Gait Biomechanics, Spatial and Temporal Characteristics, and the Energy Cost of Walking in Older Adults With Impaired Mobility

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Background. Abnormalities of gait and changes in posture during walking are more common in older adults than in young adults and may contribute to an increase in the energy expended for walking.

Objective. The objective of this study was to examine the contributions of abnormalities of gait biomechanics (hip extension, trunk flexion, and foot-floor angle at heel-strike) and gait characteristics (step width, stance time, and cadence) to the energy cost of walking in older adults with impaired mobility.

Design. A cross-sectional design was used.

Methods. Gait speed, step width, stance time, and cadence were derived during walking on an instrumented walkway. Trunk flexion, hip extension, and foot-floor angle at heel contact were assessed during overground walking. The energy cost of walking was determined from oxygen consumption data collected during treadmill walking. All measurements were collected at the participants' usual, self-selected walking speed.

Results. Fifty community-dwelling older adults with slow and variable gait participated. Hip extension, trunk flexion, and step width were factors related to the energy cost of walking. Hip extension, step width, and cadence were the only gait measures beyond age and gait speed that provided additional contributions to the variance of the energy cost, with mean R^2 changes of .22, .12, and .07, respectively.

Limitations. Other factors not investigated in this study (interactions among variables, psychosocial factors, muscle strength [force-generating capacity], range of motion, body composition, and resting metabolic rate) may further explain the greater energy cost of walking in older adults with slow and variable gait.

Conclusions. Closer inspection of hip extension, step width, and cadence during physical therapy gait assessments may assist physical therapists in recognizing factors that contribute to the greater energy cost of walking in older adults.

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Abnormalities of gait and changes in posture during walking are more common in older adults than in young adults[1–4] and may contribute to an increase in the energy expended for walking.[5,6] The energy cost of walking at a comfortable speed has been shown to differ between older and young adults, with older adults having a greater energy cost of walking than young adults.[7] Oxygen consumption ($\dot{V}O_2$) and, ultimately, energy cost (mean $\dot{V}O_2$ standardized by gait speed) are important because they represent an individual's physiological ability to provide energy to support life and various levels of physical activity. Because routine physical activity accounts for 15% to 30% of an adult's total daily energy expenditure and because walking is the most prevalent physical activity for most people,[8] assessing the energy cost of walking in older adults can play a vital role in providing interventions for maintaining optimum independent functioning in older adults. A greater energy cost of walking has been related to a poorer self-report of function in older adults with mobility disability.[9]

The reason for the greater energy cost of walking in older adults remains unclear, although previous research indicated that certain biomechanical factors and gait characteristics may explain the increased cost. Waters et al[10] demonstrated that the energy cost of walking is greater for people with hip or ankle fusions and knee motion restrictions than for people without such restrictions. Researchers studying age-related differences in gait have shown that older adults have reduced gait speed,[2–4,7] less hip and knee extension, reduced ankle dorsiflexion angle at heel-strike,[2–4,11,12] decreased step and stride length, and altered step width.[1–4,13,14] Additionally, increases in double-support time, stance time, and quadriceps energy absorption[4,12,13,15] and a reduction in power during toe-off[4] also have been reported in older adults. Although the influences of gait speed[16,17] and step width[5] on the energy cost of walking were previously explored, the association between the energy cost of walking and other frequently assessed gait biomechanical factors (trunk flexion and reduced hip and ankle motion)[18–21] and gait characteristics (cadence, stance time, and step length)[18,20,22,23] has not been as well documented.

The purpose of this study was to examine the contributions of abnormalities of gait biomechanics (hip extension, trunk flexion, and foot-floor angle at heel-strike) and gait characteristics (step width, stance time, and cadence) that are commonly assessed in physical therapy research and clinical gait evaluations[14,18–27] to the energy cost of walking in older adults with impaired mobility. Physical therapists often assess the gait of older adults to guide clinical decision making for interventions and the prevention of future disabilities in mobility and activities of daily living. By identifying the primary factor or combination of factors that contributes to a greater energy cost of walking, physical therapists can target interventions to the underlying gait characteristics and biomechanical factors with the goal of improving walking efficiency in older adults.

Method

Study Design and Participants

Gait biomechanics, gait characteristics, and the energy cost of walking in the current cross-sectional study were evaluated as part of the baseline assessment for a pilot randomized controlled trial of 2 interventions for improving walking in older adults with mobility disability.[26] Gait measurements were collected during 2 baseline clinic visits that were 1 week apart.

Older adults aged 65 years or older who were community-dwelling, were able to ambulate without an assistive device other than a straight cane and without the assistance of another person, and had slow (walking speed of 0.6–1.0 m/s) and variable (step length coefficient variability of >4.5% or step width variability of <7% or >30%) gait participated in this study.[26] People who had dyspnea at rest, diagnosed dementia or cognitive impairment (defined as a Mini-Mental State Examination score of <24), hemiparesis with lower-extremity strength (force-generating capacity) of less than 4−/5 (manual muscle test grade), a fixed or fused lower-extremity joint or amputation, or a progressive motor disorder such as multiple sclerosis or Parkinson disease were excluded.

Fifty participants completed the baseline assessment. All participants signed a consent form approved by the University of Pittsburgh Institutional Review Board.

Procedure

Gait speed, mean step width, mean stance time, and cadence were assessed during walking on a GaitMat II* instrumented walkway. Trunk flexion, hip extension, and foot-floor angle at heel contact were assessed during overground walking shortly

* EQ Inc, PO Box 16, Chalfont, PA 18914-0016.

after the GaitMat II measurements were obtained. The energy cost of walking was determined from $\dot{V}O_2$ data collected during treadmill walking. All walking conditions were completed at the participants' usual, self-selected walking speed. Participants practiced on the treadmill during the initial clinic visit and were given ample time to achieve their usual walking pace before data collection on the second visit.

Measures

Gait characteristics: gait speed, mean step width, mean stance time, and cadence. The GaitMat II system is an instrumented walkway that is approximately 4 m long; the initial and final 2 m are inactive to allow for acceleration and deceleration. The automated gait analysis system is based on the opening and closing of pressure-sensitive switches that are represented on the computer screen as footprints when the participant walks on the walkway.

After 2 practice passes on the GaitMat II, participants completed 2 additional passes at their usual, self-selected walking speed for data collection. The mean for each gait characteristic was determined from the average values recorded during the 2 passes and used as the gait characteristic measure.[28] The GaitMat II has been shown to be a reliable and valid measurement tool for older adults[24,28–30] and has been widely used for gait analysis.[14,22,24,28–32]

Gait biomechanics: trunk flexion, foot-floor angle, and hip extension. We were specifically interested in trunk flexion, foot-floor angle at heel-strike, and hip extension during gait because abnormalities are commonly observed in these aspects of gait in older adults. Trunk flexion, foot-floor angle at heel-strike, and hip extension were determined by an assessor who was unaware of the participants' other gait measurements; the assessor viewed a videotape of the participants walking at their usual, self-selected speed over a level surface, with front, side, and back views. The assessments were made shortly after the GaitMat II data were recorded by use of the modified Gait Abnormality Rating Scale[27] (GARS-M); criterion-based item scores (0–3) were assigned for items 2, 4, and 5. Higher scores represent greater biomechanical abnormalities (for intrarater item reliability, generalized kappa=.676 and intraclass correlation coefficient=.984).[27]

Trunk flexion (GARS-M item 2) was assigned a value based on the severity of trunk flexion: a value of 0 was assigned when the trunk was positioned upright over the base of support at push-off, a value of 1 was assigned when the trunk was flexed slightly in front of the base of support at push-off, a value of 2 was assigned when the trunk was flexed over the anterior aspect of the foot at push-off, and a value of 3 was assigned when the trunk was held over the rear aspect of the stance foot.

The foot-floor angle at heel-strike (GARS-M item 4) was assigned a value of 0 when there was an obvious angle of the foot during impact of the heel on the ground, a value of 1 when the foot angle was barely visible during contact of the heel (before forefoot contact), a value of 2 when the entire foot landed flat on the ground, and a value of 3 when the anterior aspect of the foot struck the ground before the heel.

Hip extension (GARS-M item 5) was assigned a value of 0 when there was an obvious backward angle of the preswing thigh during double support, a value of 1 when the preswing thigh angle was beyond the vertical projection from the ground and was just barely visible, a value of

The Bottom Line

What do we already know about this topic?

A greater than usual energy cost of walking has been demonstrated for older adults, for people with restricted lower-extremity joint motion, and for persons with altered gait characteristics. Less is known about the relative contribution of specific age-related gait abnormalities to the energy cost of walking in older adults with mobility disability.

What new information does this study offer?

Gait abnormalities of hip extension, step width, and cadence were substantial independent contributors to the energy cost of walking in older adults with mobility disability.

If you're a patient, what might these findings mean to you?

A closer inspection of hip extension, step width, and cadence during physical therapy gait assessments may assist physical therapists in recognizing inefficiencies of gait. A better understanding of the underlying mechanisms of inefficient gait could be used to develop targeted interventions to improve gait efficiency.

Table 1.
Characteristics of Study Participants (N=50)

Measure[a]	Value
Age, y	76.7 (75.3–78.3)
Sex, % female	65
Energy cost, mL/kg·m	0.30 (0.27–0.33)
Gait speed, m/s	0.88 (0.84–0.93)
Comorbidities[b]	4.3 (3.7–5.0)
Step width, m	0.09 (0.07–0.12)
Stance time, s	0.74 (0.72–0.77)
Cadence, steps/min	100 (95–104)
GARS-M hip items[c]	
0	17 (34)
1	16 (32)
≥2	17 (34)
GARS-M trunk items[c]	
0	4 (8)
1	38 (76)
≥2	8 (16)
GARS-M ankle items[c]	
0	24 (48)
1	20 (40)
≥2	6 (12)

[a] Reported as mean (95% confidence interval) unless otherwise indicated.
[b] Up to 18 comorbidities.
[c] Reported as frequency (%) (for the 50 study participants). GARS-M=modified Gait Abnormality Rating Scale.

2 when the preswing thigh angle was in line with vertical, and a value of 3 when the preswing thigh angle was forward of vertical. Few participants had scores of 3 (severe limitation); therefore, we consolidated those with scores of 2 (moderate limitation) and those with scores of 3 (severe limitation) during the initial scoring into a group with scores of greater than or equal to 2. The GARS-M has been shown to be a reliable and valid assessment tool for analyzing gait,[22,27] and the psychometric properties of individual item scores have been demonstrated.[27]

Energy cost of walking. Energy cost was determined by use of indirect calorimetry and analysis of expired gases.[33,34] A metabolic measurement system (Medgraphics VO2000[†]) was used to measure $\dot{V}O_2$ at the physiological steady state for up to 6 minutes while the participants walked on a treadmill at their usual, self-selected walking speed. A measure of mean $\dot{V}O_2$ was determined by averaging $\dot{V}O_2$ recorded for 3 minutes during the physiological steady state[8] (at ~2–3 minutes after the initiation of walking at the usual, self-selected speed). The energy cost of walking (mL/kg·m) was calculated by dividing the body mass–corrected mean $\dot{V}O_2$ (mL/kg·min) by gait speed (m/min).

All participants were given time for treadmill familiarization during the first clinic visit and were encouraged to find their usual walking speed on the treadmill. To allow for ample familiarization, the energy cost data were collected during a second clinic visit. Participants were asked whether they had experienced any events or circumstances that might influence their ability to walk as they did at the first visit; no participant reported an alteration in ability to walk at the usual, self-selected pace.

Comorbidities

The presence of comorbidities was ascertained with the Comorbidity Index,[35] which includes 18 diseases. The total number of positive responses (0–18) indicating the presence of a particular disease was recorded.

Data Analysis

We used SAS version 9.2[‡] for all statistical analyses. We used appropriate descriptive statistics (mean, standard deviation, frequency, and percentage) to summarize participant characteristics. We computed the Pearson product moment and Spearman rank correlation coefficients, as appropriate, to quantify the association between the energy cost of walking and each of the gait measures.

To assess the influence of gait biomechanics on the energy cost of walking, we fit a series of multiple regression models with the energy cost of walking as the dependent variable and predictor variables chosen to be consistent with the theoretical postulation of contributors to the energy cost of walking on the basis of the literature and our clinical experience. For the first model (model 1), we included the predictor variables age and gait speed as well-known or obvious contributors to the energy cost of walking[3–5,11,14,15,36] and each measure of gait characteristics (step width, stance time, and cadence) and gait biomechanics (GARS-M hip, trunk, and ankle items). For the second model (model 2), with recognition of the importance of the hip,[11,37,38] we added the GARS-M hip item and each of the remaining measures of gait characteristics and gait biomechanics as additional predictor variables. The total number of predictor variables was limited to only 4 to avoid model overfitting because there were only 50 study participants.

We used R^2 for each model and the increase in R^2 between models to quantify the contributions of measures of gait biomechanics beyond age and gait speed to the energy cost of walking. We used the nested-model F test to assess statistical significance.

Role of the Funding Source

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[†] Medical Graphics Corp, 350 Oak Grove Pkwy, St Paul, MN 55127.
[‡] SAS Institute Inc, 100 SAS Campus Dr, Cary, NC 27513-2414.

Table 2.
Correlations Among Gait Characteristics and Biomechanical Factors

Variable	Correlation Coefficient (*P*) for: Age	Energy Cost	Gait Speed	Step Width	Stance Time	Cadence	Hip Extension	Trunk Flexion	Foot-Floor Angle
Age[a]	1.00	−.011 (.94)	−.355 (.01)	.230 (.11)	.103 (.48)	−.027 (.85)	.199 (.17)	.236 (.10)	.130 (.37)
Energy cost[a]		1.00	−.286 (.04)	.373 (<.01)	−.069 (.63)	.166 (.25)	.523 (<.01)	.395 (<.01)	.232 (.10)
Gait speed[a]			1.00	−.242 (.09)	−.484 (.01)	.279 (.05)	−.371 (<.01)	−.465 (.01)	−.546 (.01)
Step width[a]				1.00	−.215 (.13)	.352 (.01)	.497 (<.01)	.402 (.02)	.043 (.76)
Stance time[a]					1.00	−.918 (.01)	.057 (.69)	.140 (.33)	.156 (.28)
Cadence[a]						1.00	.113 (.44)	−.068 (.64)	−.011 (.94)
Hip extension[b]							1.00	.505 (<.01)	.463 (<.01)
Trunk flexion[b]								1.00	.259 (.07)
Foot-floor angle[b]									1.00

[a] Reported as Pearson correlation coefficient.
[b] Reported as Spearman correlation coefficient.

Table 3.
Additional Explanatory Power of Variables Beyond Age and Gait Speed and Beyond Age, Gait Speed, and Hip Extension

Added Variable	Model 1 (Age + Gait Speed + Added Variable)		Model 2 (Age + Gait Speed + Hip Extension + Added Variable)	
	R^2	Change in R^2 (*P*) With Added Variable	R^2	Change in R^2 (*P*) With Added Variable
Step width	.21	.12 (.01)	.34	.03 (.17)
Stance time	.16	.06 (.06)	.34	.03 (.16)
Cadence	.17	.07 (.05)	.33	.02 (.24)
Hip extension	.31	.22 (.002)		
Trunk flexion	.17	.08 (.12)	.33	.02 (.53)
Foot-floor angle	.17	.08 (.14)	.38	.06 (.12)

Beeson Career Development Award (K23 AG026766) for personnel, participant support for travel and time, data collection, and analyses.

Results

The mean age of the participants was 76.7 years (SD=5.4 years), and 65% were women. This sample of older adults with impaired mobility walked slowly (mean gait speed=0.88 m/s); had mild to moderate severities of trunk flexion abnormalities, reduced foot-angle contact, and hip extension abnormalities; and had a greater energy cost of walking (0.30 mL/kg·m) at their usual, self-selected walking pace than older adults without mobility problems (0.16 mL/kg·m)[38] (Tab. 1).

Three of the 6 gait characteristics and biomechanical factors assessed—hip extension, trunk flexion, and step width—were related to the energy cost of walking. The greater the severity of abnormalities of hip extension and trunk flexion and the wider the step width, the greater the energy cost of walking (Tab. 2).

Multiple linear regression analyses were performed for each measure, while controlling for age and gait speed, to assess the contribution of each measure to the energy cost of walking. Hip extension, step width, and cadence were the only gait measures beyond age and gait speed that provided additional contributions to the variance of the energy cost of walking (Tab. 3, model 1), with mean R^2 changes of .22 ($P<.002$), .12 ($P=.01$), and .07 ($P=.05$), respectively. Expanding the model to include 4 gait variables, while controlling for age, gait speed, and hip extension, failed to provide any additional factor explaining the variance in the energy cost of walking (Tab. 3, model 2).

The increase in the energy cost of walking with successive increases in the severity of hip extension abnormalities is shown in the Figure. The greater the severity of reduced hip extension (none, mild, and moderate), the greater the energy cost of walking, with values of 0.23, 0.31, and 0.36 mL/kg·m, respectively

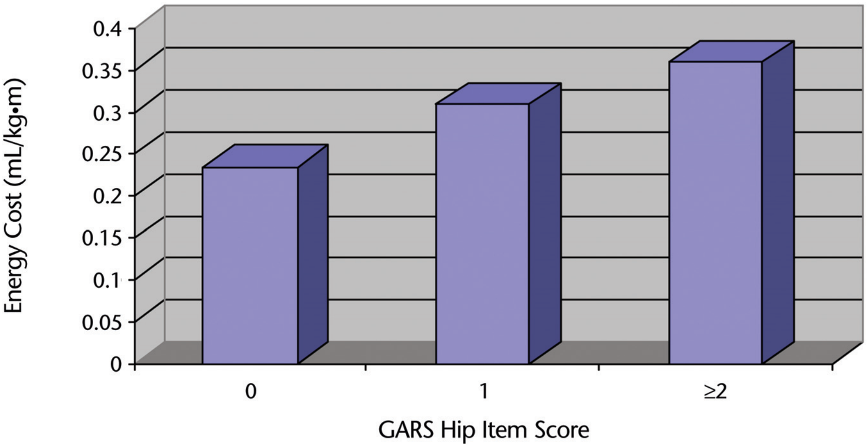

Figure.
Reduced hip extension and energy cost of walking. Energy cost was adjusted for age and gait speed. For GARS hip item scores, 0 represented no limitation in hip extension and ≥2 represented moderate to severe limitations in hip extension. For hip item scores of 1 versus 0, β=.08; for hip item scores of ≥2 versus 0, β=.13. A score of 1 was significantly different from a score of 0 at $P<.05$; a score of ≥2 was significantly different from a score of 0 at $P<.01$.

(F=4.98; df=4,48; P value for trend, .002).

Discussion

In our sample of older adults with slow and variable gait, the lack of hip extension during walking explained a substantial proportion of the variance in the energy cost of walking. Step width and cadence also contributed to the variance in the energy cost of walking, but to a lesser extent.

Our findings regarding the contributions of gait characteristics and gait biomechanics to the energy cost of walking are consistent with those of previous investigations. The older adults with greater step width values in the present study had a greater energy cost of walking. In earlier work, Donelan et al[5] reported that experimentally altered step width was a significant contributor to the energy cost of walking in adults (wider widths > narrower widths). They suggested that the increased energy cost associated with altered step widths was the result of the increased work required to redirect the body's velocity during step-to-step transitions and, to a lesser extent, the added work of moving the swing leg laterally to avoid the stance leg (narrow step width).[5] Likewise, we surmise that the additional work required with increased walking cadences is likely due to increased muscle demands for more frequent limb progression and ground contact.

Changes in muscle activity related to altered posture and associated compensation were suggested to be major contributors to the increased energy cost in a study performed by Saha et al,[6] who analyzed forceplate, kinematic, and metabolic energy data in a group of young adults. They reported that with increasing trunk flexion, there was a significant increase in $\dot{V}O_2$, most likely due to the increase in muscle activity needed to support the trunk and head against gravity and maintain upright balance.

In our sample of older adults with slow and variable gait, limitations in hip extension during walking accounted for 22% of the variance in the energy cost of walking. How do limitations in hip extension influence the energy cost of walking? In humans, the important peripheral sensory information for regulating stepping is the stimulus for signaling the transition from stance to swing. The sensory stimulus arises from sensory nerves in the anterior thigh and is activated by hip extension during gait as the foot moves behind the body.[36] Thus, hip extension is an important signal for firing of the central pattern generator neurons that are responsible for consistent stepping during gait[36,39,40]; the reduced hip extension observed with aging may diminish the signal needed for the central pattern generator to generate regular stepping. Without a clear and consistent signal for stepping, the timing of stepping in the gait cycle can become disrupted, leading to an altered and potentially more costly pattern of gait. Such disruptions to the normal gait pattern can alter muscle firing patterns and increase variability during the phases of gait, in turn requiring an increase in $\dot{V}O_2$ to meet the energy demand of additional or more frequently used muscles.

Greater energy demands during walking can have a significant impact on the energy reserves of older adults. On the basis of previous exercise testing and physiological research,[8,41] older adults with a mean age of 77 years and with slow and variable gait could be estimated to have a maximal $\dot{V}O_2$ of approximately 22 mL/kg·min.[42–44] We can estimate the $\dot{V}O_2$ associated with the severity of hip extension by multiplying the energy cost of walking at each level of hip abnormality by the mean gait speed of the sample. Oxygen consumption during walking at 0.89 m/s with no hip extension abnormality would be 12.3 mL/kg·min, or 59% of the estimated maximal $\dot{V}O_2$ for an older adult with slow and variable gait. Oxygen consumption associated with mild and moderate severities of hip extension abnormalities would be 16.6 and 19.2 mL/kg·min, respectively, and would account for 75% and 87% of the maximal $\dot{V}O_2$ for an older adult. Thus, older adults with more severe hip extension abnormalities are working closer to their maximal $\dot{V}O_2$ (75%–87%) just during typical walking, leaving a small energy reserve (13%–25%). Because walking has been shown to be the most frequently performed physical activity throughout the course of a day,[8] working at levels close to the maximum for $\dot{V}O_2$ may begin to limit how much reserve older adults have for performing other daily tasks and physical activities. Older adults with slow and variable gait and moderately severe hip extension abnormalities experience a greater energy cost during walking, reducing their reserve for completing other daily tasks. Although the difference in energy costs between mild and moderate severities of hip extension abnormalities (scores of 1 and 2) was not statistically significant, the difference of 0.044 mL/kg·m approaches a moderate meaningful difference of 0.05 mL/kg·m (SD × moderate effect size=difference) and would account for a 9% increase in $\dot{V}O_2$, to nearly 84% of maximal $\dot{V}O_2$.

A closer examination of the energy cost of walking in our sample of older adults without hip extension limitations revealed that the energy cost of walking remained greater than that reported for older adults without mobility disabilities (0.23 mL/kg·m versus 0.16–0.18 mL/kg·m). Our sample of older adults was selected on the basis of slow and variable gait, which may account for the greater cost of walking in these adults than in older adults without these characteristics. Additionally, the greater energy cost may be explained by the fact that other gait abnormalities were observed in older adults with slow and variable gait. Of the 16 older adults without hip extension limitations (GARS-M hip item score=0), 13 appeared to have altered step widths (wide or narrow), 10 had a higher-than-normal walking cadence, 14 had some trunk flexion abnormality, and 3 had a mild degree of decreased foot-floor contact angle at heel-strike. Additionally, the mean stance time variability (the SD of stance time) of our sample of older adults with slow and variable gait was 0.076 second, greater than the value of 0.037 second that has been associated with mobility disability.[45] Although not measured in the present study, stance time variability also may influence the energy cost of walking.

Limitations

The results of the present study must be interpreted with some caution and applied to similar samples of older adults with slow and variable gait. Our study was cross-sectional in nature; therefore, we cannot infer a cause-effect relationship between the gait variables and energy cost. Measurements of $\dot{V}O_2$ and gait biomechanics were not collected concurrently; gait biomechanics and characteristics were measured within minutes of each other, whereas $\dot{V}O_2$ data were collected during treadmill walking at a second clinic visit, 1 week later. We believe that nonconcurrent measurement collection had little impact on our findings because measures of mean gait speed and gait characteristics have been shown to have good test-retest reliability[28] and because all measurements were obtained at a usual, self-selected walking pace under typical circumstances.

Views regarding the energy cost of walking at similar speeds on a treadmill versus overground continue to differ within the literature. In young adults who were healthy, Stoquart et al[46] compared the cost of walking at various speeds on a treadmill with the energy cost assessed overground at the same speeds by DeJaeger et al[47] and reported that the actual cost values were lower during the treadmill walking versus overground walking, whereas the mean energy costs of walking at like speeds were similar. A different outcome was reported by Parvataneni et al,[48] who recently investigated the metabolic cost of treadmill versus overground walking in older adults who were healthy and reported a 23% higher metabolic requirement during treadmill walking. Although this is a substantial difference in energy cost between the 2 walking conditions, data are lacking regarding the potential for greater agonist-antagonist co-contraction during treadmill walking without handrails, which may account for the increased cost of walking.

As seen above, the few studies that have compared the energy cost of treadmill and overground walking have been performed primarily on young or older adults who were healthy. In our study of slow and variable older adults, we believe that there is the potential that the treadmill may have positively influenced the biomechanics (ie, improved hip extension) of the participants, thereby reducing the full impact of biomechanics on the energy cost of walking, resulting in a lower cost of walking than would have been observed overground. The treadmill has been shown to promote improved gait mechanics in individuals with abnormal gait[25] and to reduce some forms of gait variability,[49] which we think may allow for a more efficient form of gait and potentially lower the energy cost of walking in individuals with mobility disability compared with overground walking (and young adults who are healthy). The differences observed in the current literature support the need for continued research regarding the best and most accurate method of assessing the cost of walking in older adults.

We understand that factors other than those investigated in the present study (eg, interactions between gait variables, psychosocial factors, muscle strength, range of motion, body composition, resting metabolic rate) may further explain the greater energy cost of walking in older adults with slow and variable gait. We encourage future investigations with larger samples of older adults to allow more factors to be placed in models attempting to explain the variance of the energy cost of walking. We also recognize that the use of an observational assessment of gait biomechanics has a limited ability to discriminate small differences in biomechanics compared with motion analysis; however, the observational assessment has been shown to be a reliable and valid measure[22,27] of gait abnormalities and is a feasible and affordable method of assessment for most clinical settings.

Interventions aimed at addressing limitations in hip extension during gait continue to evolve. Some earlier research revealed slight improvements in peak hip extension during gait in older adults after an intervention aimed at improving static hip extension range of motion.[37] However, more recent work suggested that the reduction in peak hip extension seen during walking in older adults is related to gait (dynamic) rather than postural decline.[50] On the basis of the idea that reduced hip extension during gait may be related to gait rather than posture, VanSwearingen et al[26] implemented a movement control intervention (timing and coordination) that secondarily engaged greater hip extension. They reported an improvement in the efficiency (reduction in the energy cost) of walking in a group of older adults with mobility problems. Longitudinal studies investigating the natural history of gait abnormalities and biomechanical changes during walking would provide a better understanding of the patterns and contributions of gait limitations to the energy cost of walking and further enhance the ability to provide early and effective interventions for restoring efficient walking in older adults.

Conclusions

Mechanisms related to the initiation and stepping patterns of gait, such as hip extension, step width, and cadence, were found to be related to the energy cost of walking in older adults with slow and variable gait. A closer inspection of hip extension, step width, and cadence during physical therapy gait assessments may assist physical therapists in recognizing factors that contribute to the greater energy cost of walking in older adults and suggest specific interventions aimed at returning older adults to a more efficient pattern of walking.

All authors provided concept/idea/research design, writing, and data analysis. Mr Wert, Dr Brach, and Dr VanSwearingen provided data collection. Dr VanSwearingen provided project management. Dr Brach and Dr VanSwearingen provided fund procurement and facilities/equipment.

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