Effects of Age on Balance Control During Walking
Nataliya Shkuratova, BPh, Meg E. Morris, PhD, Frances Huxham, DipPT


Objective: To determine the effects of aging on balance control during walking.

Design: Two-group repeated-measures design.

Setting: Gait laboratory in Australia.

Participants: Convenience sample of 20 healthy older subjects (mean age, 72y) and 20 healthy young subjects (mean age, 24y).

Interventions: Changes in locomotor performance in response to perturbations to balance were quantified for healthy older adults compared with healthy young adults for (1) straight line walking at preferred speed, (2) straight line walking at fast speed, (3) figure-of-eight walking at preferred speed, and (4) figure-of-eight walking while performing a secondary motor task.

Main Outcome Measures: Gait speed, stride length, cadence, and double-limb support duration, using a footswitch system.

Results: Healthy older people screened for pathology had gait patterns comparable to young adults for straight line walking at preferred speed. However, multivariate analysis of variance (MANOVA) showed a significant interaction between age and speed when balance was perturbed by requiring subjects to change from walking at preferred to fast speeds (Pillai-Bartlett trace = 259, F(4,36) = 3.06, P < 0.029, partial η² = 0.259). This occurred because older people did not increase their speed (F(1,36) = 7.65, P < 0.01, partial η² = 0.168) or stride length (F(1,36) = 12.23, P < 0.01, partial η² = 0.243) as much as did the young adults. MANOVAs did not show statistically significant interactions between age and turning conditions or age and dual task conditions, although older people walked more slowly and with shorter steps when turning or performing a secondary task.

Conclusions: Balance strategies during gait are task specific and vary according to age. In response to challenges to balance imposed by the requirement to change from preferred to fast walking, older people did not increase their speed and stride length to the same extent as did younger adults. This was possibly a strategy to maintain their stability.

Key Words: Aging; Balance; Gait; Geriatrics; Locomotion; Rehabilitation.

© 2004 by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation

The ability to control balance while walking is a fundamental skill that is frequently compromised by advanced age. In humans, the ability to walk depends not only on being able to generate a rhythmic locomotor pattern, to maintain upright stance, and to control the trajectory of the center of mass (COM) despite a narrow and moving base of support,1,2 For older people, control of dynamic balance can become increasingly difficult,3,4 and walking is associated with an increased risk of falls.5,6

The effect of age on balance control during walking is not well understood. Until recently, balance research mainly focused on the ability of young and older adults to maintain equilibrium in standing or to recover steady stance after perturbations to the COM, by using stepping strategies.7-10 Some standing balance experiments measured the ability of older people to prepare for and respond to preplanned or unexpected perturbations to stability arising from pushing or pulling forces,10,11 Other experiments measured the ability of older people to recover standing balance in response to multidirectional floor platform translations.12 Still others measured the ability of older adults to step in response to large pushing or pulling forces or support surface motion.9,13 Older people typically showed increased postural sway in steady stance,14 inability to execute effective stepping responses, and difficulty controlling displacements of the COM and center of pressure relative to their limits of stability.15 Whether these standing balance findings generalize to the dynamic task of walking remains a question.

One of the few studies that has measured balance while walking of young adults compared with older adults is that of Gabell and Nayak.16 They concluded that pathology rather than chronologic age was the main cause of postural instability during gait. This conclusion was based on their finding that healthy older and young adults showed similar levels of variability and mean values for stride width and double-limb support duration, which, they argued, represented compensations for balance disturbance. Stringent medical screening to exclude pathology left only 32 of 1187 older individuals in their sample. Unfortunately, they did not include pathology screening of the young adults. The nonsignificant differences between groups in spatiotemporal gait variables might have arisen because variability was abnormally low in the pathology-free older people yet relatively high in the younger subjects—some of whom may have had musculoskeletal or neurologic disorders. The danger in assuming that pathology is the main cause of balance disturbance in older people is that clinicians might bias prescribed interventions to prevent falls toward people with diagnosed pathology, thus overlooking healthy older people until they fall.

The experiment by Gabell and Nayak16 also set a precedent for assessing “balance” separately from “locomotion.” This artificial division is no longer considered valid because it is now recognized that motor control and postural control are inextricably related. All motor tasks, unless performed while a subject is fully supported, require a complex interaction of postural adjustments to maintain intersegmental coordination and equilibrium during the focal activity.17 A further assumption by Gabel and Nayak16 was that stride width and double support are the primary spatiotemporal variables that reflect
balance disturbance during gait. Although this may apply for straight line walking on wide pathways at preferred speed, the ability to adapt walking speed, cadence (stepping rate), and stride length might be equally as important in maintaining dynamic balance for other tasks and contexts.

In this study, we defined balance during walking as the ability to successfully integrate postural adjustments with locomotor strategies to maintain safe gait for a range of tasks of different complexity. Postural adjustments are defined as changes in walking speed, cadence, stride length, and double-limb support duration that occur in response to perturbations during walking.

The major aim of this study was to examine whether older people adapt their stepping behavior differently than do young adults in response to various balance perturbations during locomotion. A secondary aim was to examine whether changes in speed, stride length, double-limb support, and cadence are task specific and vary according to the types of balance perturbations encountered. We used a narrow pathway for all gait trials because this type of environmental constraint increases demands on balance.

We assessed the effects of age on balance control during walking by comparing differences in performance between young and older groups in the following tasks: (1) straight line walking at preferred speed, (2) straight line walking at fast speed, (3) figure-of-eight walking at preferred speed, and (4) figure-of-eight walking while performing a secondary motor task. Fast walking challenges balance because it requires rapid postural responses to control the increased accelerations acting on the body.24 The turning condition (figure-of-eight) was included because it increases the motor control requirements for controlling the speed and trajectory of the COM and forward momentum.20,21 Turning is also associated with increased risk of falling in elderly adults.6,22 The secondary task (transferring coins from 1 pocket to another) increases the motor demands on balance control mechanisms and is a common activity of daily living.23

METHODS

Participants

Twenty healthy older adults and 20 young adults were recruited for this study from local clubs and volunteer associations in the Melbourne metropolitan region and La Trobe University, Australia. There were 11 women and 9 men in each group, and all subjects were screened by the researchers before testing. To be included, participants had to meet the following criteria: able and willing to provide informed consent according to the 1964 Declaration of Helsinki, aged between 65 to 85 years (elderly adults) and 20 to 40 years (young adults), and able to walk without assistance of any kind. Subjects were excluded if they reported any history of neurologic, orthopedic, cardiovascular, or psychiatric disorders; if they reported falls in the past 12 months; if they were taking tranquilizers or other medications that could affect balance; or if they reported having a fear of falling. Four older subjects (1 woman, 3 men) were excluded from the study. The woman was excluded because she was taking tranquilizers. The men were excluded because they reported having had more than 1 fall in the past 12 months. The characteristics of the subjects in each group are reported in table 1.

The mean age ± standard deviation was 25.3 ± 5.9 years for the young adults and 71.5 ± 5.0 years for older adults. There were no significant differences between groups in height (mean young adults, 166.8 ± 10.2 cm; older adults, 165.7 ± 11.0 cm), leg length (mean young adults, 88.45 ± 6.4 cm; older adults, 91.25 ± 5.4 cm), or weight (mean young adults, 60.9 ± 9.8 kg; older adults, 69.1 ± 16.0 kg).

Apparatus

Spatiotemporal changes in the footprint patterns of all subjects were measured with a Clinical Stride Analyzer® (CSA), according to a protocol specified previously.24 The CSA is composed of foot switches, a data-logger unit, a handheld control switch, and a waist belt. The foot switches were placed inside the shoes and were positioned under the heel, first and fifth metatarsals, and the great toe of each foot. Triggering the control switch activated the CSA. The data-logger unit, worn at the waist, recorded average stride length in meters, cadence in steps per minute, speed in meters per minute, and the percentage of the gait cycle spent in double-limb support. For the CSA, stride length is a derived measure, and total double-limb support duration values represent the sum of initial and terminal double-limb supports.

Several investigations have established the accuracy and high reliability of gait analysis using the CSA. Bilney et al25 showed high correlations (intraclass correlation coefficient [ICC]) between the CSA and the GAITRite walking system for gait speed (ICC2,1 = .99), stride length (ICC2,1 = .99), and cadence (ICC2,1 = .99). Morris et al26 found high repeatability of CSA measures for speed, cadence, stride length, and double-limb support in patients with Parkinson’s disease and in older control subjects (ICC2,1 range, .92–.99). Hill et al27 also documented high test-retest reliability of CSA spatiotemporal gait measures in subjects with hemiplegia (ICC2,1 range, .82–.98).

In research, it is important to establish whether measured differences represent true changes or measurement error. To evaluate which gait changes represented true changes in performance rather than changes resulting from measurement error, 95% confidence intervals (CIs) for estimating changes outside the boundaries of measurement error have been previously calculated in healthy older people.26 If the change scores were beyond the limits of these CIs, it was concluded that the measured changes in postural adjustments were over and above measurement error. The lower and upper 95% CIs reported by Morris26 were, respectively, as follows: walking speed, −.046 to −.117 m/s; stride length, −.034 to .072 m; cadence, −3.392 to 6.564 steps/min; and double-limb support, −1.106 to 1.128 steps/min. Thus, for example, double-limb support would need to reduce by more than 1.1% of the gait cycle or increase by

---

Table 1: Characteristics of the 20 Young and 20 Older Subjects

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (y)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Leg Length (cm)</th>
<th>No. of Coins Transfered</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>25.25±5.95</td>
<td>166.78±10.15</td>
<td>60.86±9.75</td>
<td>88.45±6.42</td>
<td>4.6±2.1</td>
<td>21.8</td>
</tr>
<tr>
<td>Older</td>
<td>71.50±5.03</td>
<td>165.68±11.02</td>
<td>69.10±16.01</td>
<td>91.25±5.44</td>
<td>4.5±1.6</td>
<td>25.0</td>
</tr>
</tbody>
</table>

NOTE. Values are mean ± standard deviation (SD). Abbreviation: BMI, body mass index.
more than 1.3% to show that a real change in double-limb support had occurred. Bilney et al.23 also showed that the measurement error for the clinical stride analyzer was 30mm for stride length, .18 steps/min for cadence, and .65m/s for gait speed, and 3.06% of the gait cycle for double-limb support duration.

The secondary motor task was a coin transfer task validated by O’Shea et al.23 Twelve 20-cent coins were transferred by the subjects from the right to the left pocket as quickly as possible. Custom-made pockets measuring 19×20cm were made from plain cotton material and worn attached to a waist belt. Subjects practiced the coin transfer for 2 minutes before data collection to familiarize themselves with this task.

Walkway for Straight Line Walking Task

For the assessment of balance control during straight line walking, 2 lines 14m long and spaced 150mm apart were marked on the floor with blue tape (fig 1). Data were collected from the middle 10m of the walkway to sample steady-state walking.

Walkway for Turning Tasks

To assess balance control during turning, subjects were required to walk around a series of 10m-long figure-of-eight pathways as described by Johansson and Jarnlo.28 The 10-m figure-of-eights comprised 2 circular paths, each 150mm wide with an inner diameter of 1.5m and an outer diameter of 1.65m (fig 2). All subjects began and ended their walking 0.5m outside each figure-of-eight to minimize acceleration and deceleration effects on performance.

Testing was performed in the Gait Laboratory at La Trobe University. After completing informed consent procedures, all subjects were interviewed about their falls history, fear of falling, medical history, and type and scheduling of medication. Height, weight, and leg length were also measured, because these variables can influence the temporal and spatial parameters of gait.1 Gait and balance data were then collected. Each testing session lasted approximately 90 minutes.

Data for 6 trials under each condition were gathered. The first 3 trials for each task were carried out at self-selected (preferred) walking speed, and the remaining 3 were conducted at fast speed. Standardized instructions were given for each activity.

For straight line walking: “Walk between the 2 blue lines to the end of the walkway at your comfortable speed/as fast as you can, starting when I say ‘Go.’ Do not step on or over the blue lines.” For the unitask turning condition: “Walk within the figure-of-eight in a clockwise direction at your own comfortable speed/as fast as you can, starting when I say ‘Go.’ Do not step on or over the blue lines.” For the dual-task turning condition: “Walk within the figure-of-eight in a clockwise direction at your comfortable speed/as fast as you can, starting when I say ‘Go.’ Do not step on or over the blue lines. This time, concentrate on the coins task, trying to transfer as many coins as you can from the right to the left pocket, using your right/left hand.”

The order of conditions was counterbalanced to minimize series effects.

A series of 2 (age) × 2 (condition) mixed-design multivariate analysis of variance (MANOVA) tests were conducted to analyze differences in postural adjustments during walking between young and older subjects. The dependent variables were gait speed (meters per second), stride length (length of 2 consecutive steps in meters), cadence (steps per minute), and double-limb support duration expressed as a percentage of the gait cycle. If a statistically significant interaction between age and walking condition was detected, data for the older and young subjects were analyzed separately with a 2-factor mixed-design analysis of variance (ANOVA) with repeated measures. To avoid the accumulation of type I error, α was adjusted to .025.

RESULTS

As seen in table 2 and figures 1 through 4, healthy older people screened for pathology had gait patterns comparable to young adults for straight line walking at preferred speed.

Postural Adjustments When Changing From Preferred to Fast Walking

Both young and older adults significantly increased walking speed, stride length, and cadence and decreased double-limb support duration when changing from preferred to fast walking (table 2). A 2 (age) × 2 (condition: preferred walking vs fast walking) MANOVA was conducted with the 4 measures of postural adjustment (gait speed, stride length, cadence, double-limb support duration). This showed a main effect for condition (Pillai-Bartlett trace = .886, F4.38 = 68.09, P < .001, partial η2 = .886). Univariate F tests showed that when changing from walking at preferred speed to walking at fast speed, both groups increased their walking speed (F1.38 = 244.07, P < .001, partial η2 = .865), stride length (F1.38 = 167.48, P < .001, partial η2 = .815), and cadence (F1.38 = 202.55, P < .001, partial η2 = .842) and decreased double-limb support duration (F1.38 = 20.12, P < .001, partial η2 = .346).

The mixed-design MANOVA also showed a main effect for age (Pillai-Bartlett trace = .476, F4.38 = 7.94, P < .001, partial η2 = .476).

Fig 1. The walkway used for straight line walking tasks.

Fig 2. The walkway used for figure-of-eight walking tasks.
Significant changes within the group (Abbreviations: Cad, cadence; DBS, double support (as a percentage of the gait cycle); M, mean; Strl, stride length.

during walking at preferred and at fast speeds for young and older groups.

Fig 3. Means and standard error of mean (SEM) for gait speed during walking at preferred and at fast speeds for young and older groups.

Table 2: Parameters of Postural Adjustments During Straight Line Walking at Preferred and at Fast Speeds

<table>
<thead>
<tr>
<th>Group</th>
<th>Speed (m/s)</th>
<th>Strl (m)</th>
<th>Cad (steps/m)</th>
<th>DBS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>1.23</td>
<td>1.38</td>
<td>106.84</td>
<td>25.66</td>
</tr>
<tr>
<td></td>
<td>0.21</td>
<td>0.12</td>
<td>11.85</td>
<td>1.95</td>
</tr>
<tr>
<td>Older</td>
<td>1.25</td>
<td>1.35</td>
<td>111.63</td>
<td>30.93</td>
</tr>
<tr>
<td></td>
<td>0.21</td>
<td>0.17</td>
<td>11.23</td>
<td>4.51</td>
</tr>
</tbody>
</table>

Table 4 shows that both young adults and older people significantly decreased their stride length and increased their cadence when changing from straight line walking to walking and turning around a figure-of-eight, although double-limb support duration showed little change. A 2 (age) × 2 (condition: straight line walking vs walking and turning) mixed-design MANOVA was conducted with the gait speed, stride length, cadence, and double-limb support duration data. This showed a main effect for condition (Pillai-Bartlett trace = .756, F_{4,35} = 27.11, P < .001, partial η² = .756). Follow-up univariate F tests showed that when changing from straight line walking to walking and turning around a figure-of-eight, all subjects walked slower (F_{1,38} = 113.01, P < .001, partial η² = .748) with shorter strides (F_{1,38} = 82.28, P < .001, partial η² = .684) and decreased cadence (F_{1,38} = 51.25, P < .001; partial η² = .574).

The mixed-design MANOVA also showed a main effect for age (Pillai-Bartlett trace = .756, F_{4,35} = 7.94, P < .001, partial η² = .476). Subsequent univariate F tests showed that, compared with young adults, older people generally walked with increased double-limb support duration (F_{1,38} = 19.92, P < .001, partial η² = .344). Despite this, there was no significant interaction between age and turning condition.

Postural Adjustments When Changing From Unitask Turning to Dual-Task Turning

Table 4 shows that both young adults and older people significantly decreased their stride length and increased their cadence when changing from straight line walking to turning around a figure-of-eight, although double-limb support duration showed little change. A 2 (age) × 2 (condition: straight line walking vs walking and turning) mixed-design MANOVA was conducted with the gait speed, stride length, cadence, and double-limb support duration data. This showed a main effect for condition (Pillai-Bartlett trace = .756, F_{4,35} = 27.11, P < .001, partial η² = .756). Follow-up univariate F tests showed that when changing from straight line walking to walking and turning around a figure-of-eight, all subjects walked slower (F_{1,38} = 113.01, P < .001, partial η² = .748) with shorter strides (F_{1,38} = 82.28, P < .001, partial η² = .684) and decreased cadence (F_{1,38} = 51.25, P < .001; partial η² = .574).
cadence when changing from unitask figure-of-eight walking to figure-of-eight walking while performing a secondary motor task, although walking speed and double-limb support duration remained unchanged. A 2 (age) × 2 (condition: unitask vs dual task) mixed-design MANOVA was conducted with the gait speed, stride length, cadence, and double-limb support duration data. This showed a significant main effect for task condition (Pillai-Bartlett trace = -.482, F_{3,35} = 48.13, P < .001, partial η^2 = .482). This was because both groups walked with shorter strides (F_{3,38} = 16.97, P < .001, partial η^2 = .56) and increased cadence (F_{3,38} = 11.93, P < .01, partial η^2 = .293) during dual-task conditions. MANOVA also showed a main effect for age (Pillai-Bartlett trace = .363, F_{3,35} = 4.98, P < .01, partial η^2 = .363), resulting from higher cadence (F_{3,38} = 5.58, P < .05, partial η^2 = .128) and longer time spent in double-limb support (F_{3,38} = 14.625, P < .001, partial η^2 = .278) in the older group. Again, however, there was no significant interaction between age and the dual-task walking and turning condition.

**Coins Transferred**

Young and older subjects transferred a similar number of coins during figure-of-eight walking, with means of 4.6 ± 2.1 coins for the young group and 4.5 ± 1.6 coins for the older group (table 1).

**DISCUSSION**

This study is among the first systematic and controlled evaluations of the effects of age on balance control during gait. All activities were measured on a narrow pathway to ensure an adequate challenge to balance. The differences between performances at preferred and fast speeds, and during figure-of-eight walking with and without a secondary task, were evaluated. The major finding was that healthy older people selected strategies that maximized stability when balance was perturbed during dynamic motor tasks. In particular, when required to change from walking at preferred speed to walking quickly, older people failed to achieve the same increases in speed and stride length relative to the increases achieved by young adults. Nevertheless, healthy older people who had been screened to exclude pathology had walking patterns that were comparable with younger adults when they were required to walk in a straight line at preferred speed.

**Effects of Speed on Straight Line Walking of All Subjects**

The results of this study support the findings of Craik.29 Ferrandez et al.19,30 Craik and Dutterer,31 all of whom showed that older people retain some capacity for modulations of gait speed, stride length, and double-limb support duration with advancing age. When instructed to walk quickly, healthy older adults were able to increase their gait speed and stride length considerably and to decrease their double-limb support duration. However, their mean speed and stride length values were reduced, and their mean double-limb support values remained higher than in younger subjects. Reduced walking speed and stride length and increased double-limb support duration in older adults are usually interpreted as age-related adaptations to produce gait that is safer and less destabilizing, to compensate for increased accelerations acting on the body during fast walking.19,29,31 Maki32 noted that shorter stride length and slower walking speed were related to fear of falling and suggested that reduction in these variables might represent fear-related adaptations in an attempt to increase postural stability.

**Postural Adjustments When Required to Turn While Walking**

Both young adults and older people significantly decreased their walking speed, stride length, and cadence when changing from straight line walking to walking and turning around a figure-of-eight, although double-limb support duration showed little change. These adaptations presumably enabled people to maintain stability by slowing down the forward momentum during turning.

**Effects of Turning During Walking for Unitask and Dual-Task Conditions**

When changing from the unitask to dual-task figure-of-eight walking, all subjects walked with shorter steps, and the older

---

### Table 3: Parameters of Postural Adjustments During Straight Line Walking at Preferred Speed and Unitask Figure-of-Eight Walking

<table>
<thead>
<tr>
<th>Group</th>
<th>Speed (m/s)</th>
<th>Strl (m)</th>
<th>Cad (steps/m)</th>
<th>DBS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>1.23</td>
<td>1.38</td>
<td>106.84</td>
<td>25.66</td>
</tr>
<tr>
<td></td>
<td>0.21</td>
<td>0.12</td>
<td>11.85</td>
<td>1.96</td>
</tr>
<tr>
<td>Older</td>
<td>1.25</td>
<td>1.36</td>
<td>111.63</td>
<td>30.93</td>
</tr>
<tr>
<td></td>
<td>0.21</td>
<td>0.17</td>
<td>11.23</td>
<td>4.51</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Speed (m/s)</th>
<th>Strl (m)</th>
<th>Cad (steps/m)</th>
<th>DBS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>0.91*</td>
<td>1.14*</td>
<td>95.86*</td>
<td>25.82</td>
</tr>
<tr>
<td></td>
<td>8.82</td>
<td>0.097</td>
<td>13.60</td>
<td>3.09</td>
</tr>
<tr>
<td>Older</td>
<td>0.96*</td>
<td>1.11*</td>
<td>103.59*</td>
<td>30.21*</td>
</tr>
<tr>
<td></td>
<td>8.51</td>
<td>0.16</td>
<td>8.66</td>
<td>4.73</td>
</tr>
</tbody>
</table>

*Significant changes within the group (P < .001).
*Significant differences between groups (P < .001).

---

### Table 4: Parameters of Postural Adjustments During Unitask and Dual-Task Figure-of-Eight Walking

<table>
<thead>
<tr>
<th>Group</th>
<th>Speed (m/s)</th>
<th>Strl (m)</th>
<th>Cad (steps/m)</th>
<th>DBS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>0.91</td>
<td>1.14</td>
<td>95.86</td>
<td>25.82</td>
</tr>
<tr>
<td></td>
<td>8.82</td>
<td>0.10</td>
<td>13.60</td>
<td>3.09</td>
</tr>
<tr>
<td>Older</td>
<td>0.96</td>
<td>1.11</td>
<td>103.59</td>
<td>30.21</td>
</tr>
<tr>
<td></td>
<td>8.51</td>
<td>0.16</td>
<td>8.66</td>
<td>4.73</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Group</th>
<th>Speed (m/s)</th>
<th>Strl (m)</th>
<th>Cad (steps/m)</th>
<th>DBS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>0.92</td>
<td>1.08</td>
<td>100.97</td>
<td>25.73</td>
</tr>
<tr>
<td></td>
<td>13.11</td>
<td>0.13</td>
<td>18.15</td>
<td>3.07</td>
</tr>
<tr>
<td>Older</td>
<td>0.95</td>
<td>1.03</td>
<td>111.15</td>
<td>31.27</td>
</tr>
<tr>
<td></td>
<td>8.71</td>
<td>0.14</td>
<td>10.97</td>
<td>5.87</td>
</tr>
</tbody>
</table>

*Significant changes within the group (P < .001).
*Significant differences between groups (P < .001).
group walked with a higher cadence. Double-limb support duration and walking speed, however, remained relatively unchanged. These results did not support Gabell and Nayak’s assumption\(^\text{16}\) that increased balance difficulty would result in changes in double-limb support duration and stride width only. The narrow pathway constrained the ability of subjects to compensate for mediolateral instability by increasing stride width. The increased cadence may therefore have been an effort to adjust for this constraint. However, because a faster stepping rate during walking and turning may compromise stability by increasing COM accelerations, the effects of increased cadence on postural stability during turning require further investigation.

**Postural Adjustments to Balance Perturbations During Gait Are Task Specific**

This study provides new data showing that changes in postural adjustments in young and older adults are task specific and vary according to the type of perturbation encountered. Previous investigators\(^\text{16}\) assumed that balance could be assessed separately from gait and that double-limb support duration and stride width were the only spatiotemporal variables that compensated for challenges to balance during walking. In contrast, our study showed that young and older adults adjusted their walking speed, stride length, cadence, and double-limb support duration differently, depending on which type of balance demand was encountered. When required to change from self-selected to fast walking speed, all subjects increased their walking speed, stride length, and cadence and decreased double-limb support duration. When required to shift from straight line walking to walking and turning, both groups decreased their speed and stride length. When required to transfer from unisegmental to dual-task performance for figure-of-eight walking along a narrow pathway, all subjects decreased their stride length, and the older adults increased their cadence rate. Thus, stride width and double-limb support duration were not the only variables that changed in response to altered balance demands during walking.

To date, clinical assessments of balance in older people have mainly examined balance in standing and unperturbed walking and have not fully captured the complex array of balance responses available for movement-related tasks. The results of this study indicate that assessing locomotor responses to balance perturbations during walking provides valuable information about how older people maintain equilibrium during walking. When clinicians perform a comprehensive assessment of balance, therefore, it may be advantageous to examine the strategies used to maintain equilibrium during gait in a variety of functional tasks. These could include straight line walking on pathways of different widths at different speeds, walking and turning with different turn angles, walking and turning while performing a secondary motor or cognitive task, walking over surfaces with different friction coefficients or slopes, or negotiating obstacles of different heights and widths during gait.

**CONCLUSIONS**

The postural adjustments used by young and older adults in response to perturbations to balance during walking were task specific and varied according to the type of perturbation encountered. When required to walk quickly, older people were not able to increase their speed and stride length to the same extent as younger adults. This was presumably because the older adults were more cautious and opted for greater stability. When required to perform a secondary motor task during figure-of-eight walking, older people showed higher cadence rates and reduced stride length than did young adults. The high cadence was an unexpected finding not readily explained by attempts to improve stability. Further experiments are planned to investigate this phenomenon more closely. The current study was, however, confined to the analysis of balance control in healthy, independent ambulators who had not reported falling. Further research should examine whether older people with a history of falls adequately alter their postural adjustments to maintain equilibrium when their balance is challenged during gait.

**References**


Supplier
a. B&L Engineering, 3002 Dow Ave, Ste 416, Tustin, CA 92780.