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Two-minute walk tests demonstrate similar age-related gait differences as a six-minute walk test

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ABSTRACT

Background: The six-minute walk test (6MWT) is used within clinical and research settings to assess gait performance across a variety of conditions and populations. Commonly, the test is used to identify specific aspects of gait that affect functional mobility. With the advancement of new technologies such as wireless inertial sensors, it has become possible to collect reliable, sensitive, and objective measures of gait. While the 6MWT has been accepted and used for many years, a more concise, while still objective gait analysis would likely benefit clinicians, researchers and patients.
Research Question: Does a concise 2-minute walk test (2MWT) provide similar information regarding gait performance and gait differences as the 6MWT in healthy young (YA) and older adults (OA)?
Methods: A total of thirty-one participants (sixteen young adults and fifteen older adults) conducted a continuous 6MWT at their self-selected pace. All participants wore six wireless inertial sensors which were placed on each foot, at the lumbar, sternum, and on each wrist. Once completed the 6MWT data was spliced into three, distinct two-minute segments. Spliced data was analyzed and compared between groups and segments.
Results: Results demonstrate significant age-related differences in several gait metrics, primarily with older adults showing increased spatiotemporal variability. Additionally, no significant differences were observed between the three, two-minute segments and the continuous 6MWT, with the exception of total number of strides completed.
Significance: These results demonstrate that the 2MWT may provide a preferable alternative to assessing gait performance by reducing confounds such as fatigue while maintaining sensitivity of measuring gait performance. These improvements may be particularly beneficial when studying populations of advanced age or with neurological disorder.

1. Introduction

The use of six-minute walk tests (6MWT) for gait analysis has a long history in clinical and research settings. Prior to the 6MWT, the first published walking measure was the 12-minute performance test in 1968 by Cooper et al., demonstrating a close relationship between distance covered and maximal oxygen consumption [1]. Additional work assessed three different walking durations, 12-, 6-, and a 2-minute walk in people with respiratory disease [2]. This study concluded the two-minute version was reproducible and provided adequate discriminatory results, however being conservative in their analysis, suggested the 6MWT was the most appropriate duration for research [2]. As a result, the 6MWT gained clinical attention as a measure of exercise capacity in both pulmonary and cardiovascular conditions [2,3]. While clearly beneficial, the 6MWT is long and potentially fatiguing to individuals of advanced age or with neurological conditions [4–6]. With this in mind, the ability to accurately assess gait performance during a briefer assessment would be advantageous for both clinical and research settings.

Conventionally, the 6MWT is assessed by having an individual walk continuously for six minutes then summing the total distance covered and number of steps completed. However, technological advancements such as inertial sensors have allowed for precise quantification of spatiotemporal parameters of gait which can be used to describe the body's movement and variability through space. Due to the ability to objectively quantify gait performance, we strove to understand how spatiotemporal metrics of gait do, or do not, change over the course of a 6MWT. To answer this question, we analyzed 10 commonly reported

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gait metrics captured during a continuous 6MWT (c6MWT) and compared the values obtained from the c6MWT when divided into three, two-minute segments. The overall objective of this project was to determine whether a more concise 2-minute walk test (2MWT) provides similar information regarding gait performance as the 6MWT and, as a secondary objective, to assess age-related differences between healthy young (YA) and older adults (OA).

2. Methods

2.1. Participants

Thirty-one healthy adults participated in this study; 16 young (average age: 24.81 years; range: 20–31) and 15 older (average age: 71.67 years; range: 64–83) participants. All participants were able to ambulate independently with no acute fall history (prior 6 months) and had no clinically diagnosed disease or disorder that would impact their ability to walk. This study was approved by the Colorado State University Institutional Review Board, all participants provided written informed consent prior to participating.

2.2. Procedures

Our gait assessment procedures have been preciously described [7]. Breifly, gait was assessed during a c6MWT using six wireless inertial sensors (Opal Sensors, APDM Inc., Portland, OR) placed on each foot, around the waist at L5, on the sternum, and around each wrist [8]. The c6MWT was conducted unshod, over-ground at their self-selected pace. Participants were asked to walk back and forth down a 30 m hallway while limiting talking and staring straight ahead.

2.3. Data and statistical analysis

Gait data was analyzed using Mobility Lab software (Version 2) [8]. A custom python script was created to split each participants' c6MWT into three equal and distinct two-minute segments (0–120 s, 121–240 s, 241–360 s). Each two-minute segment was then imported and re-analyzed by Mobility Lab software, automatically computing the same gait metrics as the original c6MWT. Additionally, coefficient of variation (CoV) (SD/Mean) was calculated for all Mobility Lab output measures.

Statistical analysis was conducted in JMP Pro 13 with an alpha level set at 0.05. Between-group differences for demographic data were assessed using independent *t*-tests. To assess for group and condition main effects of walking, and group by condition interactions a 2 × 4 (group x walking segment) repeated measure ANOVA (RMANOVA) was completed. All significant main effects and interactions from the RMANOVA were assessed post-*hoc* using Student's *t*-test corrected for multiple comparisons using a Tukey-HSD treatment.

3. Results

Demographic data of study participants are presented in Table 1.

Table 1
Characteristics of young and older adult participants. Statistically significant differences are bolded.

Characteristics	Young (n = 16) Mean ± SD	Old (n = 15) Mean ± SD	*p*-value
Age	24.81 ± 3.58	71.67 ± 6.04	**< 0.0001**
Gender (n, % Female)	6 (37.50)	7 (46.67)	
Height (cm)	172.56 ± 7.91	168.99 ± 10.75	0.30
Weight (kg)	68.80 ± 13.07	75.81 ± 16.23	0.20

3.1. Segmental differences of the 6MWT

Three variables demonstrated a main effect of walking segment (Table 2). However, in post-*hoc* analyses, one maintained significance. Strides completed between the two-minute segments and the c6MWT was significantly different based on the segmental duration. It is important to note there were no significant differences in strides between the three, two-minute segments ($p \geq 0.859$). Finally, two measures swing and stance CoV, demonstrated a significant group by walking segment interaction. Again, post-*hoc* analyses revealed no significant differences between the four walking segments and either group, signifying no differences between YA and OA for any walking segment.

3.2. Age-related gait differences

Results show a main effect of age in seven gait metrics (Table 3). Of the seven gait metrics, six are associated with variability and one is associated with spatial measures of gait. In assessing post-*hoc* analyses of the six variability measures, all demonstrated significantly increased variability for OA ($F_{(1,122)} \geq 25.934$, $p < 0.0001$ for all). Additionally, stride length was significantly shorter for OA ($F_{(1,122)} = 17.604$, $p < 0.0001$). No other metrics demonstrated a significant main effects of age group.

Additional post-hoc analysis demonstrated sex differences for cadence, gait cycle duration, and step duration. Females showed a significantly faster cadence ($F_{(1,246)} = 70.414$, $p < 0.0001$), gait cycle duration ($F_{(1,246)} = 63.869$, $p < 0.0001$), and step duration ($F_{(1,246)} = 55.200$, $p < 0.0001$) compared to males. No other metrics demonstrated a sex difference.

4. Discussion

The aim of this study was to determine if a c6MWT provided additional information for gait metrics when compared to individual two-minute segments that comprise the c6MWT. Importantly, two-minute segments revealed no significant differences between each other from the c6MWT for all gait measures with the exception of strides completed. Similar to previous literature, the current results demonstrated impaired spatial measures of gait coupled with increased gait variability for OA. These results indicate that a 2MWT provides sufficient data to objectively quantify gait metrics while still able to identify age-related gait differences.

4.1. Segmental differences of the 6MWT

In assessing performance across each of the two-minute segments and the c6MWT, three gait metrics (cadence CoV, gait speed CoV and strides) demonstrated a significant main effect. Although we observed a significant main effect of walking segment for cadence and gait speed CoV, significance was not maintained at the pairwise level (p's ≥ 0.146 for cadence; p's ≥ 0.072 for gait speed). Suggesting a potential acclimation period during the first two minutes with increased variability subsiding during the remaining segments. Interestingly, the comparison of the first segment and c6MWT for both cadence and gait speed CoV demonstrate p's ≥ 0.999, suggesting the first segment strongly reflects the c6MWT values. While strides for the c6MWT were significantly greater than the two-minute segments, no differences in strides were found between the three, two-minute segments, demonstrating that each segment achieved a similar number of strides.

4.2. Age-related gait differences

The present findings are consistent with previous reports that observed various age-related gait changes [9–12]. Consistent with existing literature, our results demonstrate that OA experience an increase in variability [10–15]. Age-related increases to variability are thought to

Table 2
Summary of the effects each two-minute walking segment and the c6MWT on gait metrics both means and variability measures. Statistically significant differences are bolded.

Gait Metric		Segment 1 (0-120 sec) Mean ± SD	Segment 2 (121-240) Mean ± SD	Segment 3 (241-360) Mean ± SD	c6MWT (0-360) Mean ± SD	*p*-value
Cadence (steps/min)	Mean	116.76 ± 9.855	116.20 ± 10.035	116.06 ± 9.830	116.34 ± 9.861	0.993
	CoV	0.02 ± 0.006	0.02 ± 0.005	0.02 ± 0.005	0.02 ± 0.006	**0.042**
Double Support (%GCT)	Mean	19.83 ± 3.338	19.97 ± 3.372	19.97 ± 3.363	19.93 ± 3.346	0.999
	CoV	0.05 ± 0.017	0.05 ± 0.015	0.05 ± 0.015	0.05 ± 0.016	0.661
Gait Cycle Duration (s)	Mean	1.04 ± 0.085	1.04 ± 0.088	1.04 ± 0.086	1.04 ± 0.087	0.989
	CoV	0.02 ± 0.006	0.02 ± 0.006	0.02 ± 0.006	0.02 ± 0.006	0.190
Gait Speed (m/s)	Mean	1.25 ± 0.201	1.19 ± 0.203	1.19 ± 0.205	1.20 ± 0.202	0.998
	CoV	0.03 ± 0.009	0.03 ± 0.008	0.03 ± 0.009	0.03 ± 0.008	**0.027**
Strides	N	90.45 ± 7.037	91.03 ± 7.441	93.00 ± 8.104	278.58 ± 21.806	**0.0001**
Single Limb Support (%GCT)	Mean	40.27 ± 1.724	40.27 ± 1.695	40.16 ± 1.716	40.18 ± 1.736	0.992
	CoV	0.02 ± 0.005	0.02 ± 0.005	0.02 ± 0.005	0.02 ± 0.005	0.888
Stance (%GCT)	Mean	59.80 ± 1.739	59.76 ± 1.718	59.76 ± 1.741	59.80 ± 1.738	0.999
	CoV	0.01 ± 0.003	0.01 ± 0.004	0.01 ± 0.004	0.01 ± 0.003	0.967
Step Duration (s)	Mean	0.52 ± 0.046	0.52 ± 0.047	0.52 ± 0.055	0.52 ± 0.039	0.990
	CoV	0.02 ± 0.007	0.02 ± 0.008	0.02 ± 0.006	0.02 ± 0.007	0.755
Stride Length (m)	Mean	1.23 ± 0.153	1.22 ± 0.155	1.22 ± 0.147	1.23 ± 0.153	0.998
	CoV	0.02 ± 0.005	0.02 ± 0.004	0.02 ± 0.005	0.02 ± 0.004	0.501
Swing (%GCT)	Mean	40.20 ± 1.721	40.24 ± 1.718	40.24 ± 1.741	40.20 ± 1.738	0.999
	CoV	0.02 ± 0.005	0.02 ± 0.006	0.02 ± 0.006	0.02 ± 0.005	0.969

%GCT – percent gait cycle time, *CoV* – coefficient of variation, *c6MWT* – continuous six minute walk test.

Table 3
Summary of the main effects of age on gait metrics both means and variability measures. Statistically significant differences are bolded. Displayed means and SD are from the c6MWT.

Gait Metric		Domain	Young Mean ± SD	Old Mean ± SD	*p*-value
Cadence (steps/min)	Mean	Temporal	117.63 ± 7.192	114.97 ± 11.847	0.462
	CoV	Variability	0.02 ± 0.004	0.02 ± 0.007	**0.008**
Double Support (%GCT)	Mean	Temporal	18.96 ± 1.800	20.96 ± 4.165	0.097
	CoV	Variability	0.05 ± 0.006	0.05 ± 0.019	0.185
Gait Cycle Duration (s)	Mean	Temporal	1.02 ± 0.063	1.05 ± 0.102	0.332
	CoV	Variability	0.01 ± 0.004	0.02 ± 0.006	**0.002**
Gait Speed (m/s)	Mean	Temporal	1.25 ± 0.120	1.13 ± 0.246	0.088
	CoV	Variability	0.03 ± 0.005	0.04 ± 0.009	**0.001**
Strides	#	Spatial	139.09 ± 82.874	137.38 ± 82.389	0.671
Single Limb Support (%GCT)	Mean	Temporal	40.56 ± 0.905	39.86 ± 2.209	0.260
	CoV	Variability	0.02 ± 0.003	0.02 ± 0.005	**0.004**
Stance (%GCT)	Mean	Temporal	59.37 ± 0.955	60.22 ± 2.186	0.166
	CoV	Variability	0.01 ± 0.002	0.01 ± 0.004	**0.004**
Step Duration (s)	Mean	Temporal	0.51 ± 0.033	0.53 ± 0.045	0.311
	CoV	Variability	0.02 ± 0.003	0.02 ± 0.005	0.072
Stride Length (m)	Mean	Spatial	1.28 ± 0.098	1.17 ± 0.179	**0.049**
	CoV	Variability	0.02 ± 0.003	0.02 ± 0.005	**0.002**
Swing (%GCT)	Mean	Temporal	40.63 ± 0.946	39.78 ± 2.179	0.164
	CoV	Variability	0.014 ± 0.003	0.02 ± 0.007	**0.004**

%GCT – percent gait cycle time, *CoV* – coefficient of variation.

be associated with several factors including increased neuromotor noise [16], sarcopenia [17], proprioception deterioration [18], nerve conduction velocities, and increased time delays in the sensorimotor feedback loops [10]. Moreover, we demonstrate a significant difference in stride length which is commonly observed in healthy aging [19]. Finally, while two measures (stance and swing CoV) demonstrated an age by walking segment interaction, significance was not maintained in post-*hoc* analysis, indicating the differences observed are consistent throughout the c6MWT. Nonetheless, for studies specifically interested in measuring stance or swing CoV they may consider using the 6MWT.

5. Limitations

Based on a lack of differences between two-minute segments and the c6MWT, a 2MWT may be an applicable assessment of gait performance for various populations experiencing fatigue and/or neurodegenerative diseases, although further assessment is clearly warranted within these populations. Additionally, it is important to note that the c6MWT remains an importat meaure for gait performance. In assessing non gait-related performance such as the physiological effects of disease (i.e. cardiovascular and pulmonary), a conventional 6MWT likely remains a more appropriate test. Finally, this study is not assessing independent walking tests and instead deriving a two minute segment from a c6MWT, however, we contend this is the most direct way to assess potential differences between the two walking tests.

6. Conclusion

The present study demonstrates no significant differences between a c6MWT split into three, two-minute segments for 10 commonly reported gait metrics as measured with wireless inertial sensors. Additionally, these results show that OA experience decreased walking performance primarily evidenced by increased variability. Thus, a 2MWT may be the pragmatic choice for clinical care and research protocol design to reduce fatigue or other clinical cofounders, while providing adequate and accurate gait performance assessment.

Conflicts of interest

The authors have no conflicts of interest to report.

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