Distance-Induced Changes in Walking Speed After Stroke: Relationship to Community Walking Activity

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**Background and Purpose:** Physical inactivity is a major contributing factor to reduced health and quality of life. The total distance walked during the 6-Minute Walk Test is a strong indicator of real-world walking activity after stroke. The purpose of this study was to determine whether measurement of distance-induced changes in walking speed during the 6-Minute Walk Test improves the test’s ability to predict community walking activity.

**Methods:** For 40 individuals poststroke, community walking activity (steps/d), the total distance walked during the 6-Minute Walk Test (6MWT_total), and the difference between the distances walked during the final and first minutes of the test (Δ6MWT_min6–min1) were analyzed using moderated regression. Self-efficacy, assessed using the Activities-specific Balance Confidence scale, was also included in the model.

**Results:** Alone, 6MWT_total explained 41% of the variance in steps/d. The addition of Δ6MWT_min6–min1 increased explanatory power by 29% (ΔR² = 0.29, P < 0.001). The final model accounted for 71% of steps/d variance (F4,32 = 19.52, P < 0.001). Examination of a significant 6MWT_total × Δ6MWT_min6–min1 interaction revealed a positive relationship between 6MWT_total and steps/d, with individuals whose distances declined from minute 1 to minute 6 by 0.10 m/s or more presenting with substantially fewer steps/d than those whose distances did not decline.

**Discussion and Conclusions:** Coassessment of distance-induced changes in walking speed during the 6-Minute Walk Test and the total distance walked substantially improves the prediction of real-world walking activity after stroke. This study provides new insight into how walking ability after stroke can be characterized to reduce heterogeneity and advance personalized treatments.

**Key words:** 6MWT, endurance, human movement system, participation, physical activity

All testing was conducted under the supervision of a licensed physical therapist. Assistive devices and orthoses were allowed if needed for safety. Participants’ community walking activity was measured using a StepWatch Activity Monitor (Orthocare Innovations, Seattle, Washington) worn on the nonparetic leg during all walking activities. An average of 3.95 ± 0.19 days of walking activity were available across participants. The total distance walked during the 6MWT (6MWTtotal), the difference between the distances walked during minute 6 and minute 1 of the test (Δ6MWTmin6–min1), and self-efficacy as measured using the Activities-specific Balance Confidence (ABC) scale served as independent variables. Participants completed the 6MWT without verbal encouragement and with instructions to “cover as much distance as possible.”

Data Analysis

All analyses were conducted using commercially available software (SPSS version 24, IBM Corp., Armonk, N.Y., USA). Averages ± standard error are reported. Moderated regression evaluated changes to a steps/d model containing 6MWTtotal and ABC score—variables known as key indicators of community walking activity after stroke. Both ABC score and 6MWTtotal were entered first, followed by Δ6MWTmin6–min1 and the 6MWTtotal × Δ6MWTmin6–min1 interaction. All assumptions for regression were ensured. Centered variables were used to minimize multicollinearity. To minimize multicollinearity, all independent variables were mean centered such that each variable’s new mean was zero. An examination of model residuals revealed 3 participants whose data were outliers that contributed to a violation of normality. Removal of these data points from the final analysis restored normality. It should be noted that Δ6MWTmin6–min1 was a major determinant of steps/d both with and without these outliers. Both the final model R² and the R² adj adjusted for sample size and the number of predictors (R² adj) are reported. A significant 6MWTtotal × Δ6MWTmin6–min1 interaction was examined within ± 1 standard deviation of the moderator variables. In addition, to facilitate clinical interpretation of the findings of the regression analysis, independent t tests compared subgroups of “endurant” and “nonendurant” individuals dichotomized on the basis of a distance-induced decline in long-distance walking speed of 0.10 m/s. More specifically, individuals with a decline in walking speed from minute 1 to minute 6 of the 6MWT that was 0.10 m/s or more were considered “nonendurant.” All other individuals were considered “endurant.” A cutoff of 0.10 m/s was selected on the basis of the findings of a recent systematic review reporting a 28- to 42-m minimal detectable change (MDC) for the 6MWT in people in the chronic phase of stroke recovery—or a 0.08 to 0.12 m/s change in long-distance walking speed. The 0.10 m/s cutoff is the midpoint of the MDC range reported.

![Figure 1. Relationships between (A) total 6MWT distance (6MWTtotal) and community walking activity (steps/d) and (B) 6MWTtotal and steps/d as moderated by distance-induced changes in speed, shown as the difference between the distances walked during minute 6 and minute 1 of the 6MWT (Δ6MWTmin6–min1). 6MWT, 6-Minute Walk Test.](image)

RESULTS

Participants were 58.4 ± 1.6 years old, 2.9 ± 0.7 years poststroke, 35% right-side paretic, and 38% female. Their average lower-extremity Fugl-Meyer assessment score was 23.5 ± 0.9 and ABC score was 73 ± 3. They walked an average 5892 ± 513 steps/d, 292 ± 21 m during the 6MWT, and 3.5 ± 0.9 m less during minute 6 versus minute 1 of the 6MWT.

Both 6MWTtotal (R² = 0.41, P < 0.001) and ABC score (R² = 0.21, P = 0.004) were each bivariately correlated with steps/d; however, in the final regression model, ABC score was not a significant independent predictor (Table). The addition of Δ6MWTmin6–min1 and the 6MWTtotal × Δ6MWTmin6–min1 interaction explained an additional 29% of the variance in real-world community walking activity. The final model accounted for 71% of the variance (R² = 0.71, F₅₋₂ = 19.52, P < 0.001). In order of importance (based on an examination of βs, see the Table), Δ6MWTmin6–min1 and 6MWTtotal were independent predictors. The interaction between these variables was also significant, indicating that the relationship between 6MWTtotal and steps/d was moderated by Δ6MWTmin6–min1 (Figure 1). More specifically, as observed in Figure 1B, examination of the interaction revealed that lower 6MWTtotal predicts fewer steps/d, with individuals whose distances decline during the 6MWT (ie, endurant individuals) presenting with the least steps/d. In contrast, individuals with minimal slowing during the 6MWT (ie, are more endurant) present with substantially more steps/d.

<table>
<thead>
<tr>
<th>Table. Regression Model of Real-World Walking Activity</th>
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<tr>
<td>Model Statistics</td>
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<tr>
<td>R² = 0.42</td>
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<td>R² adj = 0.39</td>
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<td>F₂,₃₄ = 12.49</td>
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<tr>
<td>R² = 0.71</td>
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<td>R² adj = 0.67</td>
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<td>F₃₋₂ = 19.52</td>
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Abbreviations: ABC, Activities-specific Balance Confidence; 6MWT, 6-Minute Walk Test; 6MWTtotal, total 6MWT distance; Δ6MWTmin6–min1, difference between the distances walked during minute 6 and minute 1 of the 6MWT.
Figure 2. (A) Distance walked per minute, total 6MWT distance (6MWT_{total}), and community walking activity (steps/d) for 2 participants that exemplify the (B) nonendurant (ie, those with a reduction in speed $\geq 0.10 \text{ m/s}$) and endurant (ie, those with a reduction in speed $< 0.10 \text{ m/s}$) subgroups. (C) 6MWT_{total}, self-efficacy (ABC score), steps/d for each subgroup. $^a P < 0.05$. ABC, Activities-specific Balance Confidence; 6MWT, 6-Minute Walk Test.

Pairwise comparisons of the endurant ($N = 24$) and nonendurant ($N = 13$) subgroups (Figure 2B) revealed substantial differences in steps/d ($P = 0.013$) but not 6MWT_{total} or ABC score ($Ps > 0.05$) (Figure 2C). The nonendurant subgroup walked 62% less steps/d than the endurant subgroup (4198 ± 909 vs 6810 ± 546 steps/d)—a difference that would lead to different functional classifications of “most limited community ambulator” for the nonendurant subgroup and “least limited community ambulator” for the endurant subgroup.

DISCUSSION

The total distance walked during the 6MWT has been shown to be a strong predictor of real-world community walking activity after stroke. This study builds on this prior work, motivating the coassessment of total 6MWT distance and distance-induced changes in walking speed to better explain the walking activity of community-dwelling individuals poststroke. Indeed, the model presented in this study explained 71% of variance in steps/d—a substantially higher percentage than other recent work examining other factors (eg, single- and dual-task gait speed, self-efficacy, and balance) that has ranged from 36% to 61% of variance explained.

An assessment of distance-induced changes in walking speed provides insight into locomotor deficits underlying physical inactivity that are not reflected in the total distance walked. Indeed, poststroke heterogeneity is a likely reason for the importance that distance-induced changes in speed has in our model. That is, an individual with a fast initial speed that declines over the duration of the test (ie, fast but not endurant) and an individual with a slow initial speed that is maintained over time (ie, slow and endurant) may each present with comparable 6MWT distances despite having inherently different impairments in gait mechanics, walking efficiency, or cardiovascular capacity—the variables that ultimately serve as intervention targets.

Nonphysical factors may also explain distance-induced changes in walking speed during the 6MWT. Reduced motivation may lead to distance-induced slowing in a person who otherwise has the capacity to maintain his or her speed for the duration of the test. Likewise, a competitive person may be motivated to operate at a higher percentage of his or her physiological reserve over the duration of the test. In this vein, Danks et al show that another nonphysical factor, balance self-efficacy, influences real-world walking activity. Among patients with high physical capacity, those with high self-efficacy presented with more real-world walking activity than those with low self-efficacy. Our finding that self-efficacy was not a significant predictor in our model is not necessarily suggestive of reduced importance in determining physical activity after stroke; rather, it may be the result of substantial overlap in the variance explained with the 6MWT (eg, Danks et al did not include 6MWT_{total} in their model). Further study into the mediating roles that physical and nonphysical factors (eg, motivation and self-efficacy) play in the relationship between distance-induced changes in walking speed and real-world physical activity is highly warranted to elucidate mechanisms and identify specific treatment targets.

Limitations

The generalizability of this exploratory study is limited to higher-functioning community-dwelling individuals poststroke capable of completing a 6MWT without assistance.
Moreover, these findings may not extend to studies administering the 6MWT without the instruction to “cover as much distance as possible.” In addition, we only investigated the effect of differences in walking speed from minute 1 to minute 6 of the 6MWT. Assessment of differences in speed between other minutes may provide additional information that can characterize people poststroke. Finally, participants’ real-world ambulatory activity was computed from an average of 4 days of measurement. Additional days of measurement may have provided a more stable assessment; however, recent work has shown that 2 to 3 days of measurement may be sufficient in persons poststroke.3,16

CONCLUSIONS

This study demonstrates that assessment of distance-induced changes in speed during the 6MWT explains real-world ambulatory activity after stroke better than the total distance walked—a finding of importance, given the relationships between physical activity and health and quality of life. Given the relative ease by which assessment of distance-induced changes in walking speed during the 6MWT can be made, this study motivates consideration of this variable when the goal of intervention is to improve real-world walking activity.

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REFERENCES