-to-walk phase of TUG.

2.2 Data Acquisition and Processing

Xbus Master (Xsens Technologies B.V.), a lightweight (330g) and portable device using MTx units for orientation and acceleration measurements of body segments, was used for the measurement of 3-D orientation and 3-D acceleration. Kinematic data was recorded from 5 gyro-accelerometers with a data sampling rate of 100 Hz. Units were symmetrically attached to the lateral shank of each lower leg, 4 cm above the ankle joint, and the chest, 2 cm below the sternal notch.

Before further processing, the raw angular rate signal was low-pass filtered with a zero-phase second-order Butterworth filter with a 20 Hz corner frequency. In this study, we focused on the sit-to-walk (StW) transition.

In accordance with previous studies, the chest angular rate sensor was used for further processing and computation of the StW parameters. It was showed that the TUG sit-to-walk transition can be detected as the movement with an pitch angular rate higher than 10 deg/s (Higashi et al., 2008). As a negative angular rate indicates a clockwise rotation, the beginning of the StW, i.e. the beginning of the sit-bend phase, was detected from the pitch angular rate as a value less than -10 deg/s. As the crossing of the angular rate signal to zero means a rotation or direction change, the end of sit-bend phase, i.e. beginning of bend-stand phase, was detected as the crossing of the angular rate to the value zero (Figure 1). Finally, the end of StW, i.e. end of bend-stand phase, was identified as a value lower than 10 deg/s (Higashi et al., 2008).

To assess the StW we employed the mean, peak value, duration, and variance of pitch angular rate signal. All parameters were calculated for both phases and the entire transition. Thus, we calculated 12 parameters in total.

2.3 Statistical Analysis

Statistical analyses were performed to examine the reliability of the StW parameters. The Intra-Class Correlation (ICC) between two measurements was used. Absolute agreement was reported. According to McGraw et al. (McGraw and Wong, 1996) reliability greater than 0.90 is considered as excellent, reliability greater than 0.75 is considered as good, greater than 0.50 is moderate, and lower than 0.50 is poor.

Next, the hypotheses on whether the StW parameters of both sit-to-walk phases are able to distinguish a healthy subject from a PD patient was tested. The Shapiro-Wilk test was used to verify the normality of parameters in each observed dataset. The assumption of a normal data distribution in the observed datasets had been rejected (significance level p=0.05). Therefore, the nonparametric Wilcoxon rank sum test was used to compare statistical significance differences in the sit-to-walk transition between PD patients and control group data. The significance level was set to $p<0.05$. All preprocessing and analyses were carried out offline using the MatLab (MatLab R2015, Mathworks, Inc., Natick, MA, USA) programming environment.

3 RESULTS

From Table 1, it can be seen that out of the four parameters, three parameters in the control group and one parameter in PD patients demonstrated poor reliability (ICC<0.50) in all three cases (entire StW, sit-bend, bend-stand). For the control group these were: duration, mean and variance. For PD patients this was only for duration. The peak value in the control group showed a higher reliability (moderate, ICC>0.50) in the bend-stand phase then in other cases (poor, ICC<0.50). The mean and variance in PD had poor reliability in the sit-bend phase and moderate (ICC>0.50) in the entire StW and bend-stand.

When comparing PD patients and the control group, the peak value, and variance were significantly different in the entire StW, sit-bend and bend-stand phases. The mean value showed the difference between the groups in the sit-bend and bend-stand phases (Figure 2). The duration did not show a difference in any of the tested cases. A significant difference in the entire StW but not sit-bend or bend-stand phases was not observed for any of utilized parameters.

4 DISCUSSION

In this work, we compared the results of the entire sit-to-walk transition to a more detailed approach with transition phases. We evaluated StW transition. Additionally, we divided the sit-to-walk transition into two phases, namely sit-bend and bend-stand, and evaluated them separately.

First, we analysed whether the StW measures calculated per phase have similar reliability as measures calculated for entire StW. The analyses were provided per subject group. Based of poor reliability results (Table 1) it can be inferred that the parameter duration of the entire StW and its phases is not suitable for StW assessment (the entirety or its parts). The results showed a higher reliability in PD patients than the CG for almost for all parameters and tested cases. This can be elucidated by the reduced concentration of the CG to perform a StW. In the PD group, some parameters (mean, variance) exhibited a lower reliability in the sit-bend phase than in other phases. In contrast to the peak parameter, mean and variance are affected by the accuracy of StW detection. Especially the detection of the StW beginning is a challenging task because the sit-bend phase may be preceded by gently bending forward and backward. Thus, a comparison of detection methods with respect to their impact to StW parameters is needed to make results more comparable across studies.

In addition, the training effect might play important role in reliability assessment of two consecutive trials. To our knowledge, the training effect of TUG subcomponents has not yet been studied.

Second, we tested whether StW phases can differentiate between PD patients and older adults better than entire StW. The present study is consistent with previous works. No differences between PD a CG were observed for duration and mean parameters computed for entire StW (Salarian et al., 2010; Weiss et al., 2013). Unlike duration, the mean parameter revealed a difference between these groups in both individual phases (sit-bend, bend-stand). Finally, we suggest that splitting StW into phases can benefit a TUG StW analysis.

Nevertheless, there are some limitations to this research study. The most important is that the sample size of the subjects was not high. However, 71 subjects proved to be sufficient for preliminary research which managed to test the basic attributes of the method proposed for further studies of TUG.

Table 1: Intra-class correlation and Wilcoxon rank sum test outcomes for the two TUG measurements. TUG_1-first TUG measurement, TUG_2-second TUG measurement, Var.-variance, *-statistically significant difference, $^{\diamond}$-moderate or good intraclass correlation.

	Entire StW				Sit-bend phase				Bend-stand phase			
	ICC		PD vs CG (p-value)		ICC		PD vs CG (p-value)		ICC		PD vs CG (p-value)	
	CG	PD	TUG_1	TUG_2	CG	PD	TUG_1	TUG_2	CG	PD	TUG_1	TUG_2
Time	0.12	0.40	0.06	0.38	0.17	0.48	0.06	0.42	0.09	0.33	0.14	0.16
Peak	0.42	$0.73^{\diamond}$	$<0.01^{*}$	$<0.01^{*}$	0.43	$0.74^{\diamond}$	$<0.01^{*}$	$<0.01^{*}$	$0.53^{\diamond}$	$0.74^{\diamond}$	$<0.01^{*}$	0.09
Mean	0.30	$0.72^{\diamond}$	0.80	0.49	0.19	0.39	$<0.01^{*}$	0.04^{*}	0.44	$0.53^{\diamond}$	$<0.01^{*}$	0.04^{*}
Var.	0.40	$0.53^{\diamond}$	$<0.01^{*}$	$<0.01^{*}$	0.43	0.31	0.01^{*}	$<0.01^{*}$	0.37	$0.70^{\diamond}$	0.03^{*}	0.02^{*}

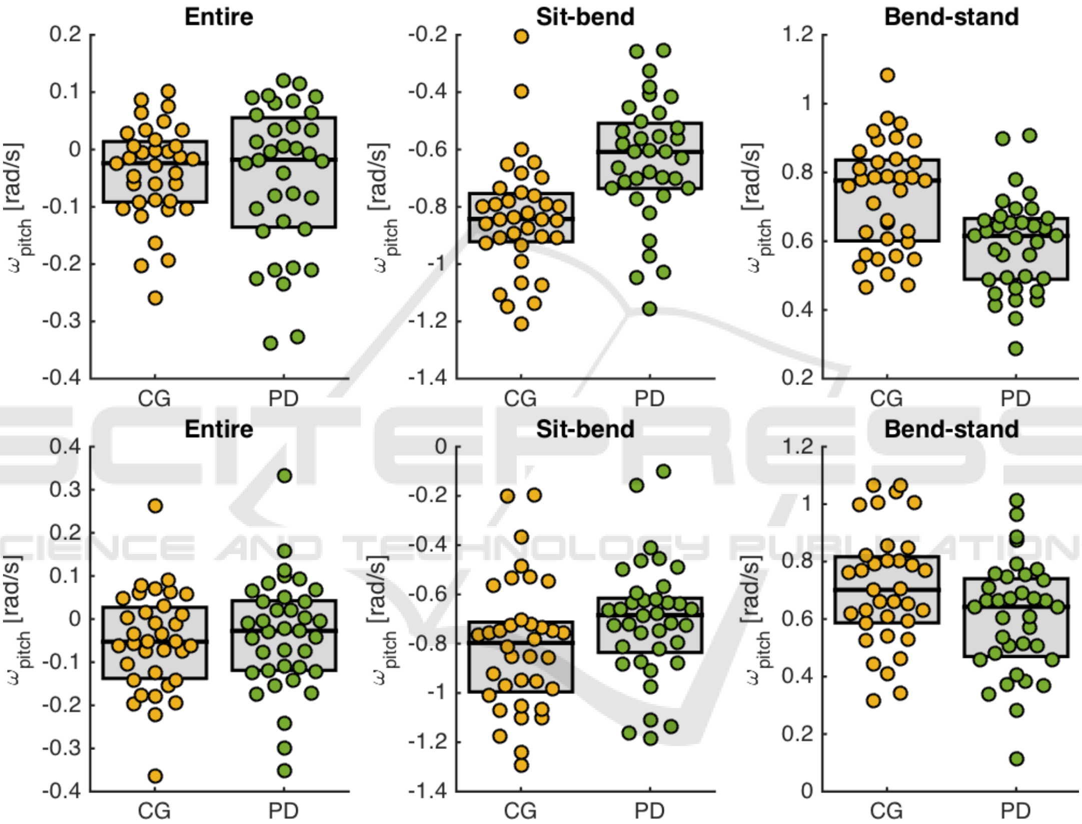

Figure 2: Scatter plots showing mean pitch angular rate differences between PD patients and control group (CG) in the entire StW, sit-bend and bend-stand phases. The top scatter plot represents the first TUG measurement (TUG_1) and the bottom represents the second TUG measurement (TUG_2).

5 CONCLUSIONS

This paper tested and compared two approaches to Timed Up & Go sit-to-walk transition analysis: the analysis of the entire transition at once and the analysis per phases. The reliability of sit-to-walk parameters was tested as well as the ability to differentiate between subject groups. We can designate that the transition splitting into phases can provide new insight into sit-to-walk transition assessment.

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