ARTICLES

Effect of a Hip Flexor–Stretching Program on Gait in the Elderly

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ABSTRACT. 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.

Objectives: To test whether a reduction in peak hip extension during the terminal stance phase of walking in elderly compared with young adult subjects represents a hip flexor contracture impairment rather than some dynamic consequence and to test the hypothesis that stretching the hip flexors improves both static and dynamic peak hip extension, as well as other age-related gait changes about the ankle.

Design: A double-blinded, randomized, controlled trial.

Setting: Stretching exercises were performed in the subjects' homes. Pre- and postassessments were performed in a gait laboratory.

Participants: Ninety-six healthy elderly individuals in 2 groups: treatment (n=47) and control (n=49).

Intervention: The treatment group received a 1-time instruction in hip flexor stretching, whereas the control group received a 1-time instruction in shoulder abductor stretching. Participants in each group were asked to perform stretching exercises on their own twice daily for 10 weeks.

Main Outcome Measures: Static and dynamic peak hip extension, peak anterior pelvic tilt, and other peak kinematic and kinetic variables during the gait cycle.

Results: There was a modest improvement in static peak hip extension as measured by a goniometer within the treatment group (mean ± standard deviation, 6.1°±2.5° to 7.7°±3.6°, P=.032) compared with no change in the control group. At comfortable walking speed, dynamic hip extension tended to increase in the treatment group (5.1°±9.7° to 7.1°±8.0°, P=.103) compared with no real change in the control group (5.3°±8.9° to 5.4°±7.5°, P=.928). Similarly, at fast walking speed, dynamic hip extension tended to increase in the treatment group (6.4°±9.8° to 8.4°±8.0°, P=.093) compared with no change in the control group. Changes in ankle kinematics and kinetics included a significant improvement in peak ankle plantarflexion and a tendency to improved ankle power generation.

Conclusion: The static and dynamic trends to improvement in peak hip extension were of similar magnitude, suggesting that age-related reduction in peak hip extension during gait is the result of a static hip flexion contracture rather than a dynamic consequence. Additionally, age-related changes in ankle kinematics and kinetics may be secondarily related to hip flexion contracture impairment rather than impairment at the ankle per se. This study was limited by the exercises being unsupervised and relying on 1-time instruction. A more rigorous and supervised hip flexor–stretching exercise program may yield more substantial improvements in gait parameters.

Key Words: Elderly; Exercise; Gait; Rehabilitation.

IMPROVING OR AT LEAST MAINTAINING gait function in the elderly is appealing, and rehabilitation clinicians are particularly concerned with prescribing exercises that are most effective in improving gait function. In search of specific gait abnormalities in the elderly to which rehabilitative therapy can be directed, our group previously compared the biomechanics of gait in the elderly, at both fast and comfortable speeds, with the gait biomechanics of young adults walking at a comfortable speed.[1] We hypothesized that many of the previously reported age-related differences in gait kinematics and kinetics could be attributed to elderly persons' slower walking speeds. Indeed, we found only 2 key differences that persisted in the elderly at both comfortable and fast walking speeds: reduced peak hip extension (associated with an increase in peak anterior pelvic tilt) and reduced peak ankle plantarflexion (associated with reduced ankle power generation). These findings suggest that performance in the elderly could be specifically limited by hip flexion contracture, ankle plantarflexor concentric weakness, or both. The latter possibility of ankle plantarflexor concentric weakness as an impairment that limits functional gait has been suggested by others.[2-5]

In a subsequent study,[6] we compared the gait of both elderly fallers and nonfallers with that of young adults. In that study, the only kinematic gait difference that was consistently more exaggerated in elderly fallers than young adults was reduced peak hip extension (and increased anterior pelvic tilt). The nonfaller elderly group had an average 5° reduction in peak hip extension compared with young adults, and the elderly faller group had an additional 4° reduction beyond the elderly nonfaller group.[6] The isolated and consistent finding of reduced hip extension supports the presence of hip flexion contractures as a key impairment limiting functionality. Still, because of the cross-sectional nature of these previous studies, we cannot rule out that these gait findings are merely dynamic consequences or secondary compensations for another key impairment to functionality, such as weakness or poor balance.

Intuitively, even a small reduction in hip extension range necessarily limits peak hip extension during walking. To compensate for the reduced peak hip extension, an increase in

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anterior pelvic tilt, a shortened step length, or both may occur.[1,6] In a population of patients with various impairments and disabilities, including hip flexion contractures evidenced by Thomas testing, our group reported a strong inverse relationship between (1) peak hip extension and anterior pelvic tilt during gait and (2) peak hip extension and contralateral step length.[7] We believe that the reduction in peak hip extension occurring during walking is the result of a static hip flexion contracture rather than a dynamic consequence of or compensation for another impairment. Moreover, we hypothesize that an isolated exercise program of hip flexor stretching will reverse this hip flexion contracture, tending to improve peak hip extension and peak anterior pelvic tilt during gait. Additionally, we believe that a greater hip extension range in the trailing limb should allow the ankle to plantarflex more fully. Thus, we hypothesize that reversing the hip flexion contracture will also improve previously reported age-related gait differences of reduced peak ankle plantarflexion (and ankle power generation).[1,4,5]

Although stretching the hip flexors is often a component of fitness and rehabilitation programs, there are limited studies on the effectiveness of stretching the hip flexors on hip extension range of motion (ROM). Godges et al[8] reported, in a group of 9 healthy young adults, that 6 sessions of stretching the hip flexors increased static hip extension. We[9] also reported, on 2 elderly patients with lumbosacral spinal stenosis, that an isolated hip flexor–stretching program increased hip extension and reduced anterior pelvic tilt during gait. These reports, combined with our clinical experience, suggest that healthy elderly persons who stretch their hip flexors will improve their static hip extension ROM.

In this study, we hypothesized that the degree to which static peak hip extension improves will correspond to the degree to which dynamic peak hip extension during gait is improved. Finding a similar improvement in static and dynamic peak hip extension would support our hypothesis that the reduction in peak hip extension during walking is the result of a static hip flexion contracture rather than some dynamic consequence. Furthermore, we hypothesized an associated improvement in ankle plantarflexion and ankle power generation. This finding would support the belief that age-related differences in ankle kinematics and kinetics are not due to impairment about the ankle but rather are secondary to more proximal impairment, that is, contractures about the hip.

METHODS

Participants

One hundred participants were recruited from the Boston, MA, area through the Harvard Cooperative Program on Aging subject registry, posted flyers, advertisements in senior housing areas and community centers throughout Boston, and word of mouth. The study was approved by the Spaulding Rehabilitation Hospital institutional review board. After potential participants were screened by a health questionnaire and fit the inclusion criteria, we obtained written, informed consent from each subject. Persons recruited were ≥65 years old and were classified as "healthy," as determined by the health questionnaire distributed by the Harvard Cooperative Program on Aging and by their medical history. Specific exclusion criteria were (1) acute medical illness; (2) diagnosis or symptoms of unstable angina or congestive heart failure; (3) pulmonary diagnosis or symptoms of emphysema, chronic obstructive pulmonary disease, or asthma; (4) neurologic diagnosis, including Parkinson's disease, stroke, brain injury, cerebellar disease, myelopathy, myopathy, peripheral neuropathy, or active radiculopathy; (5) major orthopedic diagnosis in the lower back, pelvis, or lower extremities, including hip or other fracture since the age of 50, fused joint, joint replacement, or amputation; (6) active joint or musculoskeletal pain; (7) gait or balance disorder; (8) history of falls; and (9) regular use of an assistive device for walking.

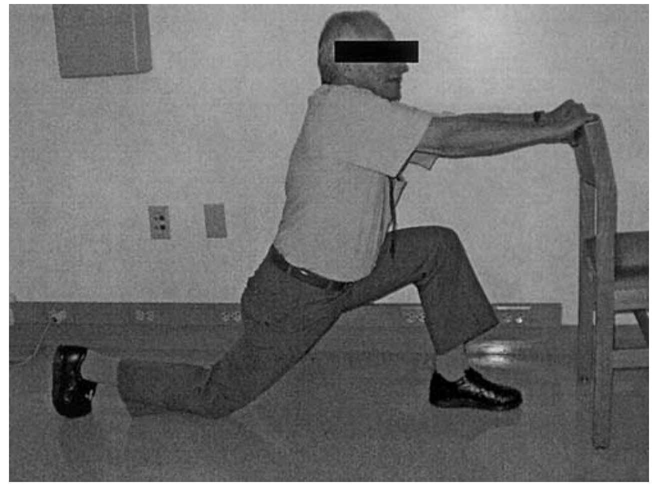

Fig 1. Hip flexor–stretching exercise performed by subjects in the treatment group (n=47).

Treatment and Control Interventions

Immediately after collection of the baseline gait data described below, participants were randomized, on the basis of a computer-generated block randomization, into 1 of 2 groups: treatment or control. After this, during the same initial visit, each subject received approximately 20 minutes of instruction on how to perform a 5-minute stretching session. One researcher trained all the participants in the program. The treatment group was instructed to perform a hip-stretching exercise (fig 1), whereas the control group received a shoulder deltoid–stretching exercise (fig 2). We believed that this particular hip-stretching exercise was feasible for elderly adults and could be performed safely and independently by using the subjects' own body weight rather than the force of an external weight or an assisting person. Subjects were instructed to perform 4 sets of stretches, holding each stretch for 30 seconds and alternating the right and left limb (8 stretches in total). The stretching exercises were preceded and followed with a warm-up and cool-down period as recommended by the American College of Sports Medicine.[10,11] The warm-up period consisted of (1) side stepping to the right and then to the left 4 times in each direction, (2) 3 sets of walking forward 3 steps, clapping, and walking backward 3 steps and clapping, and (3) holding on to a chair for balance, 4 sets of lifting the right knee up and then the left knee. The cool-down period consisted of (1) taking a deep breath in while bringing both arms over the head and letting the breath out while bringing the arms back down, (2) shaking out the arms and legs, and (3) using a chair if needed for balance, rotating the wrists and ankles alternatively clockwise and then counterclockwise. The warm-up and cool-down periods were identical between the treatment and control groups.

Participants in each group were asked to perform the 5-minute session twice daily for 10 weeks in their own homes. They each received a copy of their respective exercise program. Participants were also asked to keep a logbook, to check

Fig 2. Shoulder abductor–stretching exercise performed by subjects in the control group (n=49).

off each day whether they performed the exercise, and to submit a weekly logsheet at the end of each week of the 10-week program. Participants received remuneration at the end of the 10 weeks when they returned for their final postintervention evaluation.

Pre- and Postintervention Assessments

All pre- and postintervention assessments were performed in the Center for Rehabilitation Science at Spaulding Rehabilitation Hospital. The preintervention assessment was performed on the first visit, preceding randomization, and the postintervention assessment was performed within 1 week of completing the 10-week program. The evaluators performing the assessments were masked with respect to the subjects' treatment or control assignment. Subjects wore elastic-waist, spandex shorts while being evaluated. The static hip extension range was measured in the standing position (see fig 1), with 1 leg extended and the contralateral leg flexed. We opted to measure hip extension with the subject in this position because we believed that the measurement would rely more consistently on the stretch of the subject's own body weight rather than an evaluator's applied force. With the subject in this position, an examiner used a double-arm (30.5-cm) clear plastic goniometer to measure the degree of hip extension. The evaluator measured the degree of hip extension by using the anatomic landmarks described by Kottke and associates[12-15]: the degree of the angle between a line dropped perpendicular from a line intersecting the anterior superior and posterior superior iliac spines to the greater trochanter and a line from the greater trochanter to the lateral femoral condyle. The goniometric measurements were rounded off to the nearest degree.

Pelvic and bilateral lower-extremity joint motion and joint kinetics during walking were collected. Subjects were asked to first stand and then walk along a 10-m walkway. During the walk, kinematic and kinetic data from 3 complete gait strides were recorded. The procedures to collect pelvic and lower-extremity joint motion and kinetics were based on standard techniques reported elsewhere.[16-22] 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 per second, 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 by anatomic definitions from the VICON Clinical Manager.[a] Ground reaction forces were measured synchronously with the motion analysis data by using 2 staggered force platforms[b] imbedded in the walkway. The locations of the force platforms in the global reference plane were predetermined by acquiring coordinates of markers placed on their corners. Joint torques in each plane were calculated by means of a commercialized full-inverse dynamic model from the VICON Clinical Manager. Accordingly, joint torque and power calculations were based on the mass and inertial characteristics of each lower-extremity segment, the derived linear and angular velocities and accelerations of each lower-extremity segment, and the ground reaction force and joint center position estimates. Joint torques and powers were normalized for body weight and height and were reported as external in newton meters per kilogram meters (N·m/kg·m) and watts per kilogram meters (W/kg·m), respectively. Temporal parameters (velocity, stride length, cadence, step width) were routinely obtained by using the force platform and kinematic information to define initial foot contact times and distance parameters. Average kinematic and kinetic values for each subject's pelvic and lower-extremity joints for the pre- and posttreatment conditions were obtained from 3 trials (average of both right and left lower extremities, providing an average of 6 values for each condition).

Data Analysis

All major kinematic and kinetic peaks were compared statistically between pre- and postexercises, taking the average of 6 trials for each subject for each lower-extremity variable (3 on each side) and 3 trials for each subject for the pelvis. Between-group demographic and baseline characteristics, such as age, gender, and peak hip extension during comfortable and fast walking speeds, were compared by unpaired *t* test. For each treatment and control group, data were compared between pre- and poststretching exercises by paired *t* test. Primary outcome measures of static and dynamic peak hip extension and anterior pelvic tilt during both comfortable and fast walking were analyzed with paired Student *t* tests. Secondary outcome measures of all other kinematic and kinetic variables (total, 42 parameters) during comfortable walking speed were also analyzed with paired *t* tests. Statistical significance was defined at *P* less than .05 for primary outcome measures. A Bonferroni

Table 1: Peak Kinematic and Kinetic Parameters at Comfortable Walking Speed

Parameter	Treatment (n=47)		Control (n=49)	
	Pre-exercise	Postexercise	Pre-exercise	Postexercise
Hip extension (deg)	5.1±9.7	7.1±8.0	5.3±8.9	5.4±7.5
Hip extension torque (N·m/kg·m)	.47±.12	.52±.12	.48±.12	.48±.11
Anterior pelvic tilt (deg)	13.1±7.3	12.3±5.6	13.8±6.8	14.3±5.6
Ankle plantarflexion (deg)	11.6±5.4	13.4±5.0	13.1±6.6	13.7±6.2
Ankle plantarflexion power (W/kg·m)	1.78±.47	1.86±.47	1.83±.45	1.86±.42

NOTE. Values are mean ± SD.

adjustment was made for the other 42 peak kinematic and kinetic parameters, and statistical significance was defined at *P* less than .0012 (.05/42). Values presented in Results are mean ± standard deviation (SD).

RESULTS

Of 100 subjects, 96 completed the study. Four subjects dropped out during the 10-week period because of family tragedy (1 control, 1 treatment subject), unexpected surgery with lengthy recovery time (1 treatment subject), and persistent back pain (1 treatment subject). Forty-seven participants in the treatment group (32 women, 15 men) and 49 subjects in the control group (34 women, 15 men) completed the study. No significant differences between these groups were observed with respect to demographics, gait speed, or primary or secondary outcome gait kinematic or kinetic preintervention measures at either comfortable or fast walking speeds. Adherence to the exercise program, as calculated by numbers of checks for each exercise session on the subjects' weekly log books, averaged 94% for the treatment group and 93% for the control group.

There was a modest improvement in static peak hip extension as measured by the goniometer within the treatment group (6.1°±2.5° to 7.7°±3.6°, *P*=.032), compared with no major change in the control group (7.0°±3.6° to 7.4°±4.4°, *P*=.601). Tables 1 and 2 list dynamic (kinematic, kinetic) parameter values at the comfortable and fast walking speeds, respectively. A similar modest but not quite statistically significant improvement in dynamic peak hip extension during both comfortable and fast walking speeds was also observed in the treatment compared with the control group. At comfortable walking speed, dynamic hip extension increased in the treatment group (5.1°±9.7° to 7.1°±8.0°, *P*=.103) compared with no major change in the control group (5.3°±8.9° to 5.4°±7.5°, *P*=.928). At fast walking speed, dynamic hip extension similarly tended to increase in the treatment group (6.4°±9.8° to 8.4°±8.0°, *P*=.093) compared with no change (actually, a trend to a reduction) in the control group (7.5°±8.7° to 6.7°±7.6°, *P*=.485).

Anterior pelvic tilt improved (reduced) nonsignificantly in the treatment group at both comfortable and fast walking speeds (13.1°±7.3° to 12.3°±5.6°, *P*=.374; 14.8°±7.2° to 13.7°±5.6°, *P*=.262, respectively). Conversely, in the control group, anterior pelvic tilt increased nonsignificantly at both comfortable and fast walking speeds (13.8°±6.8° to 14.3°±5.6°, *P*=.589; 14.2°±6.5° to 15.3°±5.7°, *P*=.252, respectively).

Of the secondary kinematic and kinetic parameters evaluated, only 2 parameters significantly changed with treatment: peak ankle plantarflexion and peak ankle dorsiflexion during swing. At comfortable walking speed, peak ankle plantarflexion increased in the treatment group from 11.6°±5.4° to 13.4°±5.0° (*P*=.001), compared with no major change in the control group (13.1°±6.6° to 13.7°±6.2°, *P*=.389). Similarly, at fast walking speed, peak ankle plantarflexion significantly increased in the treatment group from 12.5°±5.5° to 14.3°±5.2° (*P*=.001), compared with a trend to an increase in the control group (13.5°±5.5° to 14.6°±6.0°, *P*=.066). Peak ankle dorsiflexion decreased at both comfortable and fast walking speeds for the treatment group (5.2°±3.1° to 3.7°±3.2°, *P*<.001; 6.4°±3.1° to 4.7°±3.3°, *P*<.001, respectively), compared with slight decreases in the control group at comfortable and fast walking speeds (5.8°±5.7° to 4.9°±3.5°, *P*=.210; 7.0°±3.6° to 5.5°±3.2°, *P*=.002; not significant with the Bonferroni adjustment).

Hip external extension torque increased with treatment (.47±.12N·m/kg·m to .52±.12N·m/kg·m, *P*=.003; not significant with the Bonferroni adjustment) at comfortable walking speed, compared with no change in the control group (.48±.12N·m/kg·m to .48±.11N·m/kg·m, *P*=.884). At fast walking speed, although the treatment group showed no increase at the fast walking speed (.66±.18N·m/kg·m to .66±.14N·m/kg·m, *P*=.951), the control group actually showed a decrease (.64±.17N·m/kg·m to .60±.12N·m/kg·m, *P*=.027).

Ankle plantarflexor power tended to increase in the treatment group at comfortable speed (1.78±.47W/kg·m to 1.86±.47W/kg·m, *P*=.059), compared with no major change

Table 2: Peak Kinematic and Kinetic Parameters at Fast Walking Speed

Parameter	Treatment (n=47)		Control (n=49)	
	Pre-exercise	Postexercise	Pre-exercise	Postexercise
Hip extension (deg)	6.4±9.8	8.4±8.0	7.5±8.7	6.7±7.6
Hip extension torque (N·m/kg·m)	.66±.18	.66±.14	.64±.17	.60±.12
Anterior pelvic tilt (deg)	14.8±7.2	13.7±5.6	14.2±6.5	15.3±5.7
Ankle plantarflexion (deg)	12.5±5.5	14.3±5.2	13.5±5.5	14.6±6.0
Ankle plantarflexion power (W/kg·m)	2.31±.47	2.28±.48	2.35±.61	2.23±.49

NOTE. Values are mean ± SD.

in the control group (1.83±.45W/kg·m to 1.86±.42W/kg·m, P=.265). No significant changes in ankle plantarflexor power were noted for either the treatment or control group at fast walking speeds.

A slight but similar increase in comfortable walking speed was observed in both the treatment and control groups before and after the intervention (treatment group: 1.19±0.18m/s to 1.23±.18m/s, P=.006; control group: 1.19±.17m/s to 1.23±.18m/s, P=.003; not significant with the Bonferroni adjustment).

DISCUSSION

As hypothesized, the degree to which static hip extension improved was of similar magnitude to the improvement in dynamic hip extension during gait. Specifically, a modest 1.6° increase in static hip extension was achieved with the hip flexor–stretching exercises; this was associated with a similar trend to a 2.0° magnitude of increase in dynamic hip extension during walking at both comfortable and fast walking speeds. The similar magnitudes of improvement in static and dynamic hip extension support our hypothesis that reduced hip extension during walking indeed represents a static impairment (hip tightness) rather than some dynamic consequence. We also observed a trend to improvement (reduction) in anterior pelvic tilt. The tendency toward a reduction in anterior pelvic tilt implies that the modest improvement in hip extension range allowed for a slight decrease (although it was not statistically significant) in anterior pelvic tilt. These findings support the hypothesis that the previously reported increase in anterior pelvic tilt in the elderly[1,6] is a compensation for hip flexion contracture rather than a compensation or direct result of another impairment. Reducing the need for anterior pelvic tilt could potentially improve the biomechanics of the spine and perhaps of the lower extremities by altering the center of mass position.

Also as hypothesized, we found an improvement in peak ankle plantarflexion with hip stretching. In addition, we observed a trend toward improved ankle plantarflexor power at comfortable walking speed. These findings support the hypothesis that the previously reported reductions in ankle plantarflexion and ankle plantarflexor power in the elderly may be secondary to proximal impairment rather than to impairment at the ankle (or ankle musculature) per se.

Although these results support the hypothesis that hip flexion contractures are largely responsible for the previously reported age-related gait changes, the improvements with hip flexor stretching are not as great as we would have hoped. We previously reported a 5° reduction in hip extension during gait in healthy elderly compared with young adults,[1,6] which would imply that the hip flexion contracture impairment is 5°. Theoretically, hip flexor stretching should reverse most, if not all, of this contracture. We suspect that the hip flexor–stretching program we performed was not quite sufficient in stretching the hip flexors to this potential 5° improvement. The unsupervised nature of the study may have been inadequate, and the 1-time instruction may not have been sufficient. To perform the stretch properly, the subject should feel a stretch in the hip flexors. The evaluators noted on the postintervention analysis that many of the subjects were not familiar with the sensation of a stretch when measuring static hip extension. This was a difficult perception to quantify, and the evaluators were blinded as to who was in the treatment or control group. Nonetheless, we suspect that subjects require subsequent instructions to ensure that they are performing the stretch properly. In addition, other stretching exercises might potentially be better than the one we used here to improve the hip extension range. Finally, the 30-second stretch we showed may not be optimal for elderly subjects. A recent study showed substantially greater improvement in ROM with a 60- versus 30-second stretch (of the hamstrings) in subjects older than 65 years.[23]

Both the treatment and control group had a slight improvement in comfortable walking speed, which might have been attributable to an improved comfort level with the laboratory setting on the follow-up assessment. The lack of treatment-specific improvement in gait speed is not surprising, considering the small improvements in hip extension that were achieved with the hip flexor–stretching program. We hope that a supervised stretching program would increase the hip extension range sufficiently to improve stride length, thus improving walking velocity. Moreover, a more notable improvement in hip extension might improve balance and reduce the risk of falls in the elderly. The elderly population studied here was healthy, with no clinically apparent balance problems. Perhaps in a more frail elderly population with a history of recurrent falls and a more pronounced reduction in hip extension (9° reduction in elderly fallers vs young adults),[6] a hip flexor–stretching program would result in greater improvements in hip range, which would produce more dramatic improvements in overall gait efficiency and reduction of falls. Future studies ought to include a supervised stretching program in both healthy elderly and frail elderly who recurrently fall.

We observed no adverse effects directly related to the stretching program. Specifically, no subject who completed the study reported any adverse effect from performing the stretches. One subject reported persistent back pain but, in retrospect, reported that he had back pain preceding the study and did not believe that the stretching exercises aggravated his back pain. The reported compliance for the stretching programs was excellent. Because the hip-stretching exercise is rather nonstrenuous and demands relatively little time compared with other types of exercise programs, compliance with this stretching program may be more feasible than with other types of exercise. It is possible that if the stretching program can improve hip extension during walking, the stretch to the hip flexors during walking itself could further increase or at least maintain the hip extension range. Consistent with this notion, we observed a trend in the treatment group (but not in the control group) toward an increase in the extending hip torque at the end of the stance during both comfortable and fast walking. An increase in extending hip torque would imply that, during walking, a greater stretching force through the hip flexors was achieved. Thus, a formal hip flexor–stretching program might improve static and dynamic hip extension directly, as well as indirectly initiate a type of perpetual stretching during walking.

CONCLUSIONS

Although the improvements in hip extension (1.6°) were modest, the similar magnitudes of the static and dynamic trends to improvement in peak hip extension (2.0°) suggest that the age-related reduction in peak hip extension during gait is the result of a static hip flexion contracture rather than a dynamic consequence. The significantly improved peak ankle plantarflexion and the tendency toward improved ankle power generation that occurred in the treatment but not the control group support the hypothesis that previously reported age-related changes in ankle kinematics and kinetics are secondarily related to hip flexion contracture impairment, rather than to impairment at the ankle per se. We expect to see more substantial (up to 5°) improvement in hip extension, as well as more substantial improvement in other gait parameters, with a more rigorous, supervised stretching program. Moreover, in frail elderly people with even greater limitations in hip extension, we might expect to see even greater improvements. Future supervised hip flexor–stretching exercise trials in both healthy and frail elderly are warranted.

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Suppliers

a. Vicon Motion Systems, 14 Minns Business Pk, West Way, Oxford OX2 0JB, UK.
b. Advanced Mechanical Technology Inc, 176 Waltham St, Watertown, MA 02472.