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The Impact of a Portable Metabolic Measurement Device on Gait Characteristics of Older Adults with Mobility Limitations

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Abstract

Background and Purpose—Increased carriage-loads have been found to alter gait biomechanics in young healthy adults and military personnel, however, less is known regarding the influence of added carriage-load on the gait characteristics of older adults- especially those with mobility limitations. The purpose of this study is to examine spatial and temporal gait characteristics during instrumented and non-instrumented overground walking in a sample of older adults with slow gait.

Methods—Forty older adults with slow gait completed 2 bouts of walking (instrumented and non-instrumented) over a computerized walkway during 1 clinic visit. Mean spatial-temporal characteristics, gait variability, and gait speed over 8 passes were recorded. Paired t-tests and intraclass correlation coefficients were used to quantify differences.

Results and Discussion—Nine of the 10 gait variables failed to statistically differ between instrumented and non-instrumented gait (p<.05). Intraclass correlation coefficients for mean gait characteristics were excellent (range ICC = .94-.98, 95% confidence interval = .89-.99), and for gait variability ranged from fair to excellent (range ICC = .56-.79, 95% confidence interval = .28-.89). Our study was able to demonstrate no significant impact of instrumentation on gait characteristics in a sample of older adults with slow gait.

Conclusion—Our findings begin to fill in the gaps in the literature regarding the impact of added carriage loads on more vulnerable populations, and lend support for the use of similar weighted metabolic devices as a component of gait assessment in older adults – with confidence that the additional carriage-load will not significantly impact concurrent measures of gait.

Keywords

Elderly; Gait analysis; load carriage

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INTRODUCTION

Once common only to the world of professional and elite-level athletic performance, portable metabolic assessment of energy expenditure (energy cost) during activity has found its way into the arena of geriatric research- specifically with the assessment of energy cost of walking among older adults.[1-3] Metabolic and energy cost of walking outcomes in older adults can serve as important indicators of decline in walking ability and overall health status, as well as key outcome measures for interventions targeting mobility disability.

The use of portable metabolic devices allows for the assessment of energy expenditure to be completed during athletic performance, or in the case of older adults – during functional task performance (i.e. walking), and within the confines of the task-specific environment. As such, portable metabolic devices need to be worn by the individual during the task, which subsequently adds to the carriage-load of the individual. While researchers have reported the physiological [4,5] and biomechanical [4-6] impact of increasing the carriage-load of an individual, the vast majority of the work has been done in healthy young adults and active military populations, using carriage-loads of up to 40-50% of body weight. [6] As such, a large gap exists in the literature regarding the impact of increased carriage-load (even subtle loads like that experienced with portable metabolic devices) on older adults, especially among older adults with mobility limitations whose walking may be more vulnerable to even subtle changes in carriage load. Older adults with mobility limitations comprise a large portion of the patient population seen by health care providers for assessment (i.e. energy expenditure, biomechanics) and treatment of gait disturbances, and are at greater risk for future mobility decline.[7-10] Therefore, it is important that we understand the potential biomechanical impact of instrumenting on older adults with portable devices, especially considering that spatial-temporal gait parameters are frequently assessed concurrently with measures of energy expenditure.

In an effort to begin bridging the existing gap in the literature regarding carriage-load in older adults, the purpose of our study was to examine spatial and temporal gait characteristics during instrumented (portable metabolic device) and non-instrumented overground walking in older adults with walking limitations. While instrumenting our sample of older adults with a portable metabolic device adds to the carriage load of each individual, we hypothesize that the additional carriage-load would not be enough to elicit meaningful changes in spatial and temporal gait characteristics, even within our sample of mobility limited older adults.

METHODS

Participants

Forty older adults with slow gait participated in this cross sectional study. Individuals were eligible to participate if they met the following criteria: 1) were 65 years of age or older, 2) able to ambulate a minimum of household distances (approximately 50 feet) without the use of an assistive device or assistance of another person, and 3) had a mean self-selected walking speed between 0.8-1.0 m/s. The range in gait speed was selected based on our interest in assessing influences on gait characteristics in a vulnerable but independent

sample of older adults at greater risk for functional decline – a population commonly assessed and treated for gait disturbances and limitations. Such characteristics have been well described in the literature for older adults with gait speeds within the range selected.

Older adults were excluded from participation for any of the following: inability to provide informed consent, concomitant neuromuscular disorders that impair movement, diagnosis of cancer with active treatment within the past 6 months, severe pulmonary disease, non-elective hospitalization for a life-threatening illness or major procedure within the past 6 months, chest pain with activity or a cardiac event within the past 6 months. Participants were recruited from a University registry, a registry of older adults interested in participating in studies of mobility and balance. The study was approved by the University Institutional Review Board, and all participants provided informed consent.

Procedures

Participants attended a single university-clinic visit. For the gait speed screening, participants were given 4 practice passes of walking over an 8-meter instrumented walkway with the instructions to "walk at your usual walking pace", after-which, 2 additional passes were completed and averaged to determine inclusion. Once eligibility was established, instrumented and non-instrumented bouts of walking were performed, each consisting of 8 consecutive passes (40-48 steps) – with a rest as needed between the two bouts. One bout of walking required participants to wear a lightweight portable gas analysis system[a] and battery pack (1.8 kg) attached to the front and back of a nylon shoulder harness, respectively (Figure 1). Participants were also fitted with a neoprene face mask typically worn during data collection with the gas analyzer. The gas analyzer had the following dimensions: width × 10.5 cm, depth × 14 cm, and height × 5 cm. A second bout of walking was performed without wearing the portable device. The order for the two bouts of walking was randomly assigned for each participant. A period of familiarization was provided prior to the start of the first trial. Although participants were fully instrumented with the gas analysis system, metabolic measures were not collected during this study visit.

Measures

Gait Characteristics—Mean gait characteristics (gait speed, step length, step width, step time, stance time, single-support time, and double-support time) over all 8 passes (40-48 steps) were recorded while participants walked at their self-selected, usual walking speed over an 8 meter long computerized walkway[b]. Gait variability measures were reported as the standard deviation of all steps for specific measures of step length, step width, and stance time. The initial and last 2 meters of the walkway were inactive and allowed for acceleration and deceleration, while the middle four meters were used for data collection.

Mean values for each gait variable were calculated by incorporating all steps within the 8 passes for each condition; variability measures were reported as the standard deviation of all steps within each condition. The instrumented walkway has shown good reliability in

[a]VO2000, Medgraphics Corp., 350 Oak Grove Pkwy, St. Paul, MN 55127
[b]GaitMat II, E.Q. Inc., PO Box 16, Chalfont, PA 18914

measuring gait characteristics, test-retest values range from ICC= .89-.99 for mean gait characteristics and from ICC= .40-63 for variability measures.[11]

Demographics and Comorbidity Measures—Demographic and comorbidity information was collected to describe our sample of older adults. The presence of co-morbidities was assessed using the Co-Morbidity Index,[12] which includes 18 different diseases, categorized to 8 domains (cardiovascular, respiratory, musculoskeletal, neurological, general, cancer, diabetes, and visual). The total number of positive domains (0-8) was recorded.

Data Analysis—Data were void of outliers, and all variables assessed for normal distribution. Descriptive statistics, mean and standard deviation, were calculated to summarize the data. Paired t-tests were used to assess significance of mean differences between the two walking conditions for each variable. For variables which were not normally distributed, nonparametric analysis (Related-samples Wilcoxon Signed Ranks Test) was used to assess significance of median differences. The intraclass correlation coefficient (ICC) (1,k) and its 95% confidence interval (CI) was used to assess the consistency and absolute agreement between the 2 walking conditions, for each variable. ICC's were interpreted as follows: less than 0.40, poor; 0.4 to 0.75, fair to good; and greater than 0.75, excellent.[13] PASW Statistics 18 (SPSS) software was used for all statistical analyses.

RESULTS

Of the 82 older adults screened, 40 participants met all criteria and went on to complete the study (Figure 2). Participants had a mean age of 76.9 years [standard deviation (SD) = 6.8 years], were primarily white (72.5%), female (90%), and reported an average 2.9 co-morbidities (SD = 1.4).

Mean Spatial and Temporal Gait Characteristics

Measures of gait speed, step length, step time, stance time, single-support time, and double-support time did not differ between instrumented and non-instrumented walking, $p > .05$ (Table 1). The lone variable to differ between the 2 bouts of walking was step width [(difference = -.003 m, p=.006), Table 1]. The negative value of the difference suggests that mean step width was greater when the portable gas-analysis system was worn; 70% (28/40) of the sample showed greater step width while wearing the device, ranging from a minimum of .001 meters to a maximum of .018 meters greater step width. The remaining 30% of the sample showed greater step width when walking without the portable device, with a similar range of .001 - .018 meters.

When assessing for agreement of each variable between the 2 bouts of walking, all 7 mean gait characteristics showed excellent agreement (ICC>.75); ICC values were highest for single-support time (ICC = .98) and lowest for gait speed (ICC = .94) (Table 1).

Gait Variability Measures

Similar to mean characteristics of gait reported above, gait variability measures (step length variability, step width variability, and stance time variability) did not differ between the 2 bouts of walking, $p > .05$ (Table 2).

The ICC values reported for the agreement of gait variability measures between instrumented and non-instrumented walking were generally lower than for the mean gait characteristics (Table 2). ICC values for the variability measures ranged from fair/good (stance time variability ICC = .56, step length variability ICC = .73) to excellent (step width variability ICC = .79).

DISCUSSION

This study assessed the impact of wearing a portable metabolic device on commonly assessed gait characteristics of older adults with mobility limitation. Despite the gait limitations of older adults in our sample, we found no evidence to suggest that instrumentation with a portable metabolic device significantly alters spatial-temporal gait characteristics.

Regardless of instrumentation with a portable device, 90% (9/10) of the spatial and temporal measures of gait failed to statistically differ from measures recorded during non-instrumented gait. Although the difference in step width was found to be statistically significant (-.003 m, p=.006), we consider this discrepancy to be clinically insignificant as the difference in step width between the 2 bouts of walking (.003 m) is less than the standard error of the measure.[8,11,14] However, it appears step-width may be more sensitive to even subtle increases in carriage load possibly due to mild changes to center of gravity when instrumented. It is also possible the difference in step width may be a compensation for mild impairment to the medial aspect of the visual field.

Carriage load

Previous studies of healthy young adults (mean age range= 21-25 years) have consistently shown that an increase in carriage load impacts levels of oxygen consumption and fatigue, as well as alters the biomechanics of gait; [4,5,15] the minimal additional carriage-load found to induce such changes in young adults was ~8 kg. While the portable metabolic device used in this study added a much smaller carriage load to our older adults, Kim and Lockhart reported that load increases as small as 10% appeared to have a greater influence on spatial-temporal gait characteristics in a healthy sample of older adults compared to their younger counterparts.[16] It would be reasonable to expect that older adults with mobility limitations, compared to their healthy older counterparts, would be more susceptible to alterations in gait and posture due to smaller loads placed on the body. Therefore, it is crucial that clinicians and researchers understand the potential impact of placing even smaller loads on more ‘vulnerable’ older adults. The portable gas analysis system used in this study imposed only a 4-pound increase in carriage load, which appears to have a negligible impact on gait in our sample of older adults with mobility limitations. While it makes sense that carriage loads weighing well below the 8 kg load would likely not impact older adults, as far as we know –

this is the first study to actually provide evidence supporting this assumption. Not only did we assess the impact of instrumentation on commonly assessed gait characteristics of older adults, but we assessed the impact in a sample of older adults with a common gait limitation. As portable measurement methods are becoming more commonplace in clinical and laboratory assessments of older adults with mobility limitations, understanding the impact of instrumentation is vital to ensuring the validity of such methods of gait assessment.

Gait Characteristics

The instrumented mean spatial and temporal gait characteristics appear consistent with non-instrumented gait values previously reported in the literature [14] for a similar population of older adults. Gait speed (.93 m/s to .93 m/s), stance time (.75 s to .76 s), step length (.54 m to .55 m), step length variability (.029 m to .029 m), and step width variability (.030 m to .037 m) recorded during instrumentation were similar to values reported by Brach et al in her study of non-instrumented older adults.[17]

Similar findings were noted for the ICC's; ICC's for our mean spatial and temporal variables ranged from 0.94 to 0.98, and were comparable to the range of non-instrumented ICC's reported by previous investigators (ICC 0.68-0.99). [11,17] Although generally lower than the ICC's for mean gait characteristics, the ICC's for gait variability between instrumented and non-instrumented gait were slightly higher (0.56-0.79) in our study compared to previous non-instrumented test/retest reports, (0.40-0.63) [11] - which is likely attributed to the greater number of walking passes performed in our study (8 passes) compared to previous reports (2 passes). [11,18]

While our primary interest was to assess the instrumentation of older adults and the potential impact the additional carriage load may have on gait characteristics, our study also able to address the possible concern that wearing a neoprene face mask could additionally impact gait by occluding portions of the visual field. Although visual fields were not formally assessed, based on the consistency of gait characteristics, it appears the face mask doesn't impact how participants view the environment to any significant degree as to impact gait outcomes.

Study Strengths

This study has important strengths. We collected data on a number functionally important and frequently assessed spatial and temporal gait characteristics in older adults, including measures of gait variability. This allowed us to perform a comprehensive assessment of the impact wearing a portable device may have on a wide range of gait characteristics in a sample of older adults who are frequently the prime target of researchers and clinicians for assessing gait, efficiency, and interventions to reduce risk for falls and decline in mobility. Furthermore, we collected data over 8 passes of 4-meter walking for each condition, increasing the total number of footfalls to be used for analyses, which in turn provided more reliable measures of gait variability in our sample of older adults.

Study Limitations

We also recognize a few limitations to our study. Our study participants were predominantly (90%) female, limiting the generalizability of the results concerning gait outcomes in males. We assessed the impact of wearing 1 type of portable gas-analysis system, the VO2000 (MedGraphics Inc), and therefore the findings should only be generalized to like systems of similar weight. Future studies should assess a range of portable devices (including those at the upper end of the weight scale) or a range of carriage loads to assess what specific load begins to impact biomechanics, energy cost, and gait characteristics in populations of older adults who are frequently prescribed such gait assessments. Additionally, we had a relatively small sample of older adults (n=40), and our findings may not represent the larger population of community-dwelling older adults. Our sample also consisted of older adults with slow gait; therefore, generalizations should be made to like groups using similar equipment.

CONCLUSION

For researchers and clinicians involved in instrumenting patients to assist with assessing gait-related outcomes (i.e. gait efficiency), it is essential that we understand the potential consequences that instrumentation may have on the gait characteristics within this vulnerable population. In our study of older adults with walking limitations, specific spatial and temporal measures of gait failed to differ and had excellent agreement between instrumented and non-instrumented walking. To further strengthen the literature in support of using portable measurement devices, we recommend ongoing research using larger samples sizes, addressing a variety of portable devices, and expanding outcome variables to include assessment of other components of gait and posture (ground reaction force, lower limb kinematics, and center of mass excursions) in older adults.

Acknowledgments

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Figure 1.
Portable metabolic measurement system

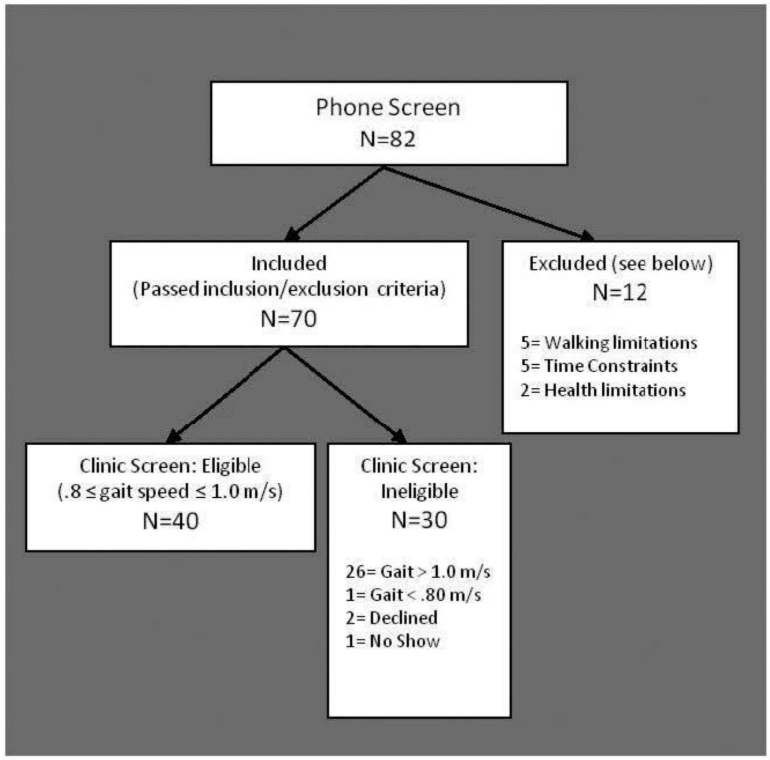

Figure 2.
Study recruitment flow chart

Table 1

Mean gait characteristics, differences, and agreement between walking conditions

Variables	Without Equipment Mean ± sd	With Equipment Mean ± sd	Difference Mean ± sd	t	p	ICC (95% CI)
Gait Speed (m/s)	.935 ± .114	.929 ± .122	.006 ± .040	.942	.353	.94 (.89-.97)
Step Length (m)	.546 ± .062	.542 ± .064	.004 ± .017	1.360	.183	.96 (.93-.98)
Step Width (m)	.038 ± .030	.041 ± .032	−.003 ± .007	−2.961	.006	.97 (.95-.99)
Step Time (s)	.587 ± .050	.588 ± .051	−.001 ± .014	−.327	.745	.96 (.93-.98)
Stance Time (s)	.751 ± .071	.755 ± .072	−.004 ± .022	−.965	.342	.95 (.91-.98)
Single-support Time (s)	.425 ± .047	.424 ± .046	.001 ± .009	.673	.506	.98 (.96-.99)
Double-support Time (s)	.162 ± .033	.165 ± .032	−.003 ± .010	−1.732	.092	.95 (.91-.98)

sd = standard deviation; ICC = intraclass correlation coefficient; CI = confidence interval

Table 2

Variability gait characteristics, differences, and agreement between walking conditions.

Variables	Without Equipment Mean ± sd	With Equipment Mean ± sd	Difference Mean ± sd	t	p	ICC (95% CI)
Step Length Variability (m)*	.030 ± .007	.029 ± .008	.002 ± .006	-	.935	.73 (.53-.85)
Step Width Variability (m)	.031 ± .008	.030 ± .008	.001 ± .005	1.024	.313	.79 (.63-.89)
Stance Time Variability (s)	.031 ± .005	.032 ± .009	−.001 ± .007	−.441	.662	.56 (.28-.75)

sd = standard deviation; ICC = intraclass correlation coefficient; CI = confidence interval

* nonparametric analysis performed