ORIGINAL ARTICLE

The Effects of Hip and Ankle Stretching on Gait Function of Older People

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ABSTRACT. Christiansen CL. The effects of hip and ankle stretching on gait function of older people. Arch Phys Med Rehabil 2008;89:1421-8.

Objective: To examine effects of hip and ankle stretching on gait function of older people.

Design: Randomized controlled trial.

Setting: Flexibility training was performed in participants' homes. Assessments were performed in a biomechanics laboratory.

Participants: Forty healthy volunteers (mean age ± SD, 72.1±4.7y) randomized to 2 groups: intervention (n=20) and control (n=20).

Intervention: Intervention participants performed an 8-week stretching program, and control group participants maintained activity level for 8 weeks. One investigator made weekly visits to instruct and monitor participants.

Main Outcome Measures: Primary outcome measures were passive joint motion for hip extension and ankle dorsiflexion and freely chosen gait speed. Secondary outcome measures were gait parameters during freely chosen gait speed and set gait speed walking (stride length, joint displacement).

Results: Compared with the control group, the intervention group had increased combined hip and knee motion ($P=.023$), ankle motion ($P=.020$), and freely chosen gait speed ($P=.016$). The intervention group showed statistically nonsignificant trends of increased stride length at freely chosen gait speed and set gait speed.

Conclusions: Findings suggest joint motion is a modifiable impairment that is effectively targeted with flexibility training for older people. Participants in the intervention group had improvements in joint motion as well as increased freely chosen gait speed. Mechanisms responsible for changes in freely chosen gait speed warrant further investigation.

Key Words: Aged; Biomechanics; Exercise; Gait; Rehabilitation.

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AGE-ASSOCIATED DECLINE in freely chosen gait speed, typically noticeable by the sixth decade of life,[1] is an indicator of abilities during daily function[2] and risk of falls[3] in older people. Thus, determining causes of decline in freely chosen gait speed is of interest for promotion of functional independence and quality of life of older people. Decreased freely chosen gait speed is associated with changes in stride length,[4,5] joint angular displacement,[3,6] and joint moment and mechanical power production.[7-9] Various factors, including desire to walk with a more stable gait,[7] desire to limit force absorption at the joints,[5,7] maximization of walking economy,[5] and global alteration of motor pattern,[9] have been postulated to create decline in freely chosen gait speed with aging. Another possibility receiving much attention is that freely chosen gait speed is limited by specific impairments of body structure and function.[4,10-12]

Examinations of persistent differences between age groups in gait parameters when subjects walk at similar speeds have provided insight into possible impairments related to decline in freely chosen gait speed. For example, joint moment and power production during stance differ between younger and older subjects and the difference is persistent across gait speeds.[4,7,9,13,14] Specifically, there is a redistribution of relative magnitudes of joint moments and powers reflected as an increase at the hip and decreases at the knee and ankle.[9] This change may reflect age-associated impairment of neuromuscular function at the ankle that is compensated for at the hip to maintain propulsion of the leg for swing.[8,9]

Differences in peak hip and ankle angular displacements during gait are also persistent between younger and older people across gait speeds.[3,4,9,13,14] It has been established that peak hip extension[4,9,14] and ankle plantarflexion[4,9,13,15] displacement during gait are lower in older versus younger people walking at the same speed. In addition, peak ankle dorsiflexion displacement during gait has been identified as a key discriminatory measure between low-performing and high-performing groups of independently living older people.[6]

Several researchers have suggested that age-associated gait changes in joint moment and power, as well as angular displacement, are directly related to limitations in joint ROM.[3-6,16] In support of this idea is the observation that declines in peak hip and ankle joint motion occur at similar ages as declines in freely chosen gait speed.[17-19] Because joint ROM is modifiable through nonstrenuous flexibility training, targeting it as an impairment related to altered gait function with aging is appealing.

While flexibility training has been established as a promising intervention for improving freely chosen gait speed of older people, findings have not been definitive.[20-22] DiBenedetto et al[20] examined the effects of an 8-week yoga program with older adults (including hip stretching) with a single group, pre-post test study design. Although no significant increase in freely chosen gait speed was observed after the yoga interven-

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List of Abbreviations

ANOVA	analysis of variance
CI	confidence interval
ICC	intraclass correlation coefficient
MTPJ	metatarsophalangeal joint
ROM	range of motion

tion, increased stride length and hip extension displacement were noted.[20] Kerrigan et al,[21] using a double-blind, randomized controlled trial design, examined the effects of a 10-week hip extension stretching program on older adult gait. Along with trends of increase in muscle performance and joint angular displacements, a trend toward increase in freely chosen gait speed was seen after the hip stretching program (1.19–1.23m/s).[21] However, no significant improvement in freely chosen gait speed has been reported as a result of flexibility training. In terms of maximal gait speed, Gajdosik et al,[22] using a randomized controlled trial design, identified a decrease in times during a fast 10-m walk related to increases in peak ankle dorsiflexion motion in older women after participation in an 8-week ankle flexibility program.

Examination of flexibility activities for older adults is also of interest because of the known decrements in joint motion associated with aging.[17-19] While systematic reviews have concluded that there is insufficient evidence to show a beneficial effect of stretching on injury risk and movement performance,[23,24] it is well established that chronic stretching can effectively increase joint ROM.[21,22,25] The increased joint motion after stretch training has been attributed to mechanical and neural factors as well as tolerance to stretch.[26,27] Because flexibility activities have shown promise for increasing joint motion during older adult gait, it seems reasonable that gait speed may be positively influenced.

The purpose of the present study was to examine the effects of a hip and ankle static stretching program on freely chosen gait speed of healthy, community-dwelling older people not active in exercise. The primary hypothesis was that increased freely chosen gait speed would occur after the stretching intervention, accompanied by increases in passive hip and ankle motion. Secondarily, measures of stride length, peak thigh extension, and peak ankle dorsiflexion during walking were examined at both freely chosen gait speed and controlled gait speed.

METHODS

Participants

A sample size estimate was calculated[28] on the basis of established recommendations indicating a meaningful change in gait speed to be .10m/s with an estimated SD of .16m/s.[29] At a power level of .80 and α level of .05, the calculated sample size required for identifying a significant change in freely chosen gait speed was 18 participants a group. On the basis of this estimate, a conservative goal of 20 participants a group was established.

Recruitment was made via verbal and written announcement at community functions, on written approval from host institutions. Volunteers agreed to participate by signing up at the time of announcement or calling to set an appointment. Neither subject nor recruiter had knowledge of group assignment prior to the subject's agreement to participate. The university institutional review board approved the study, and written informed consent was obtained from all participants.

Volunteers were deemed ineligible if they were not in the desired age range, had diagnoses or symptoms of unstable angina or congestive heart failure, had a history of chronic obstructive pulmonary disease, had a history of neurologic diagnoses, had joint or musculoskeletal pain that limited movement within the previous month, had a diagnosed gait or balance disorder, had a history of recurrent falling, participated in formal exercise during the previous 6 months, or used an assistive device for walking.

Two groups were used for the study: an intervention and a control group. Blocked random assignment to groups was used to ensure comparable group sizes. This was achieved by blind selection of numbers from a pool of numbers 1 to 40 (numbers 1–20, intervention group; numbers 21–40, control group).

Intervention

The intervention group received an 8-week hip and ankle flexibility program for both lower extremities. Two static stretches were employed in the training (fig 1). Stretches for the hip[21] and ankle[17,22] had previously been established to be feasible and safe for similar samples of older people. Both stretches were performed with participants holding onto a table or counter for balance support and shifting their weight until a maximal tolerable stretch was felt in the desired region.

Both stretching positions were held 45 seconds and repeated on each lower extremity 3 times, alternating sides with each stretch. The result was a total of 9 minutes (540s) of stretch a session, into hip extension for 2.25 minutes (135s) and into ankle dorsiflexion for 2.25 minutes (135s). Stretches of similar

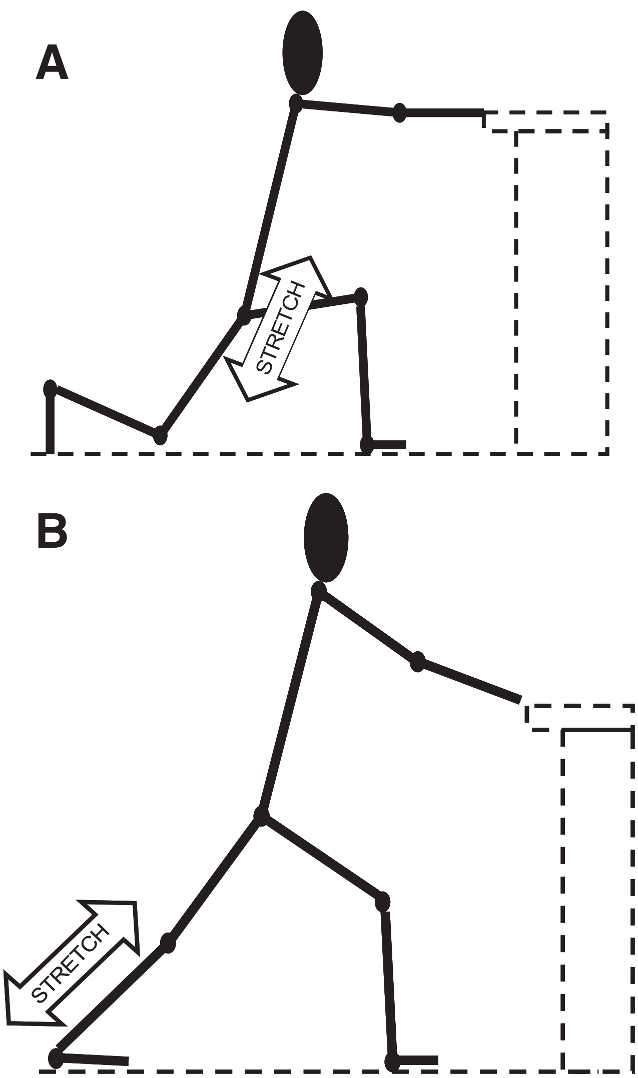

Fig 1. (A) Hip extension and (B) ankle dorsiflexion stretching activities as presented in the handout provided to participants in the intervention group.

duration have been shown to be effective for increasing motion of lower-extremity joints in older people.[20-22] Participants were instructed to perform the stretches twice daily at home for an 8-week period. Initial education of the intervention group participants was approximately 15 minutes. Before beginning the home program, each participant demonstrated ability to perform the stretches properly at the testing site under supervision.

A log worksheet was provided to each participant to record stretching activity. Participants were also given illustrated handouts (see fig 1) that included written instruction to assist with the home stretching program.

The control group was not instructed on an intervention at the time of initial assessment. Participants in this group were told that instruction on a stretching program would be provided to them after 8 weeks of maintaining their current level of physical activity. At the end of the 8 weeks, after the second assessment was made, participants in the control group were instructed on the same stretching protocol as the intervention group.

Weekly visits were made by the primary investigator to individual participants in both groups. For the intervention group, the purpose was to supervise the stretching activities in the participants' homes and provide instruction as needed. Visits to control group members were made to assure that no changes in physical activity were made.

Joint ROM

Measurements of maximal passive joint motion were made using a universal manual goniometer[a] with 35.6-cm (14-in) arm lengths and 1° increments. Each measurement required 2 testers and was repeated twice to allow evaluation of intratester reliability. During the trials, the tester aligning the goniometer, the same person administering the intervention, was blinded from measurement values by having the instrument reversed so that no angle markings were visible. The second tester read and recorded all goniometer measures. The right lower extremity was assessed for each participant. The mean of the 2 measurements served as the joint motion value for each participant.

Measurement of hip extension motion was made based on the traditional Thomas test position[30] with the participant supine with the hip allowed to extend over the edge of a plinth. This measurement of hip extension flexibility is influenced by the multijoint hip flexor muscle-tendon units. The iliopsoas, pectineus, adductor longus, adductor brevis, rectus femoris, tensor fasciae latae, and sartorius are the primary hip flexor muscles.[31] Of these, the iliopsoas, rectus femoris, tensor fasciae latae, and sartorius cross joints other than the hip so that positioning of peripheral joints must be considered during measurement. Length of the iliopsoas was controlled by positioning the lumbar spine, the proximal attachment site, in a standard position with participants maintaining their back positioned flat on the plinth. The other multijoint hip flexor muscle-tendon units cross the knee and were accounted for by measurement of the knee angle association with peak hip extension. Thus, controlling lumbar position and measuring knee angular position accounted for the influence of multijoint muscle-tendon units.

Maximum ankle dorsiflexion motion was assessed with the participant supine and the knee fully extended. The knee extended position was intended to lengthen the gastrocnemius muscle-tendon unit maximally at the knee and ankle, making it the primary limiting factor for ankle motion.[30] Knee position was controlled during dorsiflexion testing by placing it in maximal extension.

Gait Measurements

Prior to joint motion measurement, each participant walked 3 times up and down a 20-m walkway to determine freely chosen gait speed. Participants were instructed to walk at their customary pace, a pace that they would walk if going for a walk around the block. During this warm-up period, gait speed was measured using a hand-held stopwatch for 3 passes through the center 10m of the walkway. The mean of the 3 speeds was considered the freely chosen gait speed for the participant.

After the joint motion measurement, spherical reflective markers (diameter, 2cm) were placed on the right side of each participant over the following anatomic landmarks: (1) lateral aspect of the greater trochanter, (2) lateral aspect of the tibial plateau superior to the fibular head, (3) lateral malleolus of the fibula, (4) heel of the foot, and (5) immediately distal to the lateral aspect of the fifth MTPJ (ie, lateral to the head of metatarsal II). These landmarks were selected to allow for calculation of a 2-dimensional thigh angle (absolute angle of thigh segment in relation to vertical) and ankle angle (relative angle between the leg and foot segment). Participants wore shoes to simulate normative walking performance, so the markers at the MTPJ and heel of the foot were placed in the approximated position of these landmarks on the shoe.

After marker placement, participants were asked to walk on a 6-m walkway. Participants practiced on the walkway for 5 minutes prior to measurements being recorded. Gait was assessed at 2 speeds of walking: freely chosen gait speed and a set gait speed of 1.5m/s. Set gait speed trials were used to control for kinematic and kinetic variability influenced by speed. The set gait speed was based on normative data for older people with 1.5m/s established as the mean fast walking speed for people of similar age to the participants.[32] The set gait speed is also similar to fast walking speeds used with older people in previous studies.[4,9,15]

Gait speed was monitored as the time required for participants to move between 2 photocells set apart 2.44m (8ft) in the center of the 6-m walkway. To obtain the set gait speed, participants were asked to walk fast. Gait speed was then measured, and subjects were given verbal cues to increase or decrease speed after each trial until the set gait speed was obtained. Subjects performed at least 3 trials of walking at set gait speed before data were collected. When recording data, any trial not within 0.1m/s of the 1.5m/s set gait speed or the established freely chosen gait speed was reperformed. For all participants, the freely chosen gait speed trials were performed first, followed by the set gait speed trials.

During the walking trials, video data were recorded as the participant moved between photocells. The recordings provided data for 1 complete gait cycle of the right lower extremity. The video camera[b] was positioned 5m perpendicular to the sagittal plane of motion, and the video signal (sampling frequency, 60Hz) was recorded directly to a computer hard drive through an event and video control unit.[c]

Data Reduction

For gait trial data, movement of the reflective markers from the video data was digitized using automatic point-tracking software.[c] The position data were then low-pass–filtered with a fourth-order zero-lag Butterworth filter and a cutoff frequency determined with a previously established optimization approach.[33] Stride length was determined using the position data from video motion analysis to determine the horizontal distance from one heel strike to the next. Thigh segment and ankle sagittal plane angles were calculated and maximal thigh extension and ankle dorsiflexion displacement reported. Data were reduced with experimenters blinded to group allocation until statistical analysis was complete.

Statistical Analysis

Comparison of demographics, anthropometrics, and initial values of the dependent variables between the intervention and control groups were assessed by using independent *t* tests (for continuously scored variables) or chi-square tests (for dichotomous variables). Participant adherence to the stretching program was quantified by the reported number of completed sessions divided by total possible sessions. Reliability of the joint motion and freely chosen gait speed measurements was assessed using ICC model 2 and form 1 ($ICC_{2,1}$)[34] and their corresponding 95% CIs.

To address the research hypotheses, a 2-factor repeated-measures ANOVA model with 1 between-group and 1 within-group factor was used to compare changes in each dependent variable from preintervention to postintervention. The between-group factor was group (2 levels: intervention, control), and the within-group (or repeated-measures) factor was time (2 levels: preintervention, postintervention). Separate repeated-measures ANOVAs were used for each of 9 dependent variables: (1) combined hip extension and knee flexion passive motion, (2) ankle dorsiflexion passive motion, (3) freely chosen gait speed, (4) stride length at freely chosen gait speed and (5) set gait speed, (6) peak thigh extension angular displacement at freely chosen gait speed and (7) set gait speed, and (8) peak ankle dorsiflexion angular displacement at freely chosen gait speed and (9) set gait speed.

Tests of simple main effect results were calculated for each dependent variable using paired *t* tests for the intervention and control groups if a time-by-group interaction effect was present in the repeated-measures ANOVA. The tests of simple main effects allowed interpretation of how values from each group changed, or did not change, from preintervention to postintervention. Considering that statistical power for identifying an interaction effect is lower than for identifying simple main effects,[35] statistical significance for the repeated-measures ANOVA examinations was set at *P* less than .05 (basis of sample size estimation), and a Bonferroni adjustment was made considering the presence of 2 individual simple main effect tests for each of the 3 primary outcome measures (hip motion, ankle motion, freely chosen gait speed) with statistical significance defined at *P* less than .008 (.05/6). Correction for level of type I error was not used for the secondary outcome measures (stride length, angular displacement) because these were examined for exploratory purposes in the current study.

RESULTS

Group Comparison

Of 40 participants, 37 completed the study. Three participants discontinued during the course of the study because of family tragedy (1 intervention and 1 control group participant) and a fall resulting in injury (intervention group participant). Data for 1 control participant were identified as being outliers (primarily because of significantly greater gait speed than all others at both preintervention and postintervention). This case influenced the assumption of equal variance between groups. Analyses were made with and without the identified outlier data, and the results were found not to be influenced with the presence of the outlier data (analysis with outlier data excluded not shown). As a result, this participant was included in analyses although the variances between the groups were not equal for gait speed and stride length. Data from 37 participants (control, n=19; intervention, n=18) were included in the analyses. Comparison of group demographic, anthropometric, and gait data revealed no significant differences between groups at baseline (table 1).

Table 1: Group Comparison of Characteristics at Baseline

Characteristic	Intervention Group	Control Group	*P*
Sex (men/women)	3/15	5/14	.480
Age (y)	72.5±4.7	71.6±5.0	.567
Body mass (kg)	75.2±15.1	80.0±15.3	.451
Body height (cm)	164.3±7.7	165.1±6.2	.714
Passive hip extension/knee flexion angle (deg)	59.7±7.4	56.2±10.0	.236
Passive ankle dorsiflexion angle (deg)	7.8±4.9	7.8±4.9	.998
FCGS (m/s)	1.23±0.12	1.33±0.19	.064
Stride length at FCGS (m)	126.0±12.5	135.3±26.6	.173
Peak thigh extension at FCGS (deg)	16.6±5.1	18.4±5.2	.285
Peak ankle dorsiflexion at FCGS (deg)	15.2±3.9	14.4±3.8	.518

NOTE. Values are mean ± SD. Differences in sex distribution between groups examined with χ^2 test; *P* values are the result of independent *t* tests.
Abbreviation: FCGS, freely chosen gait speed.

The 37 participants ranged in age from 62 to 82 years (mean ± SD, 72.1±4.7y) and represented independently living older people who attended local community functions. Participant compliance with the stretching program for the intervention group was .85 (range, .66–.98), indicating that participants on average completed 85% of the home sessions they were instructed to perform.

Gait Characteristics

The ICC value indicating freely chosen gait speed measurement reliability was .79 (95% CI, .69–.86). Postintervention analysis revealed a difference between the intervention and control groups for freely chosen gait speed, indicated by a significant time-by-group interaction effect. Tests of simple main effects revealed an increase in freely chosen gait speed of .07m/s for the intervention group, with no change present in the control group. No significant time-by-group interaction effect was present for stride length, peak thigh extension angle, or peak ankle dorsiflexion angle at either freely chosen gait speed or set gait speed (table 2). Thigh and ankle angle data graphed over the period of the gait cycle are presented in figures 2 and 3.

Joint Motion

Resulting ICC values for passive hip extension, knee flexion, and ankle dorsiflexion measures were .80 (95% CI, .71–.87), .83 (95% CI, .75–.89), and .85 (95% CI, .70–.87), respectively. For the composite measurement of peak hip extension and knee flexion motion, an interaction effect between time and group was observed, indicating a difference between intervention and control groups. Examination of tests for simple main effects revealed an increase of 6.8° for the intervention group. In contrast, there was no change in the summed hip extension and knee flexion measure for the control group. A significant difference between groups was also noted for the ankle dorsiflexion passive motion measurement. Simple main effects testing demonstrated an increase of 3.5° for the intervention group, with no change present in the control group (see table 2).

Table 2: Change Over Time in Primary and Secondary Outcome Measures

Outcomes	Intervention Group		Control Group		Interaction Effect Testing	
	Baseline	8 Weeks	Baseline	8 Weeks	F	*P*
Primary measures						
FCGS (m/s)	1.23±0.12	1.30±0.10*	1.33±0.19	1.35±0.19	6.45	.016†
Hip extension/knee flexion (deg)	59.7±7.4	66.5±7.4*	56.2±10.0	56.1±7.5	5.70	.023†
Ankle dorsiflexion (deg)	7.8±4.9	11.3±5.4*	7.8±4.9	7.9±4.1	5.92	.020†
Secondary measures						
Stride length during FCGS (m)	1.26±0.13	1.36±0.15	1.35±0.26	1.39±0.25	4.81	.188
Stride length during SGS (m)	1.38±0.10	1.47±0.17	1.41±0.19	1.44±0.18	1.56	.216
Peak thigh extension during FCGS (deg)	16.5±5.1	17.6±4.5	18.4±5.2	16.7±3.6	3.66	.064
Peak thigh extension during SGS (deg)	18.2±4.7	19.4±3.9	18.8±4.8	17.9±3.2	2.15	.152
Peak ankle dorsiflexion during FCGS (deg)	15.2±3.9	14.7±3.3	14.4±3.8	13.7±3.5	0.01	.932
Peak ankle dorsiflexion during SGS (deg)	14.6±3.9	14.7±3.8	13.0±4.2	12.4±5.6	0.23	.637

NOTE. Values are mean ± SD. Interaction effect testing is a result of 2-factor repeated-measures ANOVAs.
Abbreviations: FCGS, freely chosen gait speed; SGS, set gait speed.
*Significant change from baseline to 8-week assessment within the group based on tests of simple main effects ($P<.008$).
†Significant group interaction effect based on repeated-measures ANOVA ($P<.05$).

DISCUSSION

The primary aim of this study was to determine whether a flexibility training program would improve the freely chosen gait speed of healthy, community-dwelling older people. As hypothesized, increases in peak passive hip extension and ankle dorsiflexion were seen. The increased passive motion was associated with increases in freely chosen gait speed. While the trend for the intervention group was an increase in

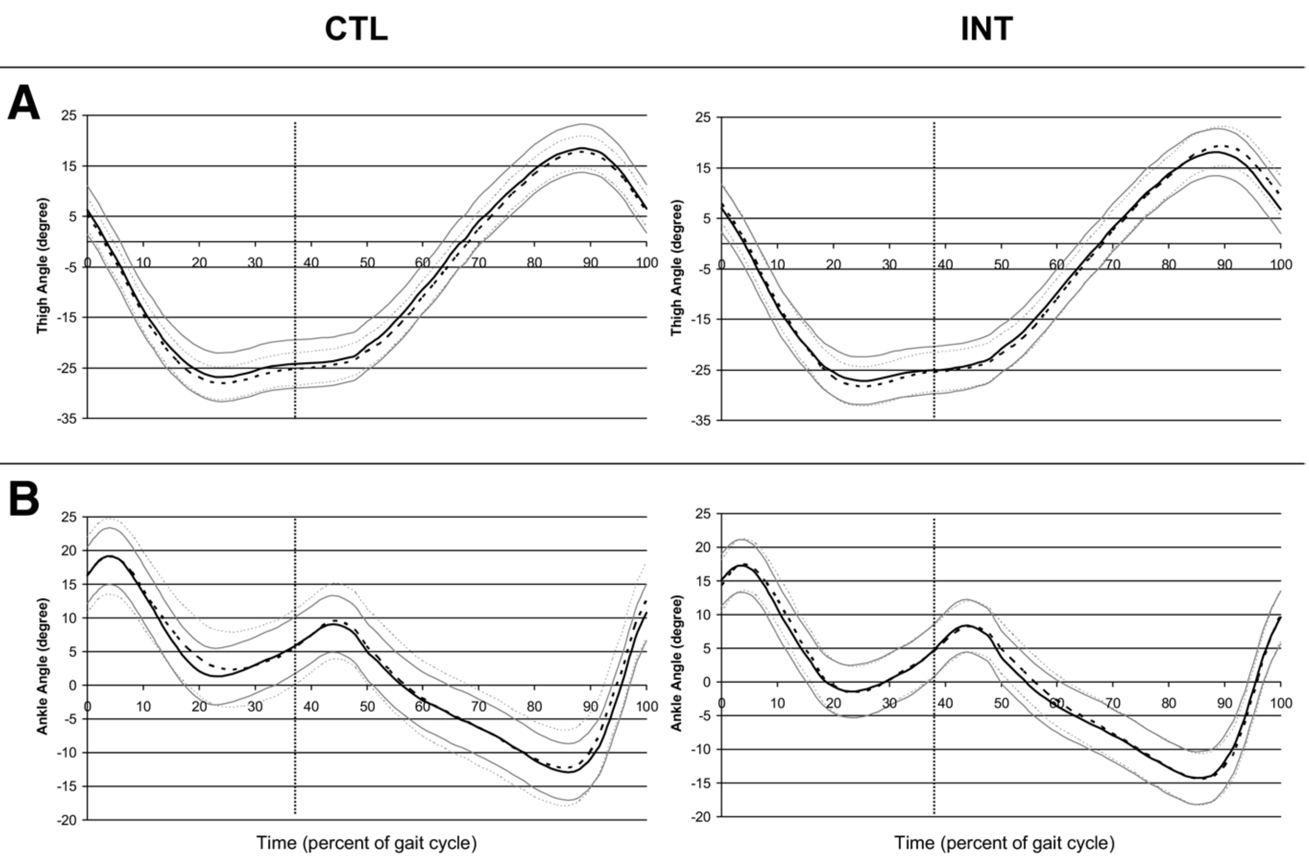

Fig 2. Angle values graphed over time for (A) the thigh segment and (B) the ankle during set gait speed (1.5m/s) trials. Abbreviations: CTL, control group; INT, intervention group. Positive values indicate extension for the thigh segment and plantarflexion for the ankle. Dark solid lines represent preintervention and dashed lines represent postintervention mean data. Light solid and dashed lines represent values ±1 SD preintervention and postintervention, respectively. Initiation of gait cycle was toe-off of the right foot, and the end was the subsequent toe-off of the same foot. Vertical dotted lines indicate mean point of transition from swing to stance phase (ie, foot contact).

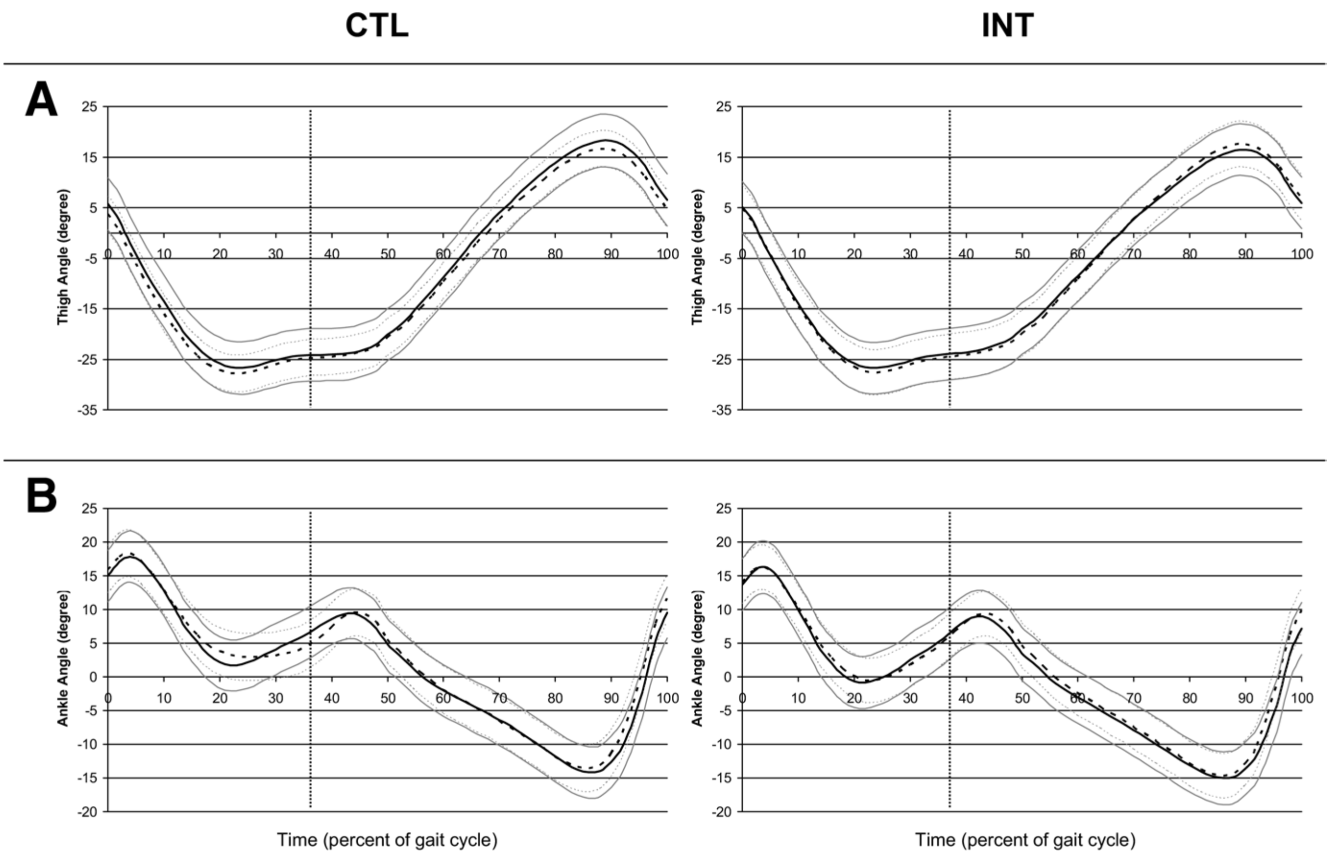

Fig 3. Angle values graphed over time for (A) the thigh segment and (B) the ankle during freely chosen gait speed trials. Abbreviations: CTL, control group; INT, intervention group. Positive values indicate extension for the thigh segment and plantarflexion for the ankle. Dark solid lines represent preintervention and dashed lines represent postintervention mean data. Light solid and dashed lines represent values ±1 SD preintervention and postintervention, respectively. Initiation of gait cycle was toe-off of the right foot and the end was the subsequent toe-off of the same foot. Vertical dotted lines indicate mean point of transition from swing to stance phase (ie, foot contact).

stride length and peak hip extension angular displacement, the changes were not significant. In addition, no change in peak ankle dorsiflexion angular displacement was noted. The reliability measures for joint motion and freely chosen gait speed are comparable to previous studies and represent favorable measurement consistency.[36,37]

It is important to address ways to limit and/or reverse the decline in freely chosen gait speed associated with aging because it is linked to decreased physical ability[2] and increased risk of falls.[3] The implication of present results is that age-related declines in joint motion may in part explain decline in freely chosen gait speed. It is acknowledged that other impairments related to aging can account for gait speed decline, including physical impairments to systems such as the muscle and nervous systems.[9,13,38] However, the present findings indicate a possible link between joint motion and freely chosen gait speed that could be tested in a future correlational analysis.

Perera et al[29] have examined the magnitude of clinically meaningful changes in common physical performance measures of older people, including gait speed. In their study, the authors concluded that the criteria for determining small meaningful change in gait speed should be .05m/s, with .10m/s representing substantial meaningful change. The present result of .07m/s magnitude of change falls between these 2 criteria. Data assessed by Perera[29] were based on gait speed performance in clinical populations (eg, frail community-dwelling subjects and stroke survivors). The fact that the present gait speed change was seen in healthy, independently functioning older people further strengthens the meaningfulness of the improvement. Such a flexibility training program applied to people with lower functional ability may result in even greater improvements.

As exploratory hypotheses, it was of interest to measure stride length and joint angular displacement. Of these secondary measures, no statistically significant changes were seen. Trends were identified that could be addressed in future studies. For example, even with gait speed controlled by design at 1.5±0.1m/s for the set gait speed trials, mean values for stride length in the intervention group were 1.38m preintervention and 1.47m postintervention. Also, peak thigh segment extension for the intervention group was 16.5° preintervention and 17.6° postintervention during freely chosen gait speed trials and 18.2° preintervention and 19.4° postintervention during set gait speed trials. No noticeable trend of change in peak ankle angular displacement was seen.

Study Limitations

Results of this study should be viewed with caution. Several assumptions were made in designing the methodology, including the use of a simple, 2-dimensional examination of angular displacements. Although use of a single camera system in the clinic is appealing for simplicity, it is acknowledged that 2-dimensional models are not comparable to gait measures captured using 3-dimensional motion capture systems with multiple markers a segment.[39] In addition, it has been shown that hip extension motion is influenced by sagittal plane motion of the pelvis.[3] Without including the pelvic segment in the current examination, no conclusions can be drawn about the influence of the training on interactions among the trunk, pelvis, and thigh. Finally, placement of markers on the footwear introduced possible measurement error by not accounting for foot movement within the shoe. Future studies in fully equipped gait laboratories are recommended for complete analysis of the influence of stretching interventions on gait kinematics and kinetics. However, considering these limitations, the peak angular displacements in this study are comparable to those seen in other samples of older people walking at similar speeds[3,9,12,20] using a variety of segmental models.

Lack of altering the sequence of freely chosen gait speed and set gait speed trials could have added a systematic bias to the data. To assess the effect of order of gait speed, future studies should randomize the sequencing of trials. For this study, the freely chosen gait speed trials were performed first in all instances to allow participants to be well acclimated to the walkway before walking at a speed that was not normally preferred. Consistency between preintervention and postintervention assessments allowed data to be compared.

In future studies, examination of clinical populations of older people is recommended. In this study, only healthy volunteers were recruited, resulting in limited generalization to functionally limited people. Samples of participants with specific functional limitations will provide a better understanding of the importance of joint motion on gait and physical function in relation to age-associated disability. Also, the size of the current sample limited statistical power of the study. While statistical power was sufficient to identify changes in freely chosen gait speed, identification of changes in stride length and joint kinematics may be possible with an increased number of participants (ie, increased statistical power), allowing for increased confidence in determining mechanisms related to the improvement in freely chosen gait speed.

Comparison of the effects of flexibility training between men and women should also be examined in future studies. There were many more women than men volunteers for the current study, and no examination of differences between sexes was made. However, comparison between the intervention and control group was deemed valid because the relative distribution of men and women in each group was remarkably similar.

Future examination of the relative importance of hip and ankle joint motion is also warranted. Because the flexibility intervention included simultaneous hip and ankle stretches, identifying the relative contribution of hip and ankle motion to freely chosen gait speed was not possible with this study. The trend of increase in peak hip extension displacement along with the lack of such a trend for peak ankle dorsiflexion indicates that ankle motion may not be as much of a factor as hip motion in dictating freely chosen gait speed. It is possible that for the healthy population sampled in this study, hip extension motion may have been a factor limiting gait speed, while ankle dorsiflexion motion was not. This finding is consistent with suggestions by some authors.[4,20] Gajdosik et al[22] did identify increases in maximal gait speed after ankle flexibility training; however, participants in their study were selected on the basis of limitations in peak dorsiflexion motion (≤10°).

Last, the measurement of joint passive motion was made with a clinically based method, without control or measurement of moment of force. While the reliability of the measurements was high, control and measurement of moment of force would allow for expanded interpretation of the effects of stretching on passive joint motion.

CONCLUSIONS

The findings of this study have implications for addressing the detrimental effects on gait function seen with aging. Evidence is provided from the results that joint motion is a modifiable impairment that can be effectively targeted for older people with a simple, static stretching home-based intervention. Improvements in both joint motion and freely chosen gait speed were seen in the intervention group but not the control group. Mechanisms responsible for changes in freely chosen gait speed after flexibility intervention warrant further investigation.

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