PRELIMINARY ANALYSIS OF WHICH SPATIAL-TEMPORAL GAIT PARAMETERS IDENTIFY ELDERLY ADULTS WHO HAVE FALLEN

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INTRODUCTION

Despite considerable research effort, we generally cannot predict fall risk for humans. There are many proposed measures [1,2], but it is unclear which measures are the most predictive or how closely correlated different measures are. Some of the more promising measures include mean walking speed [3], mean step duration [1], and the standard deviation of step duration [2]. Increased asymmetry may also increase fall risk [4]. Because falls can occur for many reasons, a fall risk model is likely to require many different measures of gait, each capturing a different component of stability. In preparation for developing such a model, this abstract presents preliminary work quantifying how well the mean, standard deviation, and asymmetry of spatial-temporal parameters identify elderly adults who have fallen recently. It further quantifies how correlated each of the measures are to each other.

METHODS

Participants were recruited from WISE (Working to Increase Stability through Exercise) Study [5] participants. Subjects were at least 65 years, had a fragility fracture in the past 3 to 10 years, and were able to walk 100 ft without assistance. A total of 99 subjects participated in this sub-study in July 2018; this abstract investigates the results from a random sample of 10 of those subjects. Every four months, subjects were asked if they had any falls resulting in injury [5]. This abstract uses falls reported between July 2018 and January 2019. Of the 10 subjects examined, one subject fell twice (faller). The remaining nine subjects are the non-fallers. During kinematic data collection, subjects walked across the room ($\approx$ 30 ft), turned around in the capture volume, and walked back. They repeated this for a total of ten trials, resting as needed. Stride events were identified using the method in [6]. Only straight walking was analyzed, so the events in the turn were removed. To identify the turn, the vertical toe velocity between sequential heel strikes was used. If the maximum velocity in this interval did not meet a pre-determined threshold, the event was in the turn and therefore ignored. While this worked for the majority of the trials, some trials required manual processing. To determine how well spatial-temporal parameters could identify fallers, the difference in values between the faller and non-fallers were determined. Three types of parameters were evaluated – step duration, step length, and step speed. Three measures for each parameter were used – mean over all steps (captures "typical" step), standard deviation over all steps (captures variation between steps), and the absolute difference in mean values between the left and right side (captures asymmetry). This gives a total of nine measures. Because some of these measures are likely correlated with each other and therefore contain redundant information, the Pearson correlation coefficient between each pair of measures was also calculated.

RESULTS AND DISCUSSION

The three step duration measures most clearly distinguished the faller from the non-fallers (Fig. 1). In particular, the standard deviation of step duration was statistically very different between the faller and non-fallers. This is consistent with previous work [1,2]. It also suggests that fall risk models should include the standard deviation of step duration because it has strong predictive capabilities. For step length and speed, the mean values of each parameter were best able to discriminate the faller. This suggests that these measures may be predictive of a future fall. The standard deviation and asymmetry measures were fairly similar for the faller and non-fallers, so they may have lower predictive capabilities. The mean values for step speed, length, and duration are all strongly correlated as expected (Table 1). Interestingly, step duration standard deviation is also strongly correlated with the mean values. Among these four measures, most correlations have magnitudes above 0.7. This suggests that these parameters capture similar information. The standard deviations for step speed and step length are also highly correlated with each other. The three asymmetry measures are not correlated with any other measure, which suggests they each capture unique information about the gait. In order to create a model to predict fall risk in the future, all included measures should be distinguishable from the other measures and have predictive capabilities. Taking into consideration both the ability to distinguish the faller from the non-fallers and the correlations between measures, the three most promising measures are the standard deviation of step duration, the asymmetry in step duration, and the asymmetry in step length. Step duration standard deviation is the measure that most distinguishes the faller from the non-faller. While mean speed, step length, and step duration also distinguish the groups, they are strongly correlated with the standard deviation of step duration and may not provide much additional information. The asymmetry in step duration and length can both distinguish the faller and appear to capture unique information. While the standard deviations in speed and step length are correlated with each other and distinct from the other measures, they do not appear to distinguish the faller from the non-fallers.

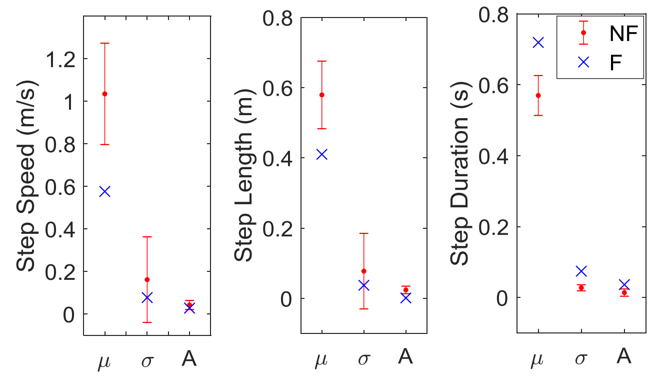

Figure 1: Step speed, length, and duration mean (μ), standard deviation (σ) and asymmetry (A) for the faller (F) and non-fallers (NF). The error bars indicate one standard deviation of that particular parameter across all non-fallers.

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Table 1: Correlations between the means (μ), standard deviations (σ) and asymmetry (A) in step speed (v), length (SL), and duration (T).

	v μ	**v σ**	**v A**	**SL μ**	**SL σ**	**SL A**	**T μ**	**T σ**	**T A**
v μ	1.00	0.01	0.04	0.93	-0.03	-0.37	-0.82	-0.74	-0.14
v σ	0.01	1.00	-0.59	-0.14	0.99	-0.17	-0.32	-0.13	0.09
v A	0.04	-0.59	1.00	-0.02	-0.60	0.06	-0.11	-0.29	-0.64
SL μ	0.93	-0.14	-0.02	1.00	-0.17	-0.35	-0.58	-0.64	-0.03
SL σ	-0.03	0.99	-0.60	-0.17	1.00	-0.16	-0.28	-0.11	0.11
SL A	-0.37	-0.17	0.06	-0.35	-0.16	1.00	0.38	0.43	0.07
T μ	-0.82	-0.32	-0.11	-0.58	-0.28	0.38	1.00	0.84	0.36
T σ	-0.74	-0.13	-0.28	-0.64	-0.11	0.43	0.84	1.00	0.51
T A	-0.14	0.09	-0.64	-0.03	0.11	0.07	0.36	0.51	1.00