Impact of Exercise to Improve Gait Efficiency on Activity and Participation in Older Adults With Mobility Limitations: A Randomized Controlled Trial

Jessie M. VanSwearingen, Subashan Perera, Jennifer S. Brach, David Wert, Stephanie A. Studenski

Background. Definitive evidence that exercise interventions that improve gait also reduce disability is lacking. A task-oriented, motor sequence learning exercise intervention has been shown to reduce the energy cost of walking and improve gait speed, but whether the intervention also improves activity and participation has not been demonstrated.

Objective. The objective of this study was to compare the impact of a task-oriented, motor sequence learning exercise (TO) intervention and the impact of an impairment-oriented, multicomponent exercise (IO) intervention on activity and participation outcomes in older adults with mobility limitations. The mediating effects of a change in the energy cost of walking on changes in activity and participation also were determined.

Design. This study was a single-blind, randomized controlled trial.

Setting. The study was conducted in an ambulatory clinical research training center.

Participants. The study participants were 47 older adults (mean age = 77.2 years, SD = 5.5) with slow and variable gait.

Intervention. The intervention was a 12-week, physical therapist–guided program of TO or IO.

Measurements. Measures of activity (gait speed over an instrumented walkway; daily physical activity measured with an accelerometer; confidence in walking determined with the Gait Efficacy Scale; and physical function determined with the total, basic lower-extremity, and advanced lower-extremity components of the Late-Life Function and Disability Instrument [Late-Life FDI]) and participation (disability limitation dimension and instrumental role [home and community task performance] domain components of the Late-Life FDI) were recorded before and after the intervention. The energy cost of walking was determined from the rate of oxygen consumption during self-paced treadmill walking at the physiological steady state standardized by walking speed. An adjusted comparison of activity and participation outcomes in the treatment arms was made by use of an analysis of covariance model, with baseline and change in energy cost of walking added to the model to test for mediation. Tests were used to determine the significance of the mediating effects.

Results. Activity improved in TO but not in IO for confidence in walking (Gait Efficacy Scale; mean adjusted difference = 9.8 [SD = 3.5]) and physical function (Late-Life FDI basic lower-extremity component; mean adjusted difference = 3.5 [SD = 1.7]). Improvements in TO were marginally greater than those in IO for gait speed, physical activity, and total physical function. Participation improved marginally more in TO than in IO for disability limitations and instrumental role.

Limitations. The older adults were randomized to the intervention group, but differences in baseline measures had to be accounted for in the analyses.

Conclusions. A TO intervention that improved gait also led to improvements in some activity and participation outcomes in older adults with mobility limitations.

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Difficulty walking is associated with reduced activity and participation, a path of decline in physical and social function, and a loss of independence. Walking underlies many activities of daily living and walking ability (eg, gait speed) can be used to predict future mobility and physical disability. Therapeutic exercise interventions for older adults with mobility limitations have focused on improving walking (speed, endurance, and gait characteristics) as a means to reduce or delay physical disability. Multicomponent exercise programs, including strength, balance, walking, and endurance, are intended to reduce impairments and improve physiological capacity for walking in older adults. Such exercise programs have resulted in modest gains in walking ability (eg, an approximate 5% increase in speed, with a range of 0%-16%). With only one study reporting disability outcomes (a reduction in emotional disability).

Do exercise interventions that improve walking ability also reduce disability? Keysor and Jette conducted a systematic review of the effects of exercise interventions on physical function and disability outcomes in older adults. Thirty-one randomized controlled trials (RCTs) of flexibility, strengthening, aerobic conditioning, balance, and multicomponent exercise interventions published between 1985 and 2000 were reviewed; 14 studies included physical disability outcomes (even fewer included social, emotional, or overall disability outcomes), and only 5 studies reported improvements in participation. The physical disability findings varied. The effects on physical disability were generally small to modest effect sizes and mean differences; larger effects were seen in older adults with substantial disabilities and in one study of older adults with osteoarthritis.

We reviewed more recent RCTs of exercise interventions for effects on physical function and disability outcomes in older adults. Of the 5 RCTs identified, 2 included disability outcomes; 1 study of older adults with osteoarthritis showed improvements in participation after interventions.

Schrack et al and Ferrucci proposed an energetic model of frailty in which the physical exertion of walking with mobility limitations may be a major factor in reduced activity and participation (disability) in some older adults. In older adults with mobility limitations, abnormalities in posture and gait contributed to a greater energy cost of walking (eg, inefficient gait), with adjustments for age and gait speed. Therapeutic exercise with task-oriented motor sequence learning (motor skill) to improve the efficiency of gait through training in the timing and coordination of the sequences of movements in walking may be an alternative to traditional multicomponent, impairment-based exercise. For motor tasks, expert movers, or those with greater motor skill for a specific activity, tired less easily than novices because of the greater efficiency of skilled motor performance. After a stroke, task-oriented, gait-related exercise treatment approaches enhanced the efficiency of gait, the efficiency of limb movement, and function in daily activities. In people with multiple sclerosis, task-oriented, treadmill gait exercise reduced the effort of walking. A task-oriented, motor sequence learning, therapeutic exercise gait intervention reduced the energy cost of walking and improved gait speed more than an impairment-oriented, walking, endurance, balance, and strengthening exercise gait intervention in older adults with mobility limitations. Although the task-oriented, motor sequence learning gait intervention appeared to reduce energy cost and increase gait speed, the impact of the intervention on activity and participation is unknown.

Definitive evidence that exercise improves gait also reduces disability and, particularly, that exercise that reduces energy expenditure for walking positively influences activity and participation is lacking. In an RCT of 2 gait interventions, we compared the impact of task-oriented, motor sequence learning exercise (TO) designed to emphasize timing and coordination to make walking easier—and the impact of impairment-oriented, multicomponent exercise (IO)—designed to emphasize strength, balance, and endurance and correct gait abnormalities to increase the capacity to walk—on activity and participation outcomes in older adults with mobility disabilities. We also determined whether an intervention-related change in gait efficiency (energy cost of walking) mediated changes in activity and participation. We expected that an exercise intervention that reduces exertion and improves the ease of walking also might improve activity and participation in older adults with mobility limitations.

**Method**

**Overview**

The study methods are described in detail elsewhere. In brief, we conducted a single-blind clini-
Improving Gait Efficiency in Older Adults With Mobility Limitations

cal RCT to compare two 12-week, protocol-driven, physical therapist-guided gait interventions based on either TO or IO (to improve the performance of body system components) for older adults with quantitative evidence of walking difficulty. In the earlier report of the RCT, the TO intervention was referred to as timing and coordination (TC) exercise, and the IO intervention was described as walking, endurance, balance, and strengthening (WEBS) exercise. All participants gave informed consent to participate.

Participants
The target population was older adults with mild to moderate mobility difficulties. Potential participants were recruited from the Pittsburgh Pepper Center Registry of older adults who were interested in participating in studies of balance and mobility and who reported walking difficulties. Eligibility was based on the ability to walk independently with or without a cane; medical safety, including a personal physician’s approval to participate in a low- to moderate-intensity exercise program; adequate cognitive function to provide informed consent and participate in the exercise interventions (Mini-Mental State Examination [MMSE] score of ≥24); and quantitative evidence of mobility difficulties, defined as slow and variable gait (see below). Randomization was based on a concealed block size of 4. The study staff was unaware of the randomization code, and participants were notified of their assignments at the first treatment visit, after consent was given and baseline data were collected. The flow diagram for the study is available in the earlier report of the RCT.

Measures
All measurements except demographic data were collected twice, at baseline (before randomization) and after 12 weeks of exercise, by assessors who were unaware of treatment arm assignments.

Descriptive Measures
Demographics and comorbid conditions. Data on age, sex, level of education, and coexisting medical conditions were collected through participant report. The Comorbidity Index was used to define medical history. Participants reported whether a physician had ever told them that they had any of 18 common conditions expected to influence physical function. Comorbidities were categorized into 8 domains (cardiovascular, respiratory, musculoskeletal, neurologic, general, cancer, diabetes, and visual) and summed to generate a summary score from the report of the 18 conditions. Potential participants also completed the MMSE measure of general cognitive function. The MMSE was used to determine whether potential participants had adequate cognitive function to provide informed consent and as a potential covariate in the analyses of the findings.

Mobility performance measures.
Gait speed and variability were recorded to determine eligibility to participate. Potential participants were instructed to walk at their usual speed on a 4-m instrumented walkway (GaitMatII, E.Q. Inc, Chalfont, Pennsylvania) with a 2-m non-instrumented section at each end to allow for acceleration and deceleration. After 2 practice walks on the mat, the potential participants performed 2 walks for data collection. Gait speed was defined as the average from the 2 walks. Step length variability and step width variability were derived from the standard deviations of all right and left steps recorded during the 2 walks and were reported as the coefficient of variation, defined as (standard deviation/mean step length or step width) × 100. Potential participants who demonstrated mobility limitations, defined as slow or variable gait, were eligible to participate. Slow gait was a walking speed of less than or equal to 1.0 m/s and greater than or equal to 0.6 m/s (slow, but not so slow as to limit the ability to participate in walking-based interventions). Variable gait was either step length variability (coefficient of variation of >4.5%) or step width variability (coefficient of variation of <7% or >30%).

Activity Measures
Gait speed. Gait speed outcomes were previously reported but are included in the present report (as activity-level outcomes) to provide a comprehensive description of the intervention effects. The exercise interventions were designed to improve gait; thus, information on the intermediate outcome of a change in gait speed may be helpful in understanding the more distal activity and participation outcomes.

Physical activity. To capture daily physical activity, participants wore a CSA/MTI Actigraph accelerometer (Actigraph LLC, Pensacola, Florida) at waist level for 7 consecutive days from rising until retiring to bed at night. Activity was reported in counts per minute, representing mean activity counts per day, divided by the mean minutes worn per day, averaged over days worn. Data were available for 44 participants, and all but 1 participant provided 6 or more days of monitoring.

Gait Efficacy Scale (GES). The GES is a self-report 10-item scale of perceived confidence in walking ability. Individual items in the GES are rated from 1 (no confidence) to 10 (complete confidence). The items represent a range of challenges from level walking to walking on uneven surfaces, curbs, or stairs. The GES total score is the sum of the scores.
for the items, with a range of 10 to 100.33,54

Late-Life Function and Disability Instrument (Late-Life FDI) function component. We used the Late-Life FDI function component7 (scores for overall functioning, basic lower-extremity functioning, and advanced lower-extremity functioning) to assess the relationship between perceived changes in physical function and walking ability. The Late-Life FDI total functioning scale includes 32 items about the usual ability to perform physical activities that are typically part of an everyday routine. The basic lower-extremity functioning subscale includes 14 activities that mainly involve standing and essential walking. The advanced lower-extremity functioning subscale (11 items) involves more physically challenging activities and endurance. The Late-Life FDI function component scales have scores ranging from 0 to 100, with higher scores indicating better function, and excellent reproducibility (intraclass correlation coefficient of >.91).7

Participation Measure: Late-Life FDI Disability Component

We used the Late-Life FDI disability component55 (scores for disability limitation dimension and instrumental role domain) to reflect changes in the ability to perform socially defined life tasks. The disability limitation dimension includes 16 items about participation in social, work, leisure, and travel activities and taking care of finances and health. The instrumental role domain reflects perceived limitations in home and community tasks.55 The Late-Life FDI disability component scales have scores ranging from 0 to 100, with higher scores indicating less disability, and excellent reproducibility (intraclass correlation coefficient of >.81).55

Measure of Gait Efficiency in Older Adults With Mobility Limitations

Energy Cost of Walking
The energy cost of walking reflects gait efficiency and is defined as the mean rate of oxygen consumption divided by walking speed. Lower energy cost reflects higher gait efficiency.38,56 Standardized methods for determining the energy cost of walking from the rate of oxygen consumption during walking were established in previous studies.39,57-61 The energy cost of walking (mL/kg/m)56,62 is a time-independent, repeatable measure of the physiological cost of gait63-65 and is influenced little by changes in oxygen consumption related to aerobic exercise64,65; the energy costs of walking can be compared across individuals and over time, regardless of changes in gait speed.60,64,65 Participants walked on a treadmill at a self-selected pace while oxygen consumption data were collected with open-circuit spirometry and expired gases were analyzed with a Medgraphics VO200 portable metabolic measurement system (Medical Graphics Corp, St Paul, Minnesota).

The energy cost of walking was calculated from the mean rate of oxygen consumption during 3 minutes of treadmill walking after the physiological steady state was reached.38,62,63,65 We used the total rather than the net energy cost of walking as the measure of gait efficiency. Net energy cost requires a correction for energy expenditure at rest, different methods, and more testing.66 Because we were interested in changes in the energy cost of walking over time and because we expected resting energy expenditure to be unchanged, we used total energy cost to reduce the burden of testing on participants. The mean between-group difference in the energy cost of walking after the intervention was previously reported.44 In the present study, we used the energy cost of walking as a measure of gait efficiency and explored the role of changes in gait efficiency in changes in activity and participation.

Interventions

General. Both interventions were 12-week, twice weekly, protocol-driven, physical therapist-led programs for small groups of participants (n=2 or 3). The interventions were previously described.44 The interventions were conducted at different times or on separate days to avoid cross-contamination. Therapists received initial training in all aspects of the protocols and were assessed for adherence before intervention implementation and periodically throughout the study. The protocols provided operational criteria for the exercise activities and standards for progression and allowed for various individual levels of initial performance and rates of change. Progression was mandated after a set of exercises were completed with 80% accuracy and self-reported ease of performance. The time spent on walking itself was monitored to equalize walking practice between the treatment arms at 20 to 30 minutes per session. Detailed logs of treatment sessions were maintained, with biweekly reviews of a sample of treatment logs for evidence of consistency with the protocols and progression.

TO program. The TO program was based on principles of motor sequence learning34,57,67-69 that enhance “skill” or smooth, subconscious, and automatic control of movement.55 The motor sequence learning exercise involved task-oriented stepping and walking patterns to promote the timing and coordination of locomotor stepping patterns, integrated with the phases of the gait cycle to enhance smooth movements in walking.67,70-72 Progression involved separately increasing the speed, ampli-
tude, or accuracy of performance before advancing to a more complex movement task.68,71 For example, the progression of diagonal stepping patterns was as follows: step forward across the midline of the body at a self-selected pace in one direction and then in the other direction, increase stepping speed, alternate the side of stepping, and alternate forward and backward stepping. Oval and spiral walking patterns were used to incorporate the motor sequence and interlimb timing of the stepping patterns into walking tasks. Walking patterns were advanced by altering the speed, amplitude (eg, narrowing the width of the oval), or accuracy of performance (eg, not straying from the desired path). The complexity of the gait exercise was increased by instructing the participants to perform the gait activities while walking past others and in combination with upper-extremity tasks, such as carrying, rolling, bouncing, or tossing a ball.67,68 To promote regular timing of the stepping patterns, treadmill-paced walking practice was performed for 10 to 15 minutes. This walking exercise was not targeted at endurance training and did not increase the rate of perceived exertion. The treadmill-paced walking occurred primarily at the preferred walking speed, with brief (30–60 seconds) repeated (3–5 times) intervals of increased speed followed by a return to a comfortable walking speed to reinforce the consistency of the timing of stepping and speed.73

IO program. The IO program was based on current standards of physical therapy for gait and balance retraining. The impairment-based exercise began with a brief warm-up of gentle stretching exercises for the leg (ankle, knee, and hip) and trunk muscles. Strength training consisted of lower-extremity progressive resistive exercises in sitting and standing positions for lower-extremity muscle groups. Progression of the strength training exercises involved increasing the repetitions to a maximum of 20 and then increasing the resistance. The resistance was provided by cuff weights.

The balance exercises were performed by redistributing the center of mass of the body over the base of support.74 The balance exercises started with the feet positioned at the participant’s self-selected comfortable distance apart for upright balance. With practice, the balance exercises progressed to a narrower base of support and less upper-extremity support. The endurance exercises were performed on a NuStep (NuStep Inc, Ann Arbor, Michigan) (which provides a seated, stair-climbing-like activity) or on a stationary bicycle.

The endurance exercise training was conducted at a submaximal workload, defined as a self-reported rate of perceived exertion of 10 to 13, or a somewhat hard level of effort.75 Heart rate and blood pressure were monitored in accordance with recommended guidelines for safe exercise.76,77 Progression involved increasing the duration of exercise (the ability to sustain a somewhat hard level of effort for up to 15 minutes) and then on increasing the intensity of exercise.

Specific gait training involved the therapist giving verbal instructions aimed at correcting abnormalities of spatial or temporal characteristics of gait or posture during walking (eg, verbal cues to facilitate heel-strike or push-off from the trailing limb and to encourage participants to look in the direction in which they were walking).

Sample Size
The original RCT was designed as a pilot study of 2 interventions and the impact on measures of gait chosen to represent the complexity of walking, gait variability, and the energy cost of walking. The sample size for the original RCT was based on having adequate power to test for differences in measures of gait variability. On the basis of data from a preclinical trial of similar interventions and mean changes in the step length variability coefficient of variation of −3.05 (SD=1.45) for the task-oriented exercise group and −0.80 (SD=2.80) for the impairment-oriented exercise group, a sample size of 2 groups of 16 participants would enable testing with 80% power. We included 25 participants in each intervention group (for a total of 50 participants) to account for a potential 20% dropout rate for older adults with disabilities and a mean expected age of greater than 80 years and to account for the potential wide variations in performance and inability to complete some measures for older adults with mobility disabilities. Given the pilot nature of the original RCT and the cost and burden of conducting an RCT, we also measured activity and participation outcomes. We report the activity and participation outcomes of the original RCT here and acknowledge that the original RCT was not powered to study the secondary outcomes described.

Data Analysis
All statistical analyses were performed with SAS version 9.2 (SAS Institute Inc, Cary, North Carolina). Participant characteristics and baseline measurements in the treatment arms were compared by use of $t$ tests for continuous variables and chi-square tests for categorical variables. To make an adjusted comparison of activity and participation outcomes in the treatment arms, we fitted an analysis of covariance model with the change in each outcome from baseline to follow-up as the response variable; with treatment arm as the

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main factor of interest; and with age, sex, and baseline value for the outcome variable as covariates. To obtain estimates of the mediating effects of changes in gait efficiency on changes in activity and participation outcomes, we fitted an analysis of covariance model with the change in each outcome from baseline to follow-up as the response variable; treatment arm as the main factor of interest; and age, sex, baseline value for the outcome variable, baseline value for the energy cost of walking, and change in the energy cost of walking as covariates. A change in gait efficiency was considered to be a partial mediator of the activity or participation outcome if the between-intervention group difference estimate was reduced with the addition of the variable “change in energy cost” to the analysis of covariance. We used methods proposed to test the significance of a mediating or indirect effect, including a bootstrap approach to obtain confidence intervals for a mediating effect.

In brief, the standard approach for testing the statistical significance of a change in an effect (ie, the between-intervention arm difference) is the Sobel test, but it is based on certain assumptions about the stochastic independence of underlying random variables. Although this assumption facilitates mathematical derivations required to obtain the necessary formulas in an otherwise intractable problem, it also makes the Sobel test vulnerable to any violation of the said assumptions. Statistical bootstrapping is a relatively new computation-intensive method based on repeated Monte Carlo simulations to obtain confidence intervals without relying on restrictive assumptions.

**Role of the Funding Source**

This work was supported by the Pittsburgh Older Americans Independence Center (NIA P50 AG024827) and a Beeson Career Development Award (NIA K23 AG026766).

**Results**

Fifty participants were randomized, and 47 completed the study—23 in the TO group and 24 in the IO group. The 3 participants who did not complete the study withdrew because of medical conditions unrelated to study participation. The participants who withdrew did not differ at baseline from the participants who completed the interventions. The mean age of the older adults completing the study was 77.2 (SD=5.5) years (in the TO group, the mean age was 76.5 [SD=5.5] years; in the IO group, the mean age was 78.4 [SD=5.5] years), 65% were women, 12% were black, 67% had more than a high school education, and all had generally good cognitive function (mean Mini-Mental State Examination score of 28.7 [SD=1.4]). On average, the participants had few of the 18 comorbidities surveyed (mean Comorbidity Index of 2.6 [SD=1.1]), and the comorbidities were predominantly in the domains of arthritis (72%), vision (66%), osteoporosis (38%), and hearing (32%). Most (72.3%) of the participants reported some difficulty walking 2 or 3 blocks. All participants demonstrated slow gait (mean gait speed of 0.85 [SD=0.13] m/s) and variable gait (step length variability of 78%; step width variability of 78%).

Despite random assignment, baseline differences between the treatment arms were observed. Compared with participants in the IO group, participants in the TO group had a lower energy cost of walking, fewer gait abnormalities, and nonsignificant but potentially meaningful between-group differences in sex, gait speed, and self-reported functional limitations. All 47 participants who completed the study participated in at least 22 of the 24 treatment sessions.

**Activity Outcomes**

After treatment, gait speed improved with both forms of exercise (Tab. 1); the improvement was marginally greater in the TO group than in the IO group. Physical activity increased marginally more in the TO group than in the IO group because of a slight increase in activity in the TO group and a slight decrease in activity in the IO group. Confidence in walking, as determined with the GES, improved 10.8 points in the TO group but did not change in the IO group. Physical function (usual daily activities) improved in the TO group but not in the IO group. Participants in the TO group demonstrated greater gains in basic lower-extremity functioning than those in the IO group (Tab. 1).

The between-group difference for TO versus IO was large for confidence in walking, but for physical function, the difference was small; for gait speed, activity, and total and advanced lower-extremity functioning, the differences were marginal. Although clinically meaningful difference values for gait speed are known, such values have not been defined for activity, the GES, or Late-Life FDI measures. Therefore, we estimated meaningful differences from the baseline sample data for these variables by using Cohen effect size criteria (eg, small effect = 0.2 × baseline standard deviation; moderate effect = 0.5 × baseline standard deviation) and applied them to the interpretation of the results. The adjusted mean difference for confidence in walking was greater than an estimated moderate effect size, and the adjusted mean differences for the remaining activity outcomes were between small and moderate effect sizes (Fig. 1).
Participation Outcomes
The improvement in participation was marginally greater in the TO group than in the IO group (Tab. 1). Values for both disability limitations and instrumental role increased marginally more in the TO group than in the IO group. Although the adjusted mean differences for the participation outcomes were marginally significant, both exceeded a moderate effect size for the measures (Fig. 1).

Mediating Effects of Changes in Gait Efficiency on Activity and Participation Outcomes
Gait efficiency improved in the TO group but did not change in the IO group (Tab. 1, mediator; change in the energy cost of walking).44 We assessed the results for a mediating effect of the change in gait efficiency by examining the change in the between-intervention difference estimate due to additionally including the change in the energy cost of walking as a predictor. The change in gait efficiency partially explained the intervention-related changes in some activity and participation outcomes, based on the reduction in the between-intervention difference estimate (Tab. 2, Fig. 2). The reduction in the difference estimate due to the change in gait efficiency represented a small meaningful change80 for the activity outcome of gait speed. The adjusted mean difference estimate increased for the Late-Life FDI disability limitation and instrumental role outcomes, an indication of no mediating effect of the change in gait efficiency on the participation outcomes. The impact of the change in the energy cost of walking on the between-group difference in mean changes in activity and participation outcomes did not persist when additional methods (Sobel test and bootstrap confidence intervals) were used to test the significance of the mediating or indirect effects78,79 (Tab. 2).
Discussion

The TO program led to greater gains in some activity and participation outcomes than the IO program. These greater gains appeared to be partially mediated by the improvement in gait efficiency; however, these indirect effects could not be substantiated by the formal statistical tests of mediation.

Both task-oriented and impairment-oriented interventions improved gait speed. The gait speed improvement was equal to or greater than that observed in previous exercise intervention trials for older adults with walking problems.11,13,16,17,19–21,23 Only the task-oriented intervention improved gait and improved some activity and participation outcomes for the older adults studied.

After the TO program, activity improved in terms of daily physical function, specifically, basic activities of daily living involving the lower extremities, and total physical function and participation improved marginally. The impact of the motor sequence learning exercise on basic lower-extremity functioning, with a marginal impact on total physical function and disability, may be secondary to the focus of the intervention on “fixing” gait. The motor sequence learning intervention was targeted at correcting deficits in the muscle patterns of stepping and integrating posture with the phases of gait through task-oriented, progressive stepping and walking tasks and treadmill-paced practice. Many of the items on the Late-Life FDI basic lower-extremity functioning subscale represent stepping activities or short-distance, indoor walking,7 which most likely require path adjustments to walk around objects such as chairs and tables and turning to enter or exit a room. Similarly, the specificity of the exercise may explain the better activity and participation outcomes after the TO program than after the IO program. The diagonal stepping and curved-path walking tasks emphasized in the TO program are similar to the steps, curbs, and indoor walking paths represented by the Late-Life FDI basic lower-extremity functioning items. Although the IO intervention involved standing balance activities and lower-extremity muscle strengthening and flexibility exercises specific for muscle groups necessary for stepping up onto curbs, rising from chairs, balancing while reaching, and providing stability while turning or changing directions, this intervention was not goal oriented for walking and did not change basic lower-extremity functioning.

The motor sequence learning exercise also differed from the impairment-based exercise in that the stepping and walking patterns in the TO program were designed to facilitate the implicit motor learning of movement patterns.37,83,84 The exercise activities in the TO program were all task oriented (eg, step across and walk around cones [to form an oval]), but there was no mention...
Table 2.
Estimates of Adjusted Mean Between-Group Differences and Mediating Effects of a Change in Gait Efficiency on Difference Estimates for Activity and Participation

<table>
<thead>
<tr>
<th>Measure</th>
<th>Estimate (SE)</th>
<th>P for Estimate</th>
<th>Change in Estimate</th>
<th>Sobel Method Change in Estimate (95% CI)</th>
<th>Sobel Method P for Change</th>
<th>Bootstrap Method Change in Estimate (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait speed, m/s</td>
<td>0.06 (0.04)</td>
<td>.16</td>
<td>−0.055</td>
<td>−0.030 (−0.069 to 0.008)</td>
<td>.1255</td>
<td>−0.031 (−0.078 to 0.000)</td>
</tr>
<tr>
<td>Activity, cpm</td>
<td>16.9 (9.5)</td>
<td>.08</td>
<td>−2.6</td>
<td>−0.78 (−6.27 to 4.70)</td>
<td>.7794</td>
<td>−0.74 (−6.91 to 4.71)</td>
</tr>
<tr>
<td>GES score, 10–100</td>
<td>9.2 (3.7)</td>
<td>.02</td>
<td>−1.3</td>
<td>−0.81 (−3.18 to 1.55)</td>
<td>.5001</td>
<td>−0.82 (−3.47 to 1.05)</td>
</tr>
<tr>
<td>Late-Life FDI total, 0–100</td>
<td>2.6 (1.2)</td>
<td>.03</td>
<td>−0.70</td>
<td>−0.27 (−1.04 to 0.50)</td>
<td>.4904</td>
<td>−0.31 (−1.46 to 0.42)</td>
</tr>
<tr>
<td>Late-Life FDI basic LE, 0–100</td>
<td>4.6 (1.7)</td>
<td>&lt;.01</td>
<td>−0.56</td>
<td>−0.44 (−1.58 to 0.70)</td>
<td>.4475</td>
<td>−0.49 (−2.14 to 0.59)</td>
</tr>
<tr>
<td>Late-Life advanced LE, 0–100</td>
<td>3.9 (1.7)</td>
<td>.03</td>
<td>−0.11</td>
<td>−0.22 (−1.30 to 0.85)</td>
<td>.6826</td>
<td>−0.25 (−1.62 to 0.80)</td>
</tr>
<tr>
<td>Participation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Late-Life FDI limitations, 0–100</td>
<td>5.6 (3.2)</td>
<td>.09</td>
<td>1.5</td>
<td>0.15 (−1.84 to 2.15)</td>
<td>.8804</td>
<td>0.13 (−1.32 to 1.77)</td>
</tr>
<tr>
<td>Late-Life FDI instrumental role, 0–100</td>
<td>6.4 (3.8)</td>
<td>.10</td>
<td>2.5</td>
<td>0.42 (−1.94 to 2.77)</td>
<td>.7281</td>
<td>0.36 (−1.38 to 2.32)</td>
</tr>
</tbody>
</table>

a CI—confidence interval, cpm—counts per minute, GES—Gait Efficacy Scale, Late-Life FDI—Late-Life Function and Disability Instrument, Total—overall functioning, Basic LE—basic lower-extremity functioning, Advanced LE—advanced lower-extremity functioning.

b Mean difference estimate for task-oriented, motor sequence learning exercise versus impairment-oriented, multicomponent exercise, adjusted for age, sex, baseline value for the outcome variable, and baseline value of the energy cost of walking.

c Change in the mean difference estimate, adjusted for age, sex, baseline value for the outcome variable, baseline value of the energy cost of walking, and mean change in the energy cost of walking.

Figure 2.
Change in the estimates of the between-group adjusted mean differences explained by a change in gait efficiency. The black bars represent the between-group mean differences in the change in each variable from baseline to follow-up, adjusted for the covariates age, sex, and baseline value for the outcome variable. The gray bars represent the between-group mean differences in each variable from baseline to follow-up, adjusted for the covariates age, sex, baseline value for the outcome variable, baseline value of the energy cost of walking, and change in the energy cost of walking. A comparison of the gray bars with the black bars illustrates the mediating effects of the change in the energy cost of walking on changes in activity and participation outcomes. The values for gait speed and activity were adjusted by a multiple of 10 so that the same scale could be used in the axes for all of the variables. For gait speed, the actual value was the value shown $\times 10^{-2}$, for activity, the actual value was the value shown $\times 10$. Asterisks indicate participation variables. cpm=counts per minute, GES=Gait Efficacy Scale, Late-Life FDI=Late-Life Function and Disability Instrument, LE=lower extremity.
of which muscles to contract or where to place steps or shift body weight. The impairment-oriented exercise facilitated improvements in body systems that contribute to the ability to walk, but the IO program was not task oriented and was not designed to facilitate the implicit learning of how to integrate increased physiological capacities with walking. Van Peppen et al\textsuperscript{12} reported a similar impact of task-oriented but not impairment-targeted physical therapy exercise interventions on functional outcomes after stroke. Although impairment-targeted exercise interventions improved range of motion, strength, and exercise tolerance, only task-oriented exercise interventions improved function in tasks representing activities of daily living.\textsuperscript{12}

Task-oriented, gait-related exercise was described as being effective and efficient in improving functional outcomes after stroke in a summary of several systematic reviews of interventions to improve mobility-related activities.\textsuperscript{72}

The change in gait efficiency after the intervention did not mediate the changes in activity and participation outcomes. The lack of mediation of the outcomes by the change in gait efficiency may be related in part to how gait efficiency was measured. Gait efficiency was derived from the energy expenditure for walking measured during treadmill walking. Treadmill walking may not be representative of walking-based activities and physical function in daily life. The treadmill path is straight, and the continuously moving belt drives the stepping pattern of walking. Physical activities typical of daily living (eg, cleaning house, taking care of oneself, shopping, and visiting others) in the home or community can involve irregular paths, repeated changes in acceleration, starts and stops, and elevation. If the energy cost of walking were measured during the performance of physical activities typical of daily living, an improvement in gait efficiency might be found to be a better mediator of activity and participation outcomes. Unfortunately, measuring the energy cost of walking during the performance of physical activities typical of daily living is difficult. The rate of oxygen consumption must be recorded at the physiological steady state to be an accurate indicator of the energy expenditure for the activity. Achieving the physiological steady state usually requires 1 to 3 minutes of continuous activity.\textsuperscript{58,63,65}

The performance of many physical activities typical of daily living does not occur continuously for 1 to 3 minutes. Rather, the performance of the activities usually is intermittent or varies in level of intensity over time.

The present study had several limitations. The study was powered to detect differences in physiological and performance measures of gait but was not powered to detect differences in self-reported, more distal outcomes or to test mediating effects.

The differences in the estimated mediating effects across the methods also warrant comment. The similarity of the results obtained with the 2 formal mediation methods (Sobel method and bootstrap method) is reassuring for the validity of the Sobel method because it relies on certain assumptions, whereas the bootstrap method does not. The difference between mediating effect results obtained with formal methods and a simple change in the effect of an intervention is likely due to the different estimation algorithms (optimizing different objective functions) used to obtain the estimates, with formal mediation analyses resulting in more conservative estimates. Consistent results across all 3 methods would have strengthened our results and allowed us to make a more forceful conclusion regarding mediating effects.

The older adults were randomized to the intervention group, but differences in baseline measures\textsuperscript{44} had to be accounted for in the analyses. Although the Late-Life FDI functioning and disability component scales were developed to measure changes in activity and participation, some of the items from each scale have been found to be more representative of a different domain of activity and participation than the original domain to which the item scores contribute.\textsuperscript{35}

**Conclusion**

An exercise intervention that improved gait also improved some activity and participation outcomes. A task-oriented, motor sequence learning intervention targeted to “fix” gait may have a greater potential to affect activity and participation. The mechanism of the effect of such an intervention on disability in older adults with mobility limitations is not clear.

Dr VanSwearingen, Dr Brach, and Dr Studenski provided concept/idea/research design. Dr VanSwearingen, Dr Perera, Dr Brach, and Mr Wert provided writing. Dr VanSwearingen, Mr Wert, and Dr Studenski provided data collection. Dr VanSwearingen and Dr Perera provided data analysis. Dr VanSwearingen provided project management and institutional liaisons. Dr VanSwearingen, Dr Brach, and Dr Studenski provided fund procurement. All authors provided consultation (including review of manuscript before submission).

This study was approved by the University of Pittsburgh Institutional Review Board.

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