ORIGINAL ARTICLE

Reduced Hip Extension in the Elderly: Dynamic or Postural?

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ABSTRACT. Lee LW, Zavarei K, Evans J, Lelas JJ, Riley PO, Kerrigan DC. Reduced hip extension in the elderly: dynamic or postural? Arch Phys Med Rehabil 2005;86:1851-4.

Objective: To test the hypothesis that reduced hip extension and increased anterior pelvic tilt in the elderly are dynamic gait phenomena that do not occur during normal standing posture.

Design: Experimental.

Setting: Gait laboratory.

Participants: Twenty-five older adult subjects (mean age ± standard deviation, 71±5y) and 25 young adult subjects (mean age, 26±5y).

Intervention: Subjects were observed during standing and walking at self-determined comfortable, slow, and fast walking speeds. Positions and kinematics of the pelvis and lower extremities were measured using a 3-dimensional video-based motion analysis system.

Main Outcome Measures: Peak hip extension and anterior pelvic tilt.

Results: There were no statistically significant differences between the older and young adult groups during standing with respect to either hip extension (3°±5° vs 1°±6°) or anterior pelvic tilt (11°±5° vs 10°±5°). On the other hand, at comfortable walking speeds, the older adult group had reduced peak hip extension (7°±6° vs 11°±6°, $P<.05$) and increased anterior pelvic tilt (15°±5° vs 11°±5°) compared with the young adult group. At fast walking speeds, peak hip extension was significantly reduced in the older adult group than in the young adult group (9°±6° vs 14°±6°, $P<.05$), but there was no significant difference at slow walking speeds (6°±6° vs 9°±5°).

Conclusions: Age-related changes in gait defined by reduced peak hip extension and increased pelvic tilt are dynamic rather than standing postural characteristics.

Key Words: Aged; Biomechanics; Gait; Hip; Posture; Rehabilitation.

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As THE PROPORTION OF OLDER adults in the United States increases dramatically over the next few decades, preventing mobility-related impairments will become increasingly important. However, designing effective interventional strategies requires an understanding of the fundamental mechanisms by which age-related loss of musculoskeletal function occurs. Gait studies of healthy elderly have demonstrated decreased comfortable walking speed, reduced peak hip extension, and increased anterior pelvic tilt.[1,2] Because older adults consistently walked at a slower speed than younger control subjects, it was unclear if these changes were related to postural and anatomic deficits, such as hip flexion contractures.

Hip flexion contractures are thought to occur with immobility,[3] because gait is probably the only regular daily activity that stretches the hip joint into full extension. Hip flexion contractures or reduced hip flexion in general are associated during gait with increased anterior pelvic tilt and reduced contralateral step length, which could lead to decreased gait velocity.[4-6] It is surmised that the increased pelvic tilt and decreased contralateral step length compensate for the reduced hip extension to maximize gait efficiency. In the elderly, anterior pelvic tilt and a flexed hip joint could also stem from postural changes, arising from weakened abdominal and hip muscles or as a compensation for fear of instability.[7]

This study examines whether reduced hip extension and increased anterior pelvic tilt found during the gait of healthy elderly are dynamic phenomena or consequences of anatomic and postural changes with increasing age. It was hypothesized that reduced peak hip extension and increased anterior pelvic tilt can be detected only during gait and do not result from anatomic and postural deficits. Our secondary hypothesis was that reduced hip extension is a persistent feature of gait, present at various walking speeds in older adults.

METHODS

Participants

Twenty-five healthy subjects aged 65 years and older (mean age ± standard deviation [SD], 71±5y; height, 1.63±0.08m; weight, 66.6±11.2kg) and 25 healthy young adult subjects aged 18 to 40 years (mean age, 26±5y; height, 1.69±0.10m; weight, 61.9±14.8kg) were studied. There were 16 women and 9 men in each group. Elderly subjects were recruited from the greater Boston area via the Harvard Cooperative Program on Aging subject registry and posted advertisements in community centers, while young adult subjects were recruited from the community. Subjects underwent a screening history and physical examination and were excluded from the study if they had a medical history of orthopedic, neurologic, cardiac, or pulmonary problems. Subjects were also excluded if they had a history of frequent falls. Approval was obtained from the institutional review boards at both the Spaulding Rehabilitation Hospital (where the data were collected), and the University of Virginia School of Medicine (where the data were analyzed).

Measurement and Analysis

The degrees of peak hip extension and peak anterior pelvic tilt were measured for each subject during comfortable standing and during walking at the 3 self-selected speeds: comfortable, slow, and fast. Measurement of pelvic and lower-extremity joint motion and kinetics was performed using standard techniques previously reported elsewhere.[8-11] Briefly, a 6-camera video-based motion analysis system (Vicon 512 system[a]), was used to measure the 3-dimensional position of reflective markers, at 120 frames/s, attached to the following bony landmarks on the pelvis and lower extremities during walking: bilateral anterior superior iliac spines, lateral femoral condyles, lateral malleoli, forefeet, and heels. Additional markers were placed over the sacrum and rigidly attached to wands over the midfemur and midshank.

Pelvic and joint angular position and motion were determined per anatomic definition using a commercially available full-inverse dynamics model, Vicon Clinical Manager,[a] and reported in degrees. Temporal parameters (velocity, stride length, cadence) were determined using the force platform and kinematic information to define a gait cycle. Force platform data were obtained from 2 staggered forceplates (BP400600 model[b]) with a sampling rate of 1080 frames/s.

Intervention

In the gait laboratory, subjects were observed during standing and were instructed to walk at various speeds while pelvic and lower-extremity joint positions were measured using the 3-dimensional video-based motion analysis system. Subjects were initially asked to stand, which allowed obtaining static pelvic and bilateral lower-extremity joint measurements. All subjects then walked barefoot at their own self-selected, comfortable speed along a 10-m walkway. They were then asked to walk at a self-selected pace faster than their own comfortable pace and then a self-selected pace slower than their comfortable pace. Six trials were observed for each subject at each of the 3 different self-determined walking speeds.

Statistical Analysis

Changes in peak hip extension and peak anterior pelvic tilt during walking were evaluated as follows: we calculated individual mean values of peak hip extension and peak anterior pelvic tilt by averaging the values obtained during 6 trials for each subject and comparing these with baseline values (standing) using paired *t* tests. We assessed the effect of age on changes in peak hip extension and peak anterior pelvic tilt during standing and walking by calculating group mean values of peak hip extension and peak anterior pelvic tilt among both elderly and young subjects during standing and during walking. We compared group means during standing and while walking using unpaired *t* tests. All tests of statistical significance were 2-tailed (α=.05).

Table 1: Gait Characteristics: Hip Extension and Anterior Pelvic Tilt Kinematics

Group	Elderly	Young Adults
Hip extension (deg)		
Comfortable speed	7±6	11±6
Slow speed	6±6	9±5
Fast speed	9±6	14±6
Anterior pelvic tilt (deg)		
Comfortable speed	15±5	11±5
Slow speed	15±4	12±5
Fast speed	17±5	13±5

NOTE. Values are mean ± SD.

RESULTS

Measurements During Standing

During standing, there were no statistically significant differences between the elderly and the young adult groups with respect to either mean hip extension (3°±5° vs 1°±6°, P=.44) or mean anterior pelvic tilt (11°±5° vs 10°±5°, P=.86).

Measurements During Walking

Compared with young adults who had an average peak hip extension of 11°±6°, average peak hip extension in the elderly was 7°±6° (P<.05) at comfortable walking speeds (fig 1). Average peak anterior pelvic tilt at comfortable walking speeds increased significantly in the elderly group—15°±5° for the elderly group and 11°±5° for the young adult group (P<.05) (table 1). Comfortable walking speed was 1.17±0.18m/s for elderly adults and 1.29±0.14m/s for the young adult group. Cadence was similar in the elderly and young adult groups (0.97±0.10 steps/s and 0.98±0.08 steps/s, respectively). Step length at comfortable walking speed was also similar: 0.60±0.06m for the elderly group and 0.66±0.05m for the young adult group (table 2).

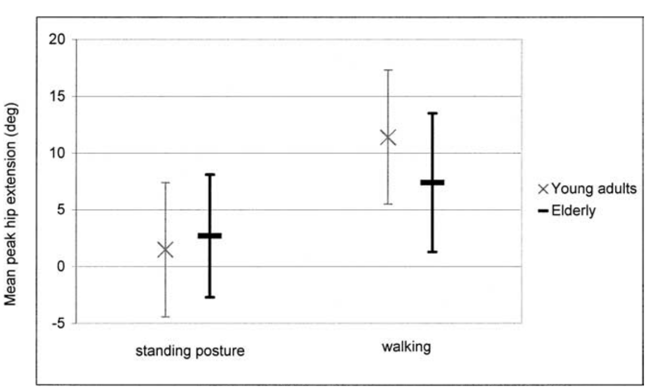

Fig 1. Comparison of peak hip extension in the elderly and young adult groups during standing and comfortable walking speed.

Table 2: Gait Characteristics: Temporal Parameters

Group	Elderly	Young Adults
Comfortable walking speed		
Velocity (m/s)	1.17±0.18	1.29±0.14
Cadence (steps/s)	0.97±0.10	0.98±0.08
Step length (m)	0.60±0.06	0.66±0.05
Slow walking speed		
Velocity (m/s)	0.93±0.15	0.94±0.15
Cadence (steps/s)	0.83±0.09	0.81±0.09
Step length (m)	0.55±0.07	0.58±0.06
Fast walking speed		
Velocity (m/s)	1.59±0.23	1.77±0.24
Cadence (steps/s)	1.17±0.13	1.15±0.13
Step length (m)	0.68±0.15	0.77±0.06

NOTE. Values are mean ± SD.

At self-determined slow walking speeds, there was no significant difference between the elderly and young adult group in peak hip extension (6°±6° and 9°±5°, respectively) (table 1). However, at self-determined fast walking speeds, there was a difference in peak hip extension between the 2 groups: 9°±6° for the elderly group and 14°±6° for the young adult group ($P<.05$) (table 1). Slow and fast walking velocity, cadence, and step length were also obtained for the elderly and young adult groups and are listed in table 2.

DISCUSSION

The data from this study demonstrate that reduced hip extension and increased anterior pelvic tilt in healthy elders occur during walking but not during standing, and the extent of the age-related changes in peak hip extension varies depending on velocity. These findings imply an alternative to previous interpretations that the decreased peak hip extension noted in the elderly arises from a stooped forward lean of the pelvis or from abdominal and hip muscle weakening leading to an anterior pelvic tilt during standing. Although we did not test hip and abdominal manual muscle strength, because hip extension and anterior pelvic tilt did not differ significantly in the elderly and young adult groups during standing, the results suggest that decreased hip extension in the elderly are gait-related rather than the manifestation of postural decline. We measured both hip extension and anterior pelvic tilt because anterior pelvic tilt is thought to be the most significant compensation for reduced hip flexion.[5,6] If only hip extension were measured, it could be argued that, despite normal hip extension measurements, reduced hip flexion was actually present and was being masked by an increased anterior pelvic tilt. In this case, because both hip extension and anterior pelvic tilt measurements were similar in young and older adults during standing, it appears that reduced hip extension and increased anterior pelvic tilt are not common postural changes in healthy older adults.

Reduced peak hip extension and increased anterior pelvic tilt seen during a self-selected comfortable walking speed confirm findings from previous studies on gait patterns in older adults.[1,2,8] These changes in hip extension and pelvic tilt also lead to smaller step length and decreased gait velocity, but with preserved cadence, as seen in prior studies comparing the gait of older with younger adults.[1,2,11] Because cadence did not differ much between older and younger adults during any of the walking speeds, increasing the number of steps per second may be difficult for older adults in order to achieve walking speeds comparable to the young adult comfortable or fast ranges. Instead, targeting interventions to increase step length may be a more effective method to reverse age-related slowing of gait velocity. For instance, an interventional study consisting of hip extension stretching in a group of older adults has demonstrated an increase in step length and gait velocity after completion of this exercise program.[12] Considering the reduced hip extension noted during gait, stretching the hip flexor muscles seems efficacious in improving step length and gait velocity.

The finding that reduced peak hip extension occurs during comfortable and fast walking speeds but not during slow walking speeds was unexpected. Prior studies[2,8] have shown that, at a self-determined fast walking speed (a speed comparable to that of a younger control group), reduced hip extension and increased anterior pelvic tilt persisted in the elderly group. However, hip extension and pelvic tilt have not been previously studied at slow walking speeds. In this study, interestingly, the difference in peak hip extension was nonsignificant between the elderly and young adult groups at slow walking speeds and became significant at faster walking speeds. The greater change in peak hip extension between the age groups with increased gait velocity may indicate that muscles involved in hip extension are not fully stretched during daily walking, because cadence is maintained over step length in older adults. People usually walk at comfortable and fast walking speeds and there are few indications for walking at a slower than comfortable walking speed during daily activities. Prolonged walking at comfortable or fast speeds without adequate hip extension stretching may cause the formation of subtle hip flexion contractures in the healthy elderly.

In general, there is a tendency with age to develop contractures of the hips more so than of the knees, because the hip joint is less often fully stretched than the knee joint when physical activity declines.[13] The older adult group in this study was comprised of healthy elderly who were community ambulators with no musculoskeletal defects. People who are more immobile or are older than our group may already have developed subtle hip flexion contractures, and may demonstrate reduced peak hip extension at all walking speeds. Further studies comparing peak hip extension of older adults over many years longitudinally or older adults with different levels of mobility tested at different walking speeds may shed insight into this possibility.

CONCLUSIONS

In healthy older adults, age-related changes in gait characterized by reduced peak hip extension and increased anterior pelvic tilt are a dynamic rather than a postural phenomenon. Moreover, these age-related changes in peak hip extension seem to be associated with gait velocity, with significant differences between the age groups at comfortable and fast walking speeds. Studying the effect of peak hip extension on gait may offer clinically important mechanisms to improve walking in older adults and thus merits further investigation.

References

1. Judge JO, Ounpuu S, Davis RB 3rd. Effects of age on the biomechanics and physiology of gait. Clin Geriatr Med 1996; 12:659-78.
2. Kerrigan DC, Todd MK, Della Croce U, Lipsitz LA, Collins JJ. Biomechanical gait alterations independent of speed in the healthy elderly: evidence for specific limiting impairments. Arch Phys Med Rehabil 1998;79:317-22.
3. Kottke FJ. Therapeutic exercise to maintain mobility. In: Kottke FJ, Lehmann JF, editors. Krusen's handbook of physical medicine and rehabilitation. Philadelphia: WB Saunders; 1990. p 436-51.
4. Perry J. Gait analysis: normal and pathological function. Thorofare: Slack; 1992.
5. Shimada T. Factors affecting appearance patterns of hip-flexion contractures and their effects on postural and gait abnormalities. Kobe J Med Sci 1996;42:271-90.
6. Lee LW, Kerrigan DC, Della Croce U. Dynamic implications of hip flexion contractures. Am J Phys Med Rehabil 1997;76: 502-8.
7. Woodhull-McNeal AP. Changes in posture and balance with age. Aging (Milano) 1992;4:219-25.
8. Kerrigan DC, Lee LW, Collins JJ, Riley PO, Lipsitz LA. Reduced hip extension during walking: healthy elderly and fallers versus young adults. Arch Phys Med Rehabil 2001;82:26-30.

9. Kadaba MP, Ramakrishnan HK, Wootten ME, Gainey J, Gorton G, Cochran GV. Repeatability of kinematic, kinetic, and electromyographic data in normal adult gait. J Orthop Res 1989; 7:849-60.
10. Kadaba MP, Ramakrishnan HK, Wootten ME. Measurement of lower extremity kinematics during level walking. J Orthop Res 1990;8:383-92.
11. Winter DA, Patla AE, Frank JS, Walt SE. Biomechanical walking pattern changes in the fit and healthy elderly. Phys Ther 1990;70: 340-7.
12. Kerrigan DC, Xenopoulos-Oddsson A, Sullivan MJ, Lelas JJ, Riley PO. Effect of a hip flexor-stretching program on gait in the elderly. Arch Phys Med Rehabil 2003;84:1-6.
13. Nonaka H, Mita K, Watakabe M, et al. Age-related changes in the interactive mobility of the hip and knee joints: a geometrical analysis. Gait Posture 2002;15:236-43.

Suppliers

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b. Advanced Medical Technology Inc, 176 Waltham St, Watertown, MA 02472.