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MULTI-SEGMENTED TRUNK MOTION OF HEALTHY NON-ELDERLY ADULTS IN DIFFERENT DECADES OF LIFE

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Abstract

Traditionally, gait analysis models the trunk as one rigid body segment. This approach has limitations; it does not capture all the movements of this area of the body throughout locomotion. Lower-extremity-gait kinematics do not routinely change in healthy non-elderly adults in different decades of life; however, it is unknown if trunk kinematics will be altered during different activities of daily living as a function of age. The purpose of this study was to determine if a previously validated multi-segmented trunk model would detect trunk movement variations in non-elderly healthy adults in different decades of life. Thirty-four non-elderly healthy adults in various decades of life (20–29 years, 30–39 years, 40–49 years, and 50–59 years) completed two tasks of ambulatory daily living (level walking and stair descent). Trunk maximum angle during the gait cycle, timing of the trunk maximum angle during the gait cycle and trunk range of motion were examined using analysis of variance procedures. Findings are that age group did not affect the trunk kinematics of individuals in different decades of life, but that may not represent the experiences of elderly individuals.

Keywords

Trunk kinematics; Ambulatory activities of daily living; Age group

INTRODUCTION

Classic gait analysis models the trunk as a single rigid segment.[1] It has been realized that this approach is not detailed enough to properly record the movement of the trunk during human locomotion, and thus numerous multi-segmented trunk models have been employed to better quantify the motion of the trunk during various dynamic situations.[2–14] To date, no study has examined if these multi-segmented trunk models can detect age-group-related differences to the trunk during ambulatory activities in non-elderly adults. The purpose of the current study was to address this commonly observed deficiency.

Lower-extremity kinematics (angles & spatiotemporal) of healthy individuals remain the same or similar for both sexes throughout different decades of life, up until individuals cross

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into the “elderly” category.[15–19] It is not known if the same observation remains true as regards the trunk. It is known there is a significant reduction in spinal range of motion (ROM) with individuals over 50 years of age.[20] Therefore, the current study sought to determine whether or not multi-segmented trunk kinematics change throughout non-elderly adulthood in healthy individuals.

The multi-segmented trunk model used *in previous studies*[5] has been able to detect different trunk kinematics between various activities of daily living (ADLs).[9] Two common ambulatory ADLs — level walking gait and stair descent — were chosen to determine if similar task-related changes exist in healthy individuals in non-elderly adulthood. Risk of falling increases in both of these tasks with advancing age and elderly individuals have reported avoiding stair descents[16,19,21] — therefore, it is important, and an ancillary purpose of this study, to determine if multi-segmented trunk kinematics are altered in a non-elderly population, is this change similar to or in line with populations — or certain pathologies — that have an increased risk of falling.

The primary purpose of this study was to observe individuals in consecutive age groups (20–29, 30–39, 40–49, and 50–59 years) as they ambulate between two different tasks (level walking and stair decent) to determine if the age group affected multi-segmented trunk kinematics. It was hypothesized that the age group would affect trunk outcomes (peak trunk angles, timing of peak trunk angles and trunk ROM). It was additionally hypothesized that the inclusion of various tasks (walking & stair descent) would influence trunk outcome measures as has been shown previously.[5]

MATERIALS AND METHODS

Thirty-four healthy non-elderly adults, demarcated by four age groups were recruited from the university and surrounding Eugene, Oregon community to participate in the study (Table 1). Height and weight demographics of each group were the same. Participants did not have any histories or clinical evidence of neurological, musculoskeletal or other medical conditions affecting gait performance. All participants reviewed and signed an informed consent forms and the study protocol was approved by the University of Oregon Institutional Review Board.

Materials

Men wore spandex shorts with no shirt and women wore a dance leotard with open back and performed two different tasks with bare feet: level ground walking and stair descent. Participants were in bare feet to minimize the effect shoes have on the kinematics. The task order was randomly selected for each subject, and the total task duration was not extensive enough to induce fatigue.[22]

Experiment

The walking task required participants to walk along a 10 m long walkway (Fig. 1(A)). During stair descent, participants were instructed to initiate from the back end of an elevated walkway, descend a three-step staircase, and continue walking for several steps (Fig. 1(B)). Participants were instructed to perform both tasks at their normal walking speed.

Two different force plate configurations were utilized to detect gait events such as heel strike (HS) and toe off (TO), as quantified through measures using vertical ground reaction force (GRFv). HS was determined to occur when the GRFv was greater than 10% of the maximum GRFv, and TO was determined to occur when the GRFv was less than 10% of the maximum GRFv.[23–25] Three force plates (FPs) (Advanced Mechanical Technologies, Inc., Watertown, MA) were placed in series and embedded level into the laboratory floor for the walking task. The first two FPs were immediately adjacent to one another, and the third plate was separated by a distance of 15 cm (Fig. 1(A)). Four FPs were used during stair descent trials. Two FPs were embedded level into the laboratory floor and two made up the steps[26] (Fig. 1(B)).

Three-dimensional marker position data were collected at 60 Hz with a ten-camera Eagle motion analysis system (Motion Analysis Corporation, Santa Rosa, CA). Sixty-two retro-reflective markers (diameter = 14 mm) were placed on the subject as described by Breloff and Chou[5] (Fig. 2).

Five *successful* trials from each task were analyzed. Walking trials were defined as the time interval between two consecutive ipsilateral HSs (FP 3 to FP 1; Fig. 1(A)) and stair descent trials were consecutive ipsilateral HSs following first step down toward the ground level (FP 4 to FP 2; Fig. 1(B)). *A successful trial consisted of clean FP striking from both participants' feet as well as the right foot striking the first FP. To ensure successful trials, several practice trials were completed — in which the starting point was altered to accommodate each participant's gait.* A MATLAB® (Mathworks, Natick, MA) program calculated segmental trunk angles using adjacent trunk levels[5] — sacrum-to-lower lumbar, lower lumbar-to-upper lumbar and upper lumbar-to-lower thorax (Fig. 2).

Outcome measures for the current study were: peak trunk angle, peak angle index and ROM. Peak trunk angles, timing of the peak trunk angle and trunk ROM have been previously used to describe spinal motion during ambulatory ADL.[27–34] Additionally, ROM has been used to detect aging effects in the spine during gait.[27,35–37] All three outcome measures were recorded for the three different planes of motion. Peak trunk flexion — forward/anterior bending of the trunk — was calculated in the sagittal plane. Frontal plane motion was represented by peak trunk ipsilateral bending — which indicates the trunk is bending toward the initial contact leg, or the ipsilateral side. Peak trunk contralateral axial rotation is presented for the trans-verse plane, which designates following the initial HS; the spine will twist away from the striking leg or toward the contralateral leg.

Statistical Analysis

Each outcome measure was analyzed using three-way — 4(age) × 3(trunk level) × 2(task) — mixed-effects analysis of variance for each plane. If the three-way interaction was not significant, then two-way ANOVA's explored differences between factors. The level of significance for these statistical tests was set at 0.05. The statistical software SPSS (version 18, IBM., New York, NY) was used for all statistical analyses.

RESULTS

Age group did not have an effect on peak trunk angles for all three motions — flexion, ipsilateral bending and contralateral rotation. No differences between age groups in the peak trunk angles were observed. The results comparing trunk levels, age and task are summarized in Tables 2 and 3 along with Figs. 3–6.

Maximum Angle During the Gait Cycle

Flexion and contralateral rotation maximum trunk angles during gait changed as a result of the different tasks. Lower lumbar-to-upper lumbar (4.14° ± 0.82°) was significantly larger than upper lumbar-to-lower thorax (1.59° ± 0.59°) *during stair descent in the course of contralateral rotation*. Introduction of a task other than walking did alter peak trunk angles in the sagittal and transverse plane (Table 3; Fig. 3).

Timing of the Maximum Angle

The timing of the peak flexion angle was used to determine what gait events were occurring when segmental trunk peak flexion was produced (Fig. 4). In all age groups (20’s, 30’s, 40’s and 50’s) the peak flexion angle at the sacrum-to-lower lumbar joint during walking occurred before contralateral HS into the weight acceptance phase on the contralateral limb (approximately 45% to 51% of the gait cycle [GC]). The lower lumbarto-upper lumbar joint produced maximum angle during the GC for all age group cohorts during weight acceptance and into mid-stance of the contralateral foot (approximately 55% to 65% of the GC). In the upper lumbar-to-lower thorax joint during walking, the 20, 30 and 40 year old clusters of individuals found the maximum angle during the GC flexion angle to occur at the end of the heel rocker into the ankle rocker of the ipsilateral leg (approximately 57% of the GC). The 50 year old cohort had the maximum angle during the GC flexion angle during mid-stance (foot-flat) of the contralateral leg.

The stair descent task incurred different peak indices than walking — though these were not statistically significant. For the 20 and 30 year old cohort, the maximum angle during the GC flexion angle occurred during mid-swing to just before HS of the contralateral limb (approximately 40% of the GC). The older cohort of participants (40 and 50 years) had a maximum angle during the GC flexion in the sacrum-to-lower lumbar joint during mid-stance of the ipsilateral foot (approximately 23% to 28% of the GC). All age groups had a maximum angle during the GC just before the contralateral foot contacted the step to mid-stance (approximately 37% of the GC) in the lower lumbar-to-upper lumbar joint. The maximum angle during the GC for upper lumbar-to-lower thorax angle for the 20’s 40’s and 50 year old-groups occurred during weight acceptance until just before foot-flat on the contralateral leg (approximately 56% of the GC). However, the 30 year old group produced a maximum flexion angle during the GC during mid-stance (approximately 38% of the GC) of the ipsilateral leg (Fig. 4).

All age groups had a maximum peak ipsilateral bending angle during terminal swing into the loading phase on the contralateral foot at the sacrum-to-lower lumbar joint during the walking task (approximately 54% of the GC). In the lower lumbar-to-upper lumbar joint, all age cohorts presented with a maximum ipsilateral bending angle during terminal swing and into initial contact loading on the contralateral limb (approximately 53% of the GC). The upper lumbar-to-lower thorax joint produced a peak ipsilateral bending angle for all age groups between initial HS of the contralateral foot until mid-stance of the contralateral foot.

All age cohorts had a maximum ipsilateral bending angle during gait between the mid-swing and terminal swing of the contralateral leg during the stair descent task in the sacrum-to-lower lumbar joint. The 20 and 40 year old cohorts at the lower lumbar-to-upper lumbar joint had a maximum ipsilateral bending angle during terminal swing of the contralateral limb (approximately 43% of the GC). The 30 and 40 year old clusters had a maximum ipsilateral bending angle during mid-swing of the contralateral leg (approximately 35% of the GC). The upper lumbar-to-lower thorax joint produced a peak ipsilateral bending angle between mid-swing to foot-flat on the contralateral leg in all age groups (Fig. 4).

During the walking task, the 20 and 30 year old cohorts had a maximum contralateral axial rotation angle in terminal swing of the contralateral limb at the sacrum-to-lower lumbar joint for all age groups (approximately 45% of the GC). The 20 and 30 year old groups had a maximum contralateral axial rotation angle during initial contact of the contralateral leg in the lower lumbar-to-upper lumbar and upper lumbarto-lower thorax joints (approximately 52% of the GC). The 40 year old cohort’s maximum contralateral axial rotation angle was found during terminal swing of the contralateral limb in the lower lumbar-to-upper lumbar and upper lumbar-to-lower thorax joints (approximately 47% of the GC). The 50 year old group’s maximum contralateral axial rotation angle in the lower lumbarto-upper lumbar and upper lumbar-to-lower thorax joints was during the heel rocker phase following contralateral HS (approximately 56% of the GC).

The 20, 30, 40 and 50 year old cohorts had a maximum contralateral axial rotation angle during the terminal swing to foot-flat of the contralateral leg at the sacrum-to-lower lumbar joint in the stair descent task (approximately 50% of the GC). In the lower lumbar-to-upper lumbar joint during stair descent, a maximum contralateral axial rotation angle during mid-swing to terminal swing of the contralateral limb was produced in all age groups (approximately 44% of the GC). The upper lumbar-to-lower thorax joint produced a peak ipsilateral bending angle between terminal swing to foot-flat on the contralateral limb (Fig. 4).

Range of Motion

Age group did not have any effect on the ROM of trunk kinematics (flexion, ipsilateral bending, and contralateral rotation) — indicating an individual’s age does not alter the amount of motion in their trunk.

The differences in trunk ROM were present at different trunk levels (sacrum-to-lower lumbar, lower lumbar-to-upper lumbar, or upper lumbar-to-lower thorax) in the different planes of motion. Pairwise comparisons on contralateral rotation ROM revealed that sacrum-to-lower lumbar (11.74° ± 3.01°) had larger ROM during walking when compared to stair descent (6.47° ± 1.19°, as in Fig. 5). Trunk level had a main effect in trunk flexion ROM ($p < 0:001$) and trunk ipsilateral bending ROM ($p = 0:003$). Trunk flexion ROM follow up pairwise comparisons of the trunk level marginal means found sacrum-to-lower lumbar (11.78° ± 10.95°) to have significantly more ROM than upper lumbar-to-lower thorax (4.93° ± 2.17°). Additionally, it was found that sacrum-to-lower lumbar had significantly more ROM than lower lumbar-to-upper lumbar (9.42° ± 7.56°, as in Fig. 5(B)). Trunk ipsilateral bending ROM *post hoc* comparisons of the trunk level marginal means revealed sacrum-to-lower lumbar (10.81° ± 2.47°) was significantly larger than both lower lumbar-to-upper lumbar (6.23° ± 1.69°) and upper lumbar-to-lower thorax (2.91° ± 0.24°, as in Fig. 5(B)).

Task Effect

Task (walking or stair descent) only changed trunk flexion ROM. There was a significant main effect of task on trunk flexion ROM ($p = 006$). When compared to walking (10.58° ± 3:05°) the stair descent task was significantly smaller (6.71° ± 1.14°).

Some significant differences between specific tasks, spine level and age group were present, however a noticeable difference in the flexion angle — in both tasks — is noticeably higher in the 50 year old cohort compared to the younger (Fig. 6).

DISCUSSION

This study examined non-elderly individuals demarcated by different age groups (20–29, 30–39, 40–49, and 50–59 years) in order to determine if age group has any effect on multi-segmented trunk kinematics during two (walking & stair descent) ambulatory tasks of daily living. It was hypothesized that age group would affect trunk outcomes (peak trunk angles, timing of peak trunk angles and trunk ROM). It additionally hypothesized the inclusion of various tasks (walking & stair descent) which would influence trunk outcome measures as has been shown previously.[5]

Age group did not have an overall significant effect on any of the outcome variables. This result is in agreement with the previous studies of lower extremity kinematics of non-elderly healthy individuals which is similar during younger decades of life[15–19] — suggesting any mechanical changes in the trunk in non-elderly individuals arise from some other factor. Similar to our previous study[5] the multi-segmented trunk model was robust enough to detect differences in trunk kinematics on different task — signifying it is necessary to model the trunk using several segments as opposed to a single rigid segment in order to explore all movements associated with the trunk.[2–14]

A possible limitation was the number of participants. This small number of participants may have resulted in larger variation of the individual parameters, which might have resulted in the insignificant trends observed in the outcome variables. Though the authors believe this is a reasonable explanation, due to the small excursions of the segmented trunk model, previous literature may suggest otherwise. For example, a population of 30 individuals were able to detect differences in trunk/spine biomechanical parameters.[38] However, a different study had a subject population of 93 individuals and were not able to detect differences in trunk biomechanical parameters.[39]

Though this study did not find changes in trunk kinematics due to age group, other studies have observed age related changes such as: knee extension, stride length and peak hip extension, decrease in center of mass (COM) motion, changes in trunk flexion-extension, and an increase in trunk and pelvic rotations.[12,17,26,38,40–42] The important difference between those studies and the current study is all participants in the aforementioned studies were older than 60 years of age. This finding suggests that more conclusive age group related multi-segmented trunk kinematic changes may be found in individuals who are greater than 60 years old. Further studies are needed with this over 60 years population constituting a study group.

A future direction is to test an elderly population with multi-segmented trunk model. The oldest participant was less than 60 years old, and the participants simply may not have started to present with the related effects of aging. The lower extremity aging studies generally look at individuals as old as 70 or 75 years old.[38–40,43] It would be most advantageous to include a subject group or groups up to 70 or 80 years of age. The current study did show the flexion in the 50-year old group was higher — not significantly — compared to the younger cohorts. With the aging of the workforce and the general population, such studies would be of interest.

A secondary hypothesis that task and trunk levels would produce different kinematics, was confirmed. These results agree with the previous studies[5,9] and reinforces *the concept the trunk is not a rigid body and should be modeled as such during human motion studies*. Therefore, it is important to include multi-segment trunk methods in gait analysis.

CONCLUSION

In conclusion, this investigation applied a segmental trunk model to determine if age-group-related changes in certain biomechanical parameters (maximum angle during gait, maximum peak trunk angle index and trunk ROM) could be observed during two different tasks in non-elderly healthy adults. Task was found to have some influence over the observable trunk angles and ROM, while age group was not found to exert any influence over the outcome measures. One possible reason for this is the age group of the testing population was possibly not old enough and had not fully exhibited the effects of aging. It is suggested that with a higher number of participants and with an increase in the age group of the participants, an age-group-related difference in trunk kinematics may present itself. Though the hypothesis of observable and recordable difference in trunk flexion as a function of age, was not fully supported, differences did exist between segmental trunk levels angles. It is encouraging that this method of segmented spinal motion can continue to be used to investigate and understand the complexity of the spine and the motions it produces.

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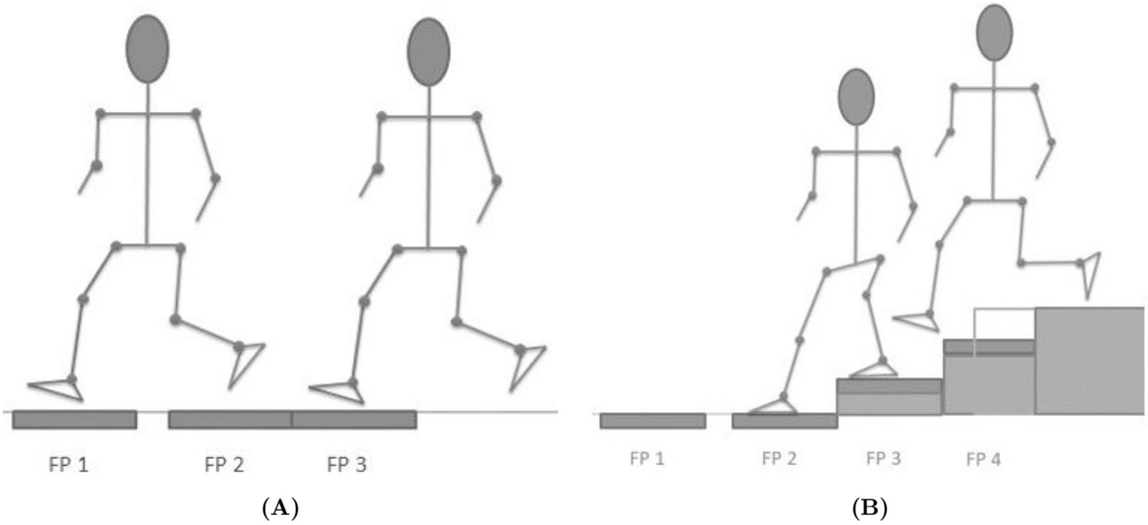


Fig. 1.
Definition of each task. (**A**) Level walking (W) — ipsilateral heel strikes, (**B**) Stair Descent (SD) — ipsilateral heel strikes. FP =forceplates.

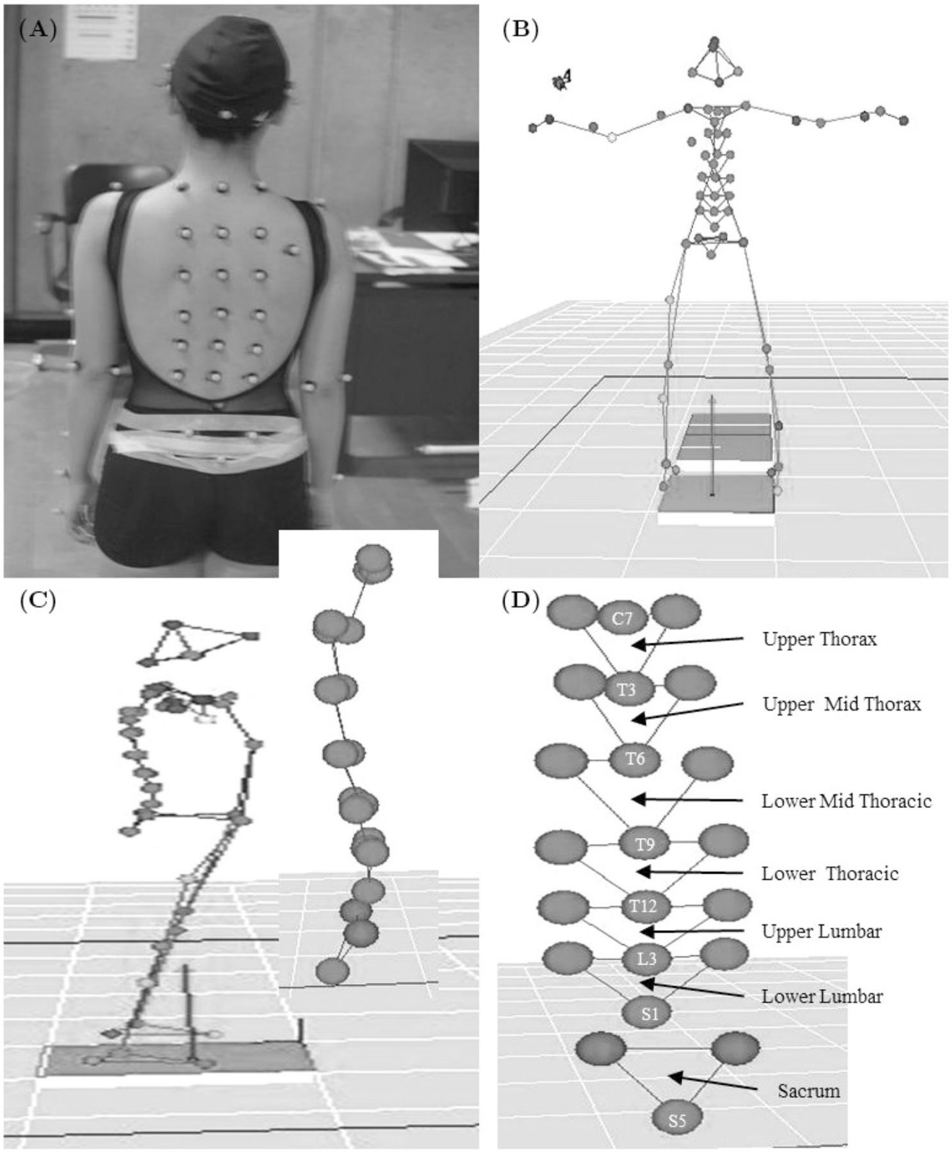


Fig. 2.

Segmental spine maker set with all six adjacent segments which angles were calculated. However, only the three most inferior three (sacrum-to-lower lumbar, lower lumbar-to-upper lumbar and upper lumbar-to-lower thorax) were analyzed.

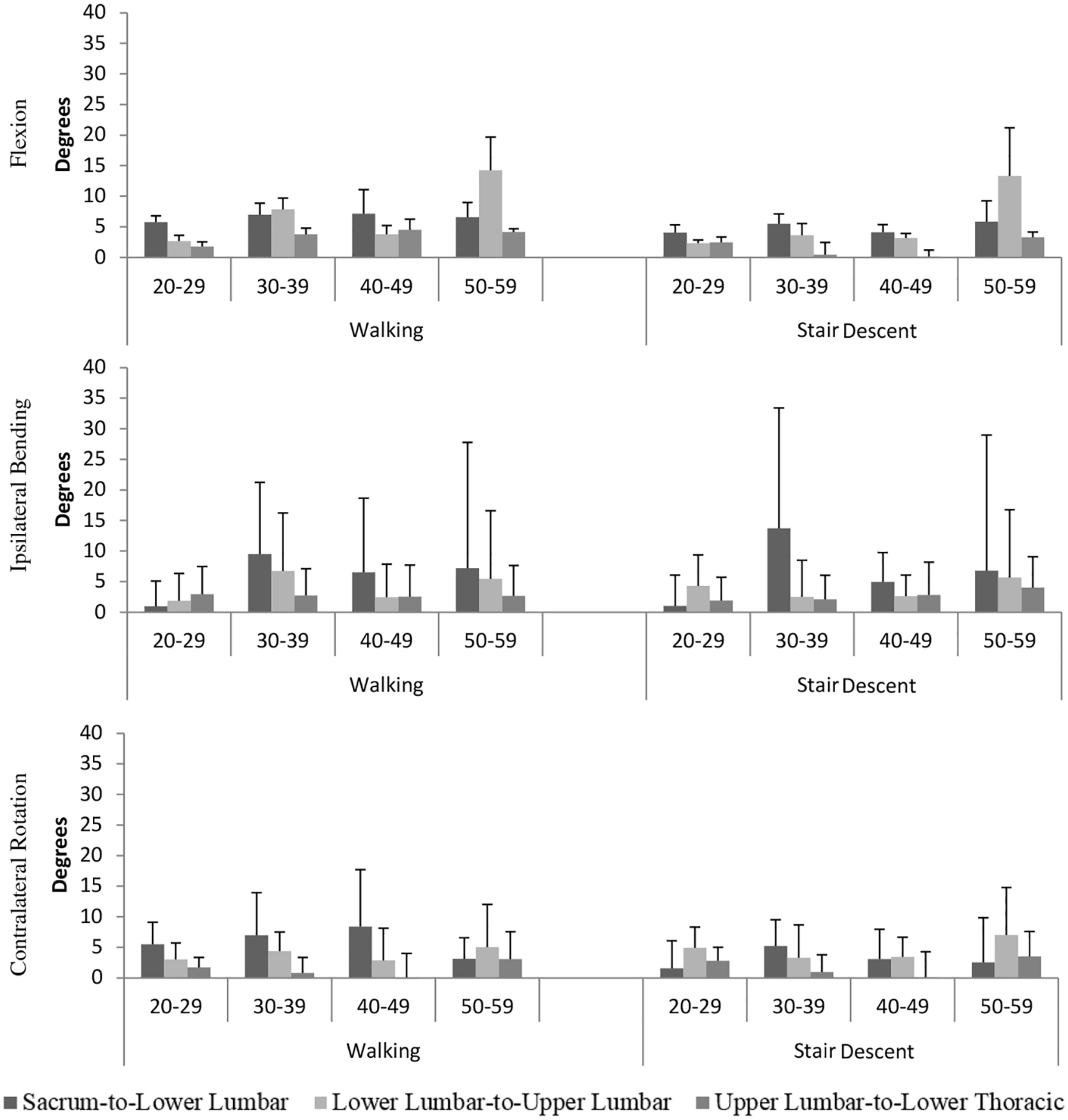


Fig. 3.

Maximum angle during the GC of each plane of motion for both ambulatory activity of daily living.

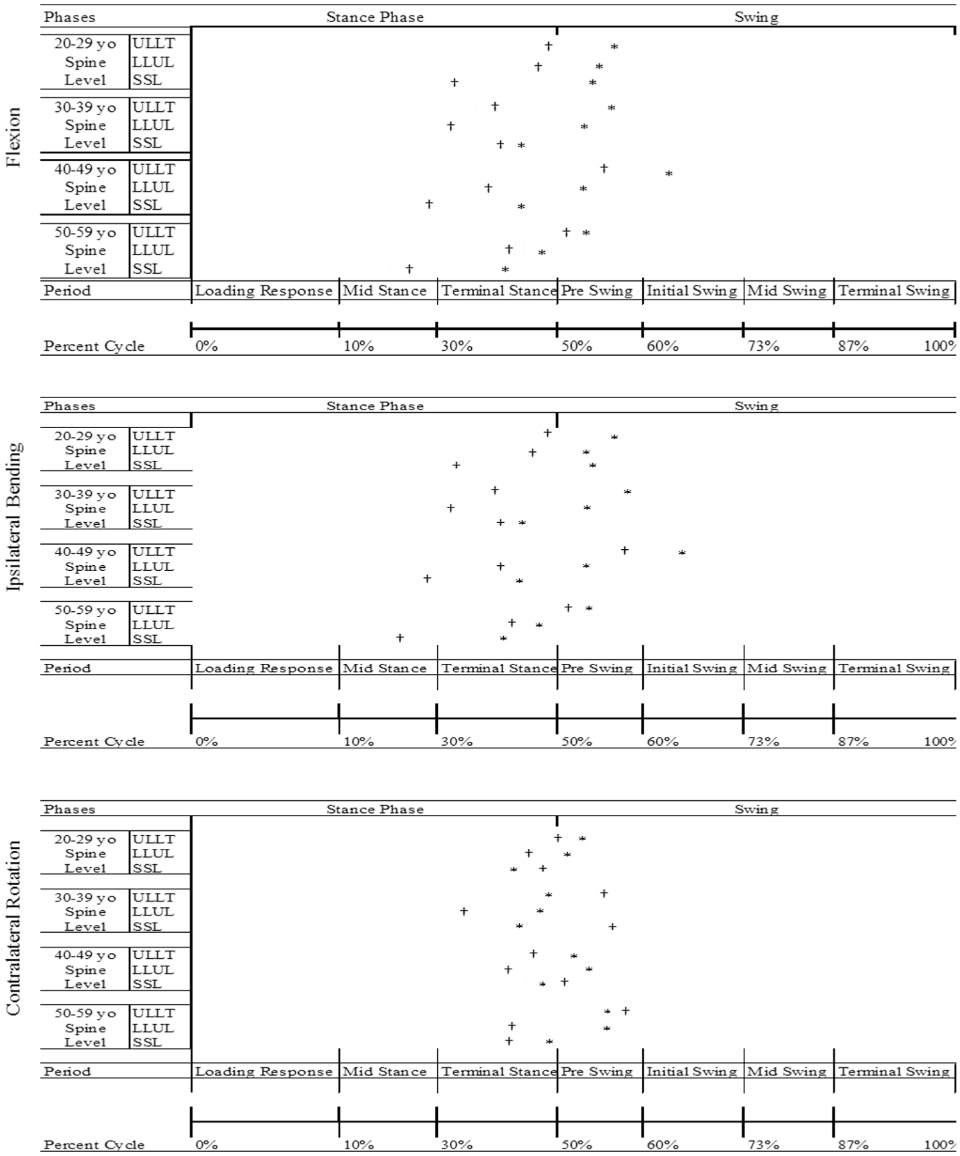
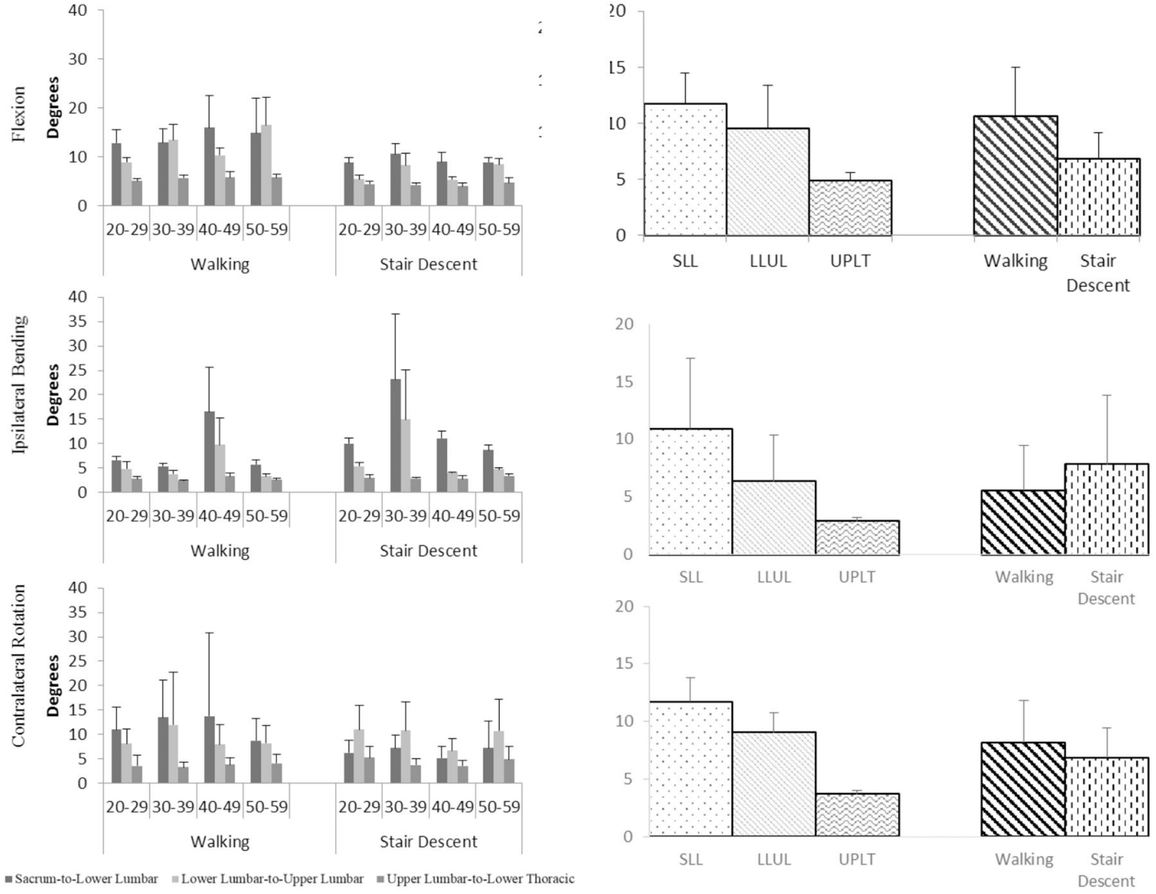


Fig. 4.

Timing of peak rotation angles for all age groups and both tasks.

Note: *Denotes walking condition.

†stair descent.



(**A**) (**B**)

Fig. 5.

Range of motion in all planes of motion. (**A**) different age groups and both tasks of daily living are on the horizontal axis. (**B**) Main effects of spine level and task.

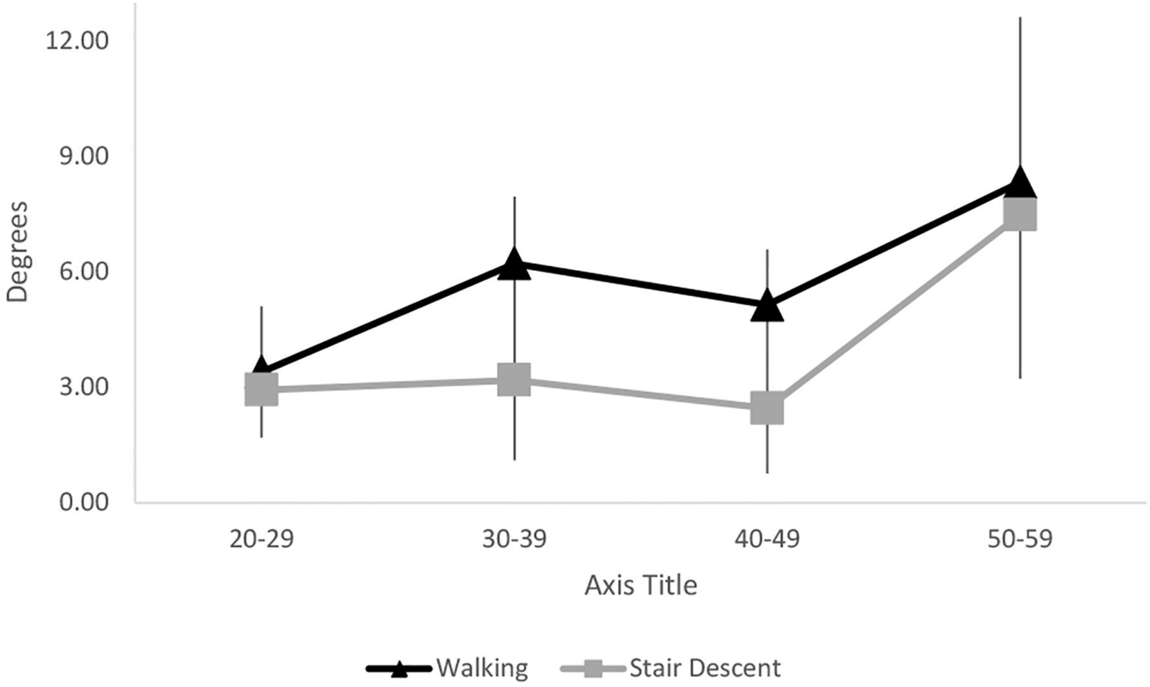


Fig. 6.

A comparison of the average flexion data between tasks by age groups.

Table 1.

Subject Demographics.

	20–29	30–39	40–49	50–59
Age (years)	24.10 ± 2.64	33.43 ± 3.14	45.09 ± 2.43	53.14 ± 2.91
Height (cm)	181.58 ± 33.53	168.68 ± 8.99	168.45 ± 4.96	164.47 ± 9.77
Weight (kg)	65.35 ± 13.33	71.74 ± 19.70	65.69 ± 8.01	69.23 ± 16.90
Sex	6men/4women	3 men/4 women	5 men/6 women	2 men/4 women

Table 2.

p-Values for Three-Way ANOVA of Each Dependent Variable in the Trunk.

	Peak Trunk Angle	Peak Trunk Angle Index	Trunk ROM
Flexion	0.804	0.063	0.809
Ipsilateral bending	0.055	0.371	0.316
Contralateral axial rotation	0.179	0.89	0.722

Table 3.

p-Values for Two-Way Interactions for Trunk.

	Flexion	Ipsilateral Bending	Contralateral Axial Rotation
Maximum Trunk Angle			
Trunk Joint * Task	0.04 *	0.301	0.001 *
Trunk Joint * Age	0.677	0.351	0.365
Task * Age	0.455	0.121	0.412
Peak Angle Index			
Trunk Joint * Task	0.286	0.004 *	0.082
Trunk Joint * Age	0.05 *	0.699	0.775
Task * Age	0.889	0.844	0.807
Trunk Range of Motion			
Trunk Joint * Task	0.094	0.249	0.001 *
Trunk Joint * Age	0.649	0.385	0.384
Task * Age	0.848	0.287	0.285

*indicates a significant interaction.