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Altered Spatiotemporal Characteristics of Gait in Older Adults with Chronic Low Back Pain

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Abstract

Previous studies in older adults have identified that chronic low back pain (CLBP) is associated with slower gait speed. Given that slower gait speed is a predictor of greater morbidity and mortality among older adults, it is important to understand the underlying spatiotemporal characteristics of gait among older adults with CLBP. The purposes of this study were to determine (1) if there are differences in spatiotemporal parameters of gait between older adults with and without CLBP during self-selected and fast walking and (2) whether any of these gait characteristics are correlated with performance of a challenging walking task, e.g. stair negotiation. Spatiotemporal characteristics of gait were evaluated using a computerized walkway in 54 community-dwelling older adults with CLBP and 54 age- and sex-matched healthy controls. Older adults with CLBP walked slower than their pain-free peers during self-selected and fast walking. After controlling for body mass index and gait speed, step width was significantly greater in the CLBP group during the fast walking condition. Within the CLBP group, step width and double limb support time are significantly correlated with stair ascent/descent times. From a clinical perspective, these gait characteristics, which may be indicative of balance performance, may need to be addressed to improve overall gait speed, as well as stair-climbing performance. Future longitudinal studies confirming our findings are needed, as well as investigations focused on developing interventions to improve gait speed and decrease subsequent risk of mobility decline.

Keywords

Aging; Low Back Pain; Gait; Stairs

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INTRODUCTION

Among older adults, low back pain is a highly prevalent condition and costs are on the rise. [1–3] Estimates from Medicare data suggest a nearly \$1 billion increase in costs in recent years.[3] The majority of these costs are associated with the management of individuals who develop chronic low back pain (CLBP).[4] Since 75% of long term care residents and more than 50% of community dwelling older adults experience some form of chronic pain,[5] it is critically important to consider the direct impact of pain on daily function in older adults.

Although all older adults are at risk for mobility limitations, older adults with CLBP may be at greater risk for functional decline. In fact, several epidemiologic studies have demonstrated that low back pain is independently associated with functional decline, particularly walking performance.[6–8] In previous studies of geriatric low back pain, walking performance has primarily been assessed through evaluation of walking on level surfaces;[6, 9] but, stair negotiation, which has been rated as one of the top five most difficult mobility tasks for older adults, has undergone limited evaluation in the geriatric CLBP population.[10] It is well-established in the geriatric literature that gait speed over level ground is a powerful predictor of mobility disability and mortality.[11–13] Oh-Park and colleagues have also demonstrated that stair negotiation time is associated with functional decline in the general geriatric population.[14] Further, there is a large body of literature describing the spatiotemporal characteristics of gait that underpin and explain walking performance in older adults; and these individual characteristics have also been independently linked to mobility problems.[15, 16] By having a greater understanding of the underlying spatiotemporal gait characteristics seen in this group, we may be able to more effectively address mobility deficits in the geriatric CLBP population,

In this study, we examined differences in gait speed at both self-selected and fast walking paces, as well as differences in stair negotiation time, between older adults with and without CLBP. We also examined differences in spatiotemporal parameters of gait between the pain groups, with and without adjustment for walking speed. Finally, we sought to determine whether any of the spatiotemporal parameters of gait captured during overground walking on a level surface would be correlated with stair negotiation performance in the CLBP population.

METHODS

Participants

This secondary analysis included baseline participant data from a sample of community-dwelling, cognitively intact (Folstein Mini-Mental State Exam score ≥ 24) older adults with CLBP who were enrolled in a randomized preliminary trial;[17] CLBP participants were compared to a sample of older adults without CLBP. For this study, older adults were defined using the range 60–85 years. CLBP participants met the following pain criteria: 3/10 pain intensity, occurring ≥ 4 days per week, and a minimum duration of 3 months.[9] CLBP participants were excluded if they had any of the following: a prominent component of radicular pain below the knee, known spinal pathology other than osteoarthritis (i.e. a history of recent trauma, vertebral compression fractures, ankylosing spondylitis, carcinoma

metastatic to the spine), history of lumbar surgery, severely limited mobility (i.e. needed assistive device for household ambulation), progressive neurological disorders, or terminal illness. Older adults without CLBP were included if they had no LBP at enrollment and were excluded if they had any of the following: history of lumbar surgery, received treatment for CLBP in the past 6 months, severely limited mobility, progressive neurological disorders, or terminal illness. All participants were recruited from newspaper advertisements, retirement communities, and local community centers. For the CLBP group, 211 people were screened, 145 were excluded, and 66 were enrolled in the study. For the group without CLBP, 71 people were screened, 14 were excluded, and 57 were enrolled. Participants from the CLBP and non-CLBP groups were matched on sex and age (± 2 years); and, 54 participants from each group were included in the final analysis. All policies and procedures were followed in accordance with the proposal approved by the University of Delaware Institutional Review Board. All participants signed an informed consent form.

Demographics and Self-Ratings

Participants reported their age and sex, while the modified Oswestry Disability Questionnaire (mODQ) was used to measure low back pain-related disability. The mODQ is a self-report instrument, which measures perceived functional limitation due to low back pain on a 0–100% scale. Higher scores indicate greater disability. Hicks & Manal have found the mODQ to be reliable and valid among older adults.[18] The numeric pain rating scale (0–10) was used to measure pain intensity with anchors from 0 (“no pain”) to 10 (“worst possible pain”). Current pain intensity, as well as best and worst pain intensity in the previous 24 hours, were measured using this method, which has shown to be reliable and valid[19]. All three pain ratings were averaged for a composite pain intensity rating.

Gait Assessment

The GaitMat II™ system (E.Q. Inc., Chalfont, PA), a computerized 4-meter walkway, was used to collect and analyze gait data. At either end of the walkway, there are inactive segments (1 meter) which allow for walking acceleration and deceleration. After two practice trials, each participant walked on the GaitMat II™ three times at their self-selected walking speed and three times at their fastest, safe walking speed. The following gait characteristics were measured: gait speed, stride length, step width, swing time, stance time and double limb support time.

Stair Negotiation

The stair climbing test (SCT) was used to assess stair negotiation as older adults have rated stairs as one of the top 5 tasks “most difficult” due to “old-age.”[10, 20, 21] Participants were timed as they ascended and descended 12 standard steps. A hand rail was available for participants during testing if needed; but, they were encouraged to ascend and descend the stairs with their legs only if able to do so safely. Ascent and descent were performed at each person’s self-selected speed and timed to the nearest hundredth of a second with a standard stopwatch. Given the challenge of stair-climbing, the SCT is able to measure higher levels of function than other performance tests and reduces possible ceiling effects.[22]

Statistical Analysis

Statistical analyses were performed using SPSS 23 (SPSS, Inc. Armonk, NY). Descriptive analyses were performed for both groups, including demographic characteristics, pain-related disability, and average pain intensity. Controlling for differences in body mass index (BMI), multivariate analysis of variance (MANOVA) was performed to test overall between-group differences in gait speed and stair negotiation time. Analysis of covariance (ANCOVA) was then used to further explore univariate differences in performance. For the analysis of spatiotemporal parameters, the same approach of using MANOVA followed by ANCOVA was used for each walking pace condition (self-selected and fast); but, initially, the analyses were adjusted for BMI alone followed by an additional adjustment for gait speed to explore whether between-group differences were independent of speed. To better understand the magnitude of differences between pain groups, standardized effect sizes were calculated for all gait outcomes. Standardized effect size was calculated by subtracting the mean gait value of the CLBP group from the mean value of the group without CLBP and then dividing the difference by the pooled standard deviation of the 2 scores.[23]

For the CLBP group, separate linear regression models were computed with stair ascent and descent times as the dependent variables. This approach allowed exploration of the unique correlation between spatiotemporal gait measures and stair negotiation, beyond age, sex, BMI and pain. Multicollinearity was found between stance time and double limb support time (i.e. variance inflation factor >4)[24]; therefore stance time was not included in regression modeling. In the first step, age, sex, BMI and pain were entered, followed by addition of stride length, step width, swing time and double support time from the self-selected walking speed assessment. Finally, for each dependent variable, a reduced, final regression model was constructed that only included those independent variables that were significantly associated with the dependent variable of interest. Standardized beta (β) coefficients are reported for each independent variable included in the final reduced models to allow for direct comparison between independent variables in the model as they relate to the dependent variable being studied.

RESULTS

Participants

Participant demographics are provided in TABLE 1. Groups were matched on age (± 2 years) and sex, but those with CLBP had a higher BMI ($p=.044$). The average pain rating, pain duration and mODQ scores indicate that our CLBP group met the inclusion criteria of longstanding, moderately severe pain.

Gait speed and stair negotiation time between older adults with and without CLBP

After controlling for BMI, MANOVA indicated a significant overall difference between groups for gait speed and stair negotiation time ($p=.003$). Follow-up univariate ANCOVAs, as seen in table 2, indicated that older adults with CLBP walked slower than their pain-free peers at both self-selected and fast gait speeds, as well as during stair ascent and stair descent.

Spatiotemporal parameters between older adults with and without CLBP

After controlling for BMI, MANOVA indicated a significant overall difference between groups for spatiotemporal parameters of gait ($p=.002$) at a self-selected speed. At self-selected speed with adjustment for BMI alone (Table 3), there were significant between-group differences with medium to large effect sizes for all spatiotemporal characteristics under examination, except swing time ($p=.358$). After additional adjustment for gait speed, MANOVA indicated that the overall significant between-group differences in spatiotemporal characteristics cease to exist ($p=.538$).

Under the fast walking condition, MANOVA indicated a significant overall difference between groups for spatiotemporal parameters of gait ($p=.036$), when controlling for BMI alone; but, univariate analyses indicated that the only statistically significant difference was found for step width. While the overall difference from MANOVA was found to be non-significant after adjustment for gait speed ($p=.395$), there was still a significant between-group difference for step width with CLBP patients walking with a wider base of support ($p=.034$).

Association of spatiotemporal characteristics of gait with stair negotiation

For stair ascent, the covariates entered in step 1 (age, sex, BMI and pain) explained 39.7% of the variance in stair ascent time ($F \text{ Change}=10.75$, $p<.0001$); the addition of the spatiotemporal characteristics (stride length, step width, swing time and double support time) explained an additional 26.7% of the variance ($F \text{ Change}=8.91$, $p<.0001$). For stair descent, the covariates entered in step 1 explained 31.7% of the variance in stair descent time ($F \text{ Change}=7.57$, $p<.0001$); inclusion of the spatiotemporal characteristics explained an additional 38.9% of the variance ($F \text{ Change}=14.89$, $p<.0001$). Assumptions of parametric testing were satisfied, so no further analysis was needed.

Table 3 delineates the final reduced regression models for stair ascent and descent. Age, sex, step width and double support time explained a significant amount of variance in both stair ascent and descent. Double support time is a strong predictor in both models. The standardized beta coefficient would indicate that a one standard deviation (SD) increase in double support time would be associated with a .486 SD increase in stair ascent time and a .467 SD increase in stair descent time. Greater step width was also associated with slower stair negotiation, as well as older age and being female. We also explored the same relationships in older adults without CLBP. No additional variance in stair ascent time was explained by any spatiotemporal parameters. But, for stair descent, double limb support time was a significant predictor that explained an additional 9.8% of variance, above the 19.5% of variance explained by age, sex and BMI.

DISCUSSION

In this comparative study of older adults with and without CLBP, we have found that the presence of CLBP is associated with slower gait speed; and, this finding is consistent with previous research.[6, 9] But, we have also been able to advance knowledge regarding gait speed in the CLBP population by describing the underlying spatiotemporal characteristics of

gait that are associated with walking speed when walking at a self-selected or fast pace. Notably, greater step width was consistently associated with the presence of CLBP during the fast walking condition, regardless of adjustment for gait speed. Additionally, we have identified step width and double limb support time as spatiotemporal characteristics of gait that are significantly correlated with stair-climbing performance, a more challenging form of locomotion than gait on a level surface.

This is the first study to elucidate the gait characteristics of older adults with CLBP beyond just speed. In the context of this investigation, we found that older adults with CLBP had shorter stride lengths, greater step width, greater stance times and longer periods of double support time, as well as slower walking speeds overall. Once we controlled for speed in our analyses, the differences in the spatial (stride length and step width) and temporal parameters (stance time and double support time) of gait were significantly reduced; but, from an intervention standpoint, these spatiotemporal characteristics, which impact overall gait speed, may deserve further exploration. Since gait speed is a strong predictor of future mobility limitations and falls among older adults[11–13], it appears that the CLBP population may be at greater risk for incident mobility disability than their pain-free counterparts. It has also been posited that a self-selected gait speed of 1.2m/s or greater is indicative of exceptional life expectancy, whereas a gait speed of 1.0m/s may indicate a better than average life expectancy.[11] Given that the average self-selected gait speed of these CLBP participants is closer to 1.0m/s, it is also likely that CLBP patients may be at risk for a reduced life expectancy compared to their pain-free peers, potentially through a pathway of mobility disability. Future intervention studies for this CLBP population may need to include focused gait interventions that target specific gait parameters during training to address the important outcome of gait speed. For example, recent clinical trials from Brach et al. and VanSwearingen et al. have shown that motor skill gait training, which targets specific gait characteristics through repetitive practice of timing and coordination of gait, can improve gait speed and improve the energy cost of walking more efficiently than a standard walking and strengthening program.[25–27]

It is also important to note that this is the first study to explore self-selected and fast gait speeds among older adults with CLBP; these two speeds provide overlapping, but different information about functional capacity in the geriatric population. Self-selected gait speed provides us with data regarding the individual's preferred pace in everyday life; whereas, fast gait speed provides information about the actual walking capacity of the individual when a more robust effort is undertaken. Interestingly, under fast walking conditions, we see that CLBP participants walk with a significantly wider base of support, regardless of whether the analysis controls for gait speed. While we cannot ascertain what is considered a clinically important difference in step width from existing literature, our effect sizes represent a medium-sized between-group difference for step width. Future work is needed to determine the clinical significance of this finding. Widened bases of support during gait are typically indicative of poor dynamic balance control.[28] We did not do a formal assessment of dynamic balance in this study, but we did assess static balance performance. Therefore, in a post-hoc analysis, we explored the relationship between step width and balance performance using the balance component of the Short Physical Performance Battery (side by side stance, semi-tandem stance and tandem stance; scored 0–4 with higher scores

indicating better balance).[29] The Spearman Rank correlation coefficient between step width and balance performance was -0.39 ($p=.003$) in the CLBP group and -0.13 ($p=.270$) in the group without CLBP. It would appear that greater step width is associated with worse balance performance amongst these older adults with CLBP. Given that poor balance control is a risk factor for falls in the geriatric population, [30] our findings of increased step width during gait may begin to explain why other studies have consistently demonstrated that older adults with CLBP are at increased risk for falling as compared to pain-free elders.[31–33] These findings of greater step width in the CLBP population may indicate that more thorough assessment and treatment of balance is required in the geriatric CLBP population.

Consistent with their performance on level ground, older adults with CLBP were slower in their stair negotiation time than their peers. When one considers that poor stair performance is a predictor of functional decline in older adults, independent of gait speed[14], it becomes even more critical to gain an understanding of specific factors associated with stair performance in this already vulnerable CLBP population. Step width and double limb support time during self-selected gait were strongly associated with stair negotiation time, explaining nearly 26% and 38% of the variance in stair ascent and descent times, respectively. It is also interesting to find that the same strength of relationships do not exist among our participants without CLBP, who walk at a more ideal gait speed. Future work should also focus on stair negotiation performance as an important outcome in the CLBP population if we hope to improve function and delay mobility disability in this group.

Several limitations must be considered. Due to the cross-sectional nature of the study, we cannot draw any conclusions about how self-selected and fast gait speeds may change over time; nor can we determine whether there is a causal link between spatiotemporal gait characteristics and stair performance. Another limitation is the racial homogeneity of the sample, which limits the generalizability to community-dwelling older white adults. Finally, the difference in BMI between pain groups may have predisposed the CLBP group, which has the higher BMI, toward walking slower and having wider steps. While this may be a limitation, it is important to note that we have appropriately controlled for BMI in the analyses.

CONCLUSION

Our results indicate that older adults with CLBP exhibit significantly different gait patterns compared to age- and sex-matched older adults without CLBP during both self-selected and fast walking conditions. Under fast walking conditions, greater step width was clearly associated with CLBP. Step width and double limb support time, were significantly associated with stair ascent and descent performance. From a clinical perspective, these gait characteristics, which may be indicative of balance performance, may need to be addressed to improve overall gait speed, as well as stair-climbing performance. Future longitudinal studies confirming our findings are needed, as well as longitudinal intervention studies designed to equally address both pain and gait performance in this geriatric CLBP population.

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Highlights

- Older adults with low back pain (LBP) walked slower than pain-free peers.
- Increased step width was uniquely associated with the presence of low back pain.
- For those with LBP, step width uniquely contributed to stair performance.
- These data may indicate the reason for mobility decline in the geriatric LBP group.

Table 1

Participant Characteristics

Characteristics	CLBP (n=54)	No CLBP (n=54)
Age, yrs	69.3 (6.7)	71.1 (6.8)
Female sex, n (%)	37 (68)	37 (68)
BMI, kg/m ²	29.1 (5.6) *	27.0 (4.8)
White race, n (%)	51 (94.4)	49 (90.7)
LBP Duration, months	34.9 (3.9)	-
Average Pain Intensity (0–10)	3.4 (1.6)	-
Oswestry LBP Questionnaire (0–100)	33.9 (10.9)	-

Data represent mean and SD unless otherwise noted.

*
p<.05

Between-group differences for gait speed and stair negotiation time for older adults with and without CLBP

Table 2

	CLBP	No CLBP	Difference (95% CI)	p-value	Effect Size
Gait Speed (m/s)					
Self-Selected	1.06	1.22	-.158 (-.272, -.014)	.000	.76
Fast	1.46	1.59	-.143 (-.244, -.073)	.030	.42
Stair Negotiation Time (s)					
Stair Ascent	7.11	6.10	1.01 (0.28, 1.75)	.007	.50
Stair Descent	7.12	5.55	1.56 (0.30, 2.83)	.016	.46

Between-group differences for spatiotemporal parameters of self-selected gait for older adults with and without CLBP

Table 3

	CLBP	No CLBP	Difference (95%CI)	p-value	Effect Size
Adjusted for BMI					
Stride Length (m)	1.19	1.31	-.122 (-.192, -.052)	.001	.70
Step Width (m)	.048	.032	.016 (.001, .032)	.035	.44
Swing Time (s)	.395	.388	.007 (-.008, .022)	.358	.20
Stance Time (s)	.741	.700	.042 (.006, .077)	.021	.48
Double Support Time (s)	.166	.146	.020 (.005, .035)	.009	.50
Adjusted for BMI and self-selected gait speed					
Stride Length (m)	1.25	1.26	-.013 (-.053, .027)	.518	.07
Step Width (m)	.046	.035	.011 (-.005, .027)	.161	.31
Swing Time (s)	.389	.394	-.005 (-.020, .010)	.526	.14
Stance Time (s)	.717	.723	-.008 (-.014, .030)	.485	.09
Double Support Time (s)	.157	.156	.001 (-.009, .012)	.810	.03

Between-group differences for spatiotemporal parameters of fast gait for older adults with and without CLBP

Table 4

	CLBP	No CLBP	Difference (95%CI)	p-value	Effect Size
Adjusted for BMI					
Stride Length (m)	1.34	1.41	-.069 (-.170, .032)	.178	.29
Step Width (m)	.055	.035	.019 (.004, .035)	.016	.50
Swing Time (s)	.345	.329	.015 (-.016, .047)	.327	.21
Stance Time (s)	.599	.570	.029 (-.009, .068)	.133	.31
Double Support Time (s)	.118	.105	.012 (-.002, .027)	.093	.33
Adjusted for BMI and fast gait speed					
Stride Length (m)	1.38	1.37	.014 (-.059, .087)	.704	.06
Step Width (m)	.053	.037	.016 (.001, .032)	.034	.42
Swing Time (s)	.339	.335	.005 (-.025, .035)	.760	.07
Stance Time (s)	.586	.583	.003 (-.024, .030)	.821	.03
Double Support Time (s)	.113	.110	.003 (-.006, .012)	.543	.08

Table 5

Reduced final linear regression models for Stair Negotiation

	Stair Ascent	Stair Descent
R ²	.655	.697
Adjusted R ²	.619	.665
F	17.87	21.62
p-value	<.0001	<.0001
Independent Variable	Standardized β	Standardized β
Age	.248	.234
Sex	-.367	-.211
Step Width	.271	.439
Double Support Time	.486	.467
	t	t
	p-value	p-value
	.016	.015
	<.0001	.017
	.006	<.0001
	<.0001	<.0001