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Age-Related Hip Proprioception Declines: Effects on Postural Sway and Dynamic Balance



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Abstract

Objective: To evaluate the effects of age on hip proprioception, and determine whether age-related hip proprioception declines disrupt balance.

Design: Survey of proprioception and balance differences between 3 age groups.

Setting: University balance laboratory.

Participants: Volunteer sample of independent community-dwelling adults (N=102) without sensory or other neurologic impairments in 3 age groups: younger (mean age, 24.6y; range, 19–37y), mid-aged (mean age, 53.3y; range, 40–64y), and older adults (mean age, 76.3y; range, 65–94y).

Interventions: Not applicable.

Main Outcome Measures: Hip joint position sense (JPS) and kinesthesia were measured using a custom-built device. JPS error was determined by the magnitude of matching errors during vision and no-vision conditions. Kinesthesia was evaluated by the ability to detect passive limb rotation without vision. Postural sway was assessed during static stance and measured using root mean square of center of pressure (COP) displacement and velocity of COP displacement. Clinical balance and fear of falling were assessed with the mini-Balance Evaluation Systems Test (mini-BESTest) and Activities-specific Balance Confidence Scale, respectively.

Results: Both older and mid-aged adults had significantly increased JPS error compared with younger adults ($P<.05$). Kinesthesia accuracy was significantly decreased in older adults compared with mid-aged and younger adults ($P\leq.01$). Both measures of proprioception error correlated with age ($P\leq.001$). There were no relationships between hip proprioception error and postural sway during static stance. However, older adults with lower proprioceptive error had significantly higher mini-BESTest scores of dynamic balance abilities ($P=.005$).

Conclusions: These results provide evidence of significant hip proprioception declines with age. Although these declines are not related to increases in postural sway, participants with hip proprioception declines demonstrated disrupted dynamic balance, as indicated by decreased mini-BESTest scores.

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Upright postural stability relies on vision, vestibular sense, and proprioception, and the acuity of each sense likely decreases with age (for review, see Sturnieks et al¹). Proprioception is the sense of both body segment position (joint position sense [JPS]) and movement (kinesthesia).² Previous studies have shown age-related declines in proprioception (for review, see Goble et al³) at the

knee,⁴⁻⁷ ankle,⁸⁻¹¹ and the upper extremity,^{12,13} yet few studies have evaluated hip proprioception across the lifespan. Additionally, most research on hip proprioception in older adults has involved participants with either total hip replacement or hip fracture, and neither significantly decreased proprioceptive acuity.^{14,15} To date, Pickard et al¹⁶ have conducted the only known study assessing the effects of aging on hip proprioception. Their study showed no such declines but only included older adults who were highly physically active, averaging 10 hours of physical activity per week.¹⁶ Whether hip proprioception declines in older adults with more typical activity levels has not been reported.

Several researchers have linked lower extremity proprioception and balance. Increased JPS error of the great toe is associated with

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increased sway, decreased performance on clinical balance measures, and an increased history of falls.^{17,18} Similar increases in sway have been associated with age-related declines in knee and ankle JPS.¹⁹ Decreased hip proprioception may similarly affect postural stability and contribute to increased fall risk in older adults.

Direction of sway also appears to be an important factor in fall morbidity and mortality. In older adults, wrist fractures have been associated with anterior-posterior (AP) falls, whereas hip fractures have been associated with medial-lateral (ML) falls.^{20,21} Furthermore, numerous studies²²⁻²⁴ linked increased ML sway to future falls. Since motor control strategies at the hip are primarily responsible for controlling ML sway,^{22,25} decreased hip proprioception may be related to excessive ML sway and falls, especially in the lateral direction. However, the precise role of hip proprioception in postural control and fall risk remains unclear.

The primary purpose of this study was to quantitatively assess hip JPS and kinesthesia across the lifespan. Secondly, this study aimed to determine whether decreased hip proprioception contributes to age-related postural instability and fall risk. We hypothesized that the magnitude of hip JPS and kinesthesia error would correlate with age, so that proprioception error would be greatest in older adults, and also increased in mid-aged adults compared with younger adults. Here proprioception was measured in the transverse plane using a protocol that has previously detected proprioception deficits, and linked those deficits to increased postural sway, in a patient population.^{26,27} We also hypothesized that age-related decreases in proprioception would correlate with changes in static stance postural sway and clinical measures of dynamic balance. More specifically, we hypothesized that older adults with higher proprioceptive error would demonstrate increased sway in stance and diminished performance on clinical balance tests.

Methods

Participants

The analyzed sample consisted of 102 participants in 3 age groups: 34 younger adults (22 women; mean age, 24.6y; age range, 19–37y), 34 mid-aged adults (23 women; mean age, 53.3y; age range, 40–64y), and 34 older adults (24 women; mean age, 76.3y; age range, 65–94y). Younger adults were recruited from the university community. Mid-aged and older adults were recruited from the university community, a local lifelong learning institute, and 2 apartment complexes inhabited predominantly by older adults. Recruitment was via advertisements and word of mouth. In total, 122 community-dwelling adults volunteered for

this study. However, 20 volunteers were not tested as a result of not meeting inclusion criteria because they were unable to independently ambulate, scored ≤ 25 on the Mini-Mental State Examination, had conditions affecting somatosensation (eg, diabetes mellitus, stroke, peripheral neuropathy, or other neurologic diseases), or used medications affecting cognition, balance, or sensory perception. This study was approved by the Human Studies Committee at the University of North Carolina Asheville; all participants signed an informed consent before data collection.

Participants self-reported the number of falls experienced in the 12 months before the study; falls were defined as an event resulting in unintentionally coming to rest on the ground or lower level, with or without injury.²⁸ Participants also reported the number of minutes per week spent in endurance, strength, and balance training exercise. Researchers used the self-reported activity values to determine whether each participant regularly engaged in (1) physical activity according to the American College of Sports Medicine guidelines²⁹ (≥ 150 min/wk of moderate-intensity cardiorespiratory activity and resistance, flexibility, and neuromotor exercise 2–3 times/wk); and (2) balance exercise on a weekly basis (eg, yoga or tai chi). A modified Edinburgh Handedness Inventory^{26,30} determined limb dominance; the dominant leg was assumed to be ipsilateral.²⁶

Participants then completed the following testing in a randomized order: proprioception testing (JPS and kinesthesia), the mini-Balance Evaluation Systems Test (mini-BESTest), Activities-specific Balance Confidence (ABC) Scale, and postural sway measurement during normal stance and feet together, in both eyes open and closed conditions.

Proprioception

The proprioception assessment methods have been previously described.²⁶ A custom-built device allowed for rotation around the axis of a semi-goniometer to measure JPS and kinesthesia in the transverse plane at the hip joint while the participant was sitting with the knee extended (fig 1). Order of leg (side) testing was randomly determined.

JPS was assessed by measuring the accuracy of actively pointing a marked line on the second toe to target angles along the semi-goniometer during 2 conditions. In the vision condition, participants viewed both their foot and the target angle; in the no-vision condition, an opaque curtain obscured the foot, requiring participants to rely on JPS to complete the task. Ten vision condition target trials were followed by 10 no-vision target trials. Target angles were clearly visible to the participant and were at 5° intervals, comfortably within their range of motion. The order of target angles was randomly determined, and all participants received the same target angles in the same order. The tester both pointed to and named the target angle aloud to the participant, and subsequently recorded the orientation angle of the marked toe to the nearest degree. In order to account for proprioceptive contribution to the task, the difference between error in the no-vision condition and error in the vision condition was calculated for each target. The root mean square (RMS) of the no-vision–vision JPS error difference for each target was calculated for analysis.

The same device was used to measure kinesthesia; however, participants' eyes were closed for all trials. The experimenter used a rod on the rear of the device to rotate the participant's limb

List of abbreviations:

ABC	Activities-specific Balance Confidence (Scale)
AP	anterior-posterior
CI	confidence interval
COP _D	center of pressure displacement
COP _V	velocity of center of pressure displacement
FDR	false discovery rate
JPS	joint position sense
mini-BESTest	mini-Balance Evaluation Systems Test
ML	medial-lateral
RMS	root mean square



Fig 1 Proprioception device.

internally or externally a maximum of 4° from the previous position at a speed of approximately $1^\circ/\text{s}$. Participants stated “external” or “internal” immediately when movement was sensed; 4 seconds was allowed for a response. The direction of movement was pseudo-randomly selected by the experimenter per trial; however, all participants experienced 10 trials: 5 trials in the internal direction and 5 trials in the external direction. Performance accuracy was recorded as the number of correct responses out of 10 trials for each leg.

Force platform protocol

An AMTI AccuSway Plus Force Platform^a measured postural sway during 4 standing conditions: (1) normal stance width with eyes open; (2) normal stance with eyes closed; (3) participants standing with their feet side-by-side, as close together as possible with eyes open; and (4) feet together with eyes closed. Participants were barefoot and instructed to remain still for two 60-second trials, with 30 seconds of rest between trials. Kinetic data were collected at 200Hz and filtered (6-Hz low-pass Butterworth), and average centers in the ML and AP directions were calculated in Matlab^b for each trial. The first/last 2 seconds of each trial were discarded to remove possible transients.³¹ The following variables were analyzed for each eye and stance condition: RMS of center of pressure displacement (COP_D) (in mm) and RMS of velocity of COP displacement (COP_V) (in mm/s), in both AP and ML directions. Finally, in order to account for the contribution of vision to overall postural control, the differences between eyes closed and eyes open conditions were calculated for both stance conditions.

Clinical balance measures

The ABC Scale asked participants to self-report their confidence level (from 0% to 100%) on their ability to not lose their balance or fall when performing 16 mobility activities. The total score was the average of the 16 scores.³²

Each participant completed the mini-BESTest, a 14-item clinically based assessment taken from sections of the BESTest related

to postural adjustments, gait stability, and the Timed Up & Go test with and without simultaneous backwards counting task.^{33,34}

Statistical analyses

All data were tested for normative distributions with the D’Agostino-Pearson omnibus and Shapiro-Wilk tests. Because some variables were not normally distributed, the Kruskal-Wallis test was used to determine group differences in JPS, kinesthesia, and postural sway. Multiple comparisons were corrected by the Benjamini-Hochberg³⁵ false discovery rate (FDR) approach to control for an FDR level (Q) of .05. FDR-adjusted P values are reported. Group physical activity differences were compared using Fisher exact tests. Spearman rank correlation tested the relationships between (1) proprioceptive error (both JPS and kinesthesia) and age, and (2) proprioceptive error and postural sway in the various stance and eye conditions.

Subjects in the older group were then subdivided based on their performance on the JPS task into upper half (poor) versus lower half (good) on JPS error scores.¹⁹ We chose JPS data (over kinesthesia data) for stratification and further analysis because (1) active proprioception tasks are considered more accurate than passive tasks,^{3,16} and (2) the JPS error data were continuous as opposed to the kinesthesia data that were dichotomous (ie, internal vs external). Mann-Whitney U tests evaluated JPS performance (good vs poor) group differences in ABC Scale, mini-BESTest, and postural sway within the older adult group.

Results

Table 1 describes the demographic characteristics of the participants. On the mini-BESTest, older adults had significantly lower scores compared with both mid-aged ($P=.007$) and younger adults ($P<.001$), and mid-aged adults scored significantly lower than younger adults ($P=.003$). However, there were no group differences on self-reports of the number of falls over the past year, physical activity levels, or ABC Scale (see **table 1**).

All groups had comparable JPS performance distributions bilaterally when assessing JPS in the vision condition (**table 2**). In contrast, with exclusive reliance on somatosensory input, there were significant between-group differences in JPS error (**fig 2**, see **table 2**). In the dominant leg, older adult JPS error was nearly twice the magnitude of error observed in younger adults ($P<.0001$). Older adults also had significantly higher JPS error compared with mid-aged adults ($P=.008$). Mid-aged adults had significantly higher JPS error than younger adults ($P=.006$). In the nondominant leg, younger adults had significantly lower JPS error than both mid-aged ($P=.03$) and older adults ($P<.0001$).

Similarly, older adults had lower kinesthesia accuracy than mid-aged and younger adults bilaterally (**fig 3**, see **table 2**). In the dominant leg, older adults had significantly lower kinesthesia than mid-aged ($P=.01$) and younger adults ($P=.0004$). In the nondominant leg, older adults had significantly lower kinesthesia accuracy than both mid-aged ($P=.008$) and younger adults ($P=.0009$).

Both JPS and kinesthesia accuracy were slightly lower for all groups in the dominant compared with the nondominant leg; however, the within-group differences between sides were not significant.

To examine whether hip proprioception decreases with age, JPS error and kinesthesia accuracy from both legs were averaged,

Table 1 Comparison of demographic information

Characteristics	Younger (n=34)	Mid-age (n=34)	Older (n=34)
No. of women	22	23	24
Age (y), mean (range)	24.6 (19–37)	53.3* (40–64)	76.3*† (65–94)
No. of falls–12mo, mean (95% CI)	0.7 (0.0–1.4)	0.6 (0.3–1.0)	0.9 (0.1–1.7)
ABC Scale, mean (95% CI)	91.1 (87.3–94.9)	89.9 (87.1–92.7)	86.5 (81.3–91.6)
Mini-BESTest score, mean (95% CI)	96.0 (94.7–97.2)	87.0* (80.7–93.4)	73.8*† (67.8–79.8)
Physical activity			
ACSM guidelines, Yes (%)	32	44	26
Balance activity, Yes (%)	24	32	18

NOTE. Kruskal-Wallis with FDR (Q) = .05 correction for multiple tests compared groups, except for physical activity data in which Fisher exact tests were used.

Abbreviation: ACSM, American College of Sports Medicine.

* Differences are significant ($P < .05$) compared with younger adults.

† Differences are significant ($P < .05$) compared with mid-age adults.

yielding single values that reflect mean JPS error and mean kinesthesia accuracy for each participant. Spearman rank correlation tests determined a significant positive relationship between mean JPS error and age (fig 4A) (Spearman $r = .60$; 95% confidence interval [CI], .45–.71; $P < .0001$), and revealed a significant negative correlation between mean kinesthesia accuracy and age (fig 4B) (Spearman $r = -.34$; 95% CI, $-.50$ to $-.15$; $P = .0005$).

Forceplate data from 2 subjects in the younger and mid-aged groups were not included in postural sway analyses because of calibration errors. Older adults had higher COP_D and COP_V compared with both mid-aged and younger adults in the AP and ML directions, reaching significance on most measures, especially during the eyes-closed condition ($P < .05$) (table 3). Mid-aged and younger adults had similar postural sway.

Pearson correlation showed no relationships between hip proprioception error and COP_D or COP_V in older adults. Similarly, no sway differences between older adults with good versus poor hip JPS were detected.

To evaluate hip proprioception contribution to dynamic balance, older adults were stratified by JPS error. Participants with good JPS had significantly higher mini-BESTest scores compared with those with poor JPS (fig 5); the between-group mean

difference was 14.2% (95% CI, 3.0–25.3; $P = .005$). Older adults with good JPS had a higher ABC Scale score than those with poor JPS, but this difference was not statistically significant.

Discussion

Older adults had significantly higher hip proprioception errors compared with younger and mid-aged adults. Mid-aged adults also had significantly higher JPS error than younger adults, but kinesthesia performance was similar between these 2 groups. The latter indicates that JPS may be affected earlier in life than kinesthesia or that the JPS test more sensitively measured group differences than the kinesthesia test.

The hip proprioception declines observed in this study were consistent with previous reports of similar age-related declines in other joints, distally in the toe,^{17,18} ankle,^{8–11} and knee,^{4–7} and in the upper extremity.^{12,13} The findings of the current study differ from the only known study of hip proprioception in older adults, in which Pickard et al¹⁶ found no such age-related declines in JPS acuity at the hip. However, Pickard¹⁶ only included older adults who were highly physically active, averaging 10 hours of physical

Table 2 Comparison of hip joint position and kinesthesia error across age groups

Variable	Dominant Lower Extremity			Nondominant Lower Extremity		
	Younger	Mid-age	Older	Younger	Mid-age	Older
Joint position error						
Vision						
Mean (deg)	0.52	0.69	0.64	0.57	0.83	0.79
95% CI	0.40–0.65	0.46–0.91	0.51–0.77	0.47–0.68	0.66–1.01	0.57–1.00
No vision–Vision						
Mean difference	4.22	5.83*	8.31*†	4.18	5.4*	6.81*
95% CI	3.68–4.77	4.82–6.84	6.75–9.86	3.60–4.76	4.47–6.32	5.70–7.91
Kinesthesia						
Mean (% correct)	95.00	90.59	73.24*†	96.18	93.82	79.12*†
95% CI	91.04–98.96	84.96–96.22	62.97–83.50	93.20–99.15	87.87–99.78	69.31–88.93

NOTE. Kruskal-Wallis tests with FDR correction for multiple comparisons assessed differences between groups.

* Differences are significant ($P < .05$) compared with younger adults.

† Differences are significant ($P < .05$) compared with mid-age adults.

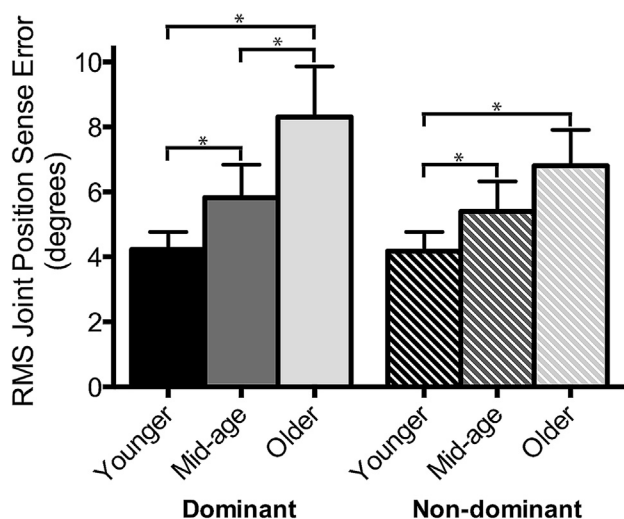


Fig 2 Bar graphs of group RMS magnitude (in degrees) of hip JPS error for younger (black), mid-age (gray), and older adults (light gray). Solid bars represent dominant side, and hashed bars represent nondominant side. Error bars represent 95% CIs around the mean. Asterisk indicates where group differences were significant.

activity per week. The current study included a more diverse sample of older adults, in which all volunteers were independently community-dwelling, but only 26% met the current American College of Sports Medicine minimum physical activity guidelines.²⁹ The differences between the findings of Pickard¹⁶ and the current study suggest that physical activity may protect aging adults from hip proprioception loss, a hypothesis that should be investigated. In addition, Pickard et al¹⁶ examined hip proprioception in the frontal plane, whereas the current study assessed the

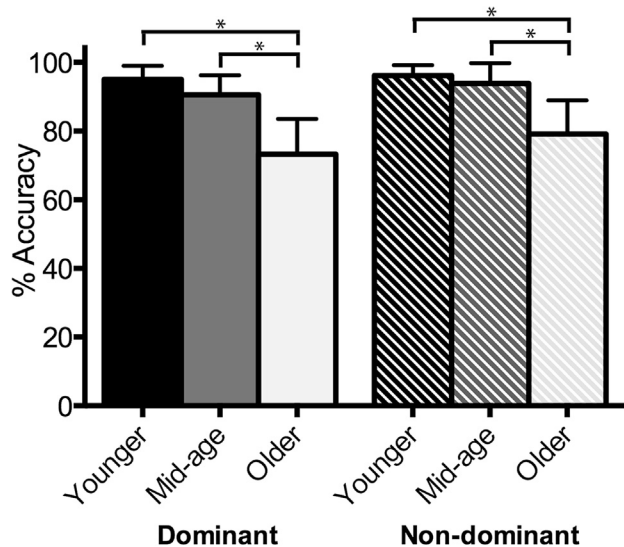


Fig 3 Bar graphs of accuracy (mean and 95% CI) in detecting passive limb movements (kinesthesia) for younger (black), mid-age (gray), and older adults (light gray). Solid bars represent dominant side, and hashed bars represent nondominant side. Error bars represent 95% CIs around the mean. Asterisk indicates where group differences were significant.

transverse plane. Whether aging affects proprioception in these planes differently is currently unknown.

Age-related changes in central or peripheral somatosensory function, or both, likely underlie proprioception declines in older adults. Evidence for peripheral changes include decreased number and function of muscle spindles,³⁶⁻⁴⁰ cutaneous receptors,⁴¹ and joint receptors.^{42,43} Additionally, recent neuroimaging studies in older adults have related decreased proprioceptive function to decreased right-sided subcortical activity and structural changes, most notably in the right putamen.^{44,45} Such structural and functional changes peripherally in somatosensory receptors or centrally in the right putamen may underlie the decreases in proprioceptive performance in older adults observed in the current study.

Previous studies^{46,47} have suggested that decreased attention, memory, and cognitive resources in older adults compromise proprioceptive acuity compared with younger adults. The proprioception paradigm used in this study did not require short-term memory of a remembered position to match because participants immediately aligned their foot with a visibly designated target. In addition, the vision and no-vision trials required identical attention and cognitive abilities to complete. Therefore, the fact that no between-group performance differences on the vision trials existed indicated that all groups were equally able to match their foot to the target, suggesting that group JPS error differences are not attributable to cognitive differences across groups. Similarly, group differences in motor control or range of motion are unlikely to explain the observed decreases in JPS in older adults. Although the JPS test involved a matching task, identical motor and range-of-motion requirements existed between the 2 vision conditions. Therefore, diminished proprioception observed here in older adults was not due to diminished cognitive or motor abilities, but to peripheral or central proprioceptive processing deficits, or both.

Decreased proprioception in the lower extremities increases body sway,⁴⁸⁻⁵⁰ which in older adults may increase the risk of falling.^{1,28} Therefore, this study was designed to relate proprioception measures to stance postural sway and clinical measures of dynamic balance. A forceplate assessed static balance under conditions that varied in proprioceptive difficulty (eyes open vs eyes closed, normal stance vs feet together), and the ABC Scale and mini-BESTest were clinically validated measures of fear of falling and dynamic balance, respectively.

Our static posturography results revealed increased sway displacement and velocity in older adults, consistent with previous studies.^{31,51} Older adults also had increased COP_D and COP_V with eyes closed, suggesting that vision plays an increasing role in stabilizing posture as one ages.³¹ An increased reliance on vision for maintenance of balance in older adults may be a compensatory strategy for proprioception deficits in the lower extremity.

However, our hypothesis that age-related decreases in proprioception would correlate with postural sway measures was not supported by this study, differing from previous data in other joints showing increased sway in people with diminished proprioception at the knee,¹⁹ ankle,⁵² and toe.¹⁷ Perhaps the transverse plane, which was tested here, provides less salient information than other planes for postural control in stance, or distal joints provide more useful proprioceptive information for stance postural sway.⁵² Increased hip transverse plane proprioception error has recently been correlated with increased stance postural sway in children and young adults with cerebral palsy.²⁷ Similarly, the role of hip proprioception in balance in older adults with neurologic comorbidities, such as stroke and peripheral neuropathy, should be examined.

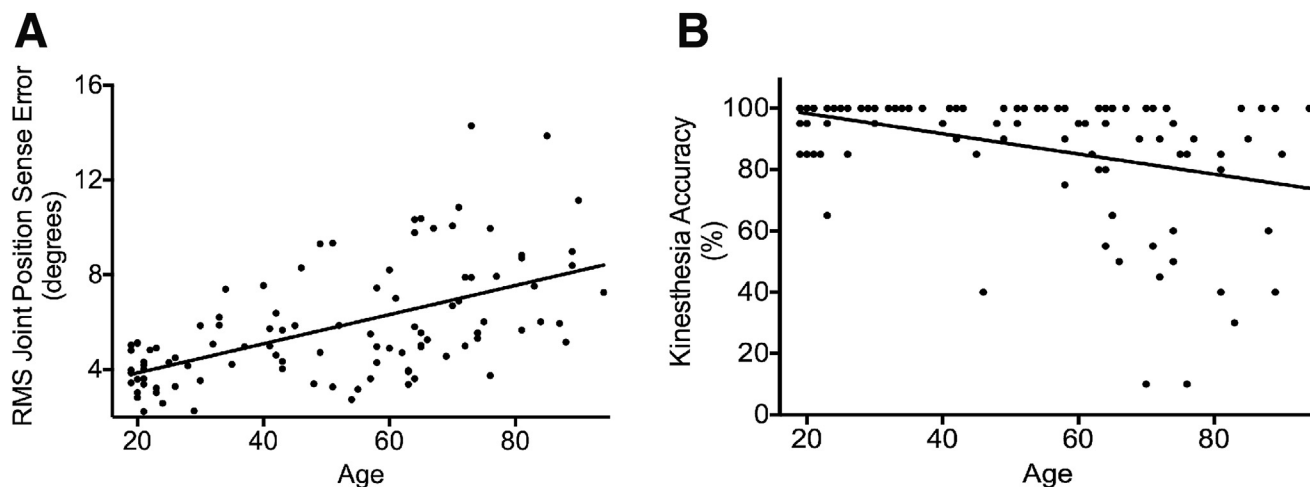


Fig 4 (A) Positive correlation between JPS error (averaged between dominant and nondominant sides) and age (Spearman $r = .60$; 95% CI, .45–.71; $P < .0001$). (B) Significant negative correlation existed between kinesesthesia performance and age (Spearman $r = -.34$; 95% CI, $-.50$ to $-.15$; $P = .0005$). Lines are from linear regression analysis.

In contrast to the postural sway findings, the hypothesized relationship between hip proprioception and dynamic balance was supported by this study. When older adults were stratified by JPS

performance (good vs poor), those with higher hip proprioceptive acuity scored significantly higher on the mini-BESTest. This finding suggests that hip proprioception is important for maintaining

Table 3 Comparison of postural sway during static stance conditions

Stance	Younger			Mid-age			Older		
	EO	EC	EC-EO Difference	EO	EC	EC-EO Difference	EO	EC	EC-EO Difference
Normal stance									
COP _{D-AP}									
RMS	19.2	24.6*	4.8	18.9	22.8*	4.1	26.1 ^{††}	31.4* ^{††}	5.2
95% CI	16.8–21.6	21.3–27.9	2.0–7.7	17.0–20.9	20.9–24.8	1.5 to 6.7	23.1–29.2	28.2–34.5	2.1–8.4
COP _{D-ML}									
RMS	9.0	11.1	2.0	9.4	10.0	0.5	14.7 ^{††}	16.5 ^{††}	1.8
95% CI	7.7–10.3	9.2–12.9	0.7–3.3	7.6–11.2	8.6–11.4	-.68 to 1.7	12.3–17.0	14.0–18.9	0.2–3.5
COP _{V-AP}									
RMS	57.5	78.7*	20.5	62.7	87.0*	24.8 [†]	102.1 ^{††}	156.7* ^{††}	54.6 ^{††}
95% CI	49.7–65.4	68.1–89.3	15.3–25.7	57.0–68.5	78.7–95.3	20.0 to 30.1	85.9–118.3	129.8–183.5	40.8–68.3
COP _{V-ML}									
RMS	30.9	41.6	6.4	29.6	32.0	2.5 [†]	39.8 ^{††}	50.3* ^{††}	10.4 [†]
95% CI	26.1–35.7	31.4–51.9	3.8–8.9	22.9–36.2	27.1–37.0	–6.2 to 11.1	35.5–44.2	45.0–55.8	7.5–13.3
Feet together stance									
COP _{D-AP}									
RMS	23.4	30.3*	6.8	25.7	29.6	3.9	29.6 ^{††}	39.3* ^{††}	9.6 [†]
95% CI	20.8–25.9	27.0–33.7	4.1–9.6	23.0–28.4	26.1–33.0	1.2 to 6.5	27.2–32.1	35.8–42.8	7.1–12.1
COP _{D-ML}									
RMS	26.2	30.7	4.6	26.4	31.6	5.1	32.5 ^{††}	41.1* ^{††}	8.6
95% CI	23.2–29.3	27.6–33.8	1.9–7.3	23.4–29.5	27.1–36.0	2.3 to 8.0	28.8–36.2	35.7–46.5	5.7–11.5
COP _{V-AP}									
RMS	74.1	103.6*	29.4	82.0	113.3*	31.4	137.9 ^{††}	206.3* ^{††}	68.4 ^{††}
95% CI	63.5–84.6	89.2–118.0	22.6–36.3	70.8–93.1	96.7–130.0	18.8 to 43.9	116.9–157.9	175.8–236.8	53.2–83.7
COP _{V-ML}									
RMS	91.4	114.6	32.5	90.6	124.8*	34.2	134.7 ^{††}	189.0* ^{††}	54.3 [†]
95% CI	69.5–113.4	99.4–129.6	25.4–39.6	78.3–103.0	103.0–146.5	19.4 to 48.9	114.8–154.6	159.0–216.5	38.8–69.7

NOTE. Kruskal-Wallis tests with FDR correction for multiple comparisons assessed differences between group means.

Abbreviations: EC, eyes closed; EO, eyes open.

* Differences within groups, between conditions (EC vs EO) are significant.

[†] Within forceplate conditions are significant ($P < .05$) compared with the younger group.

^{††} Within forceplate conditions are significant ($P < .05$) compared with the mid-aged group.

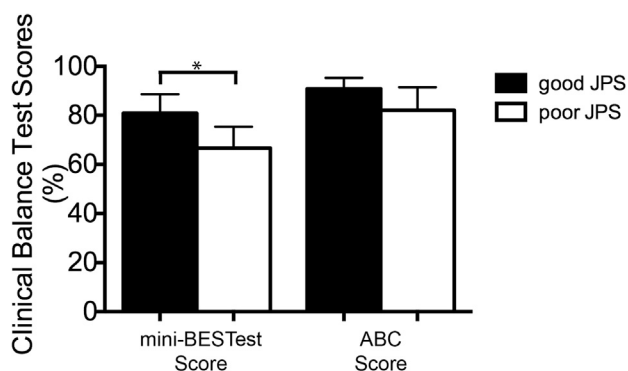


Fig 5 Bar graphs of mini-BESTest and ABC Scale score (mean and 95% CI) in older adults, stratified by JPS performance (good JPS vs poor JPS). Both tests are scored out of 100%. Asterisk indicates where group differences were significant ($P \leq .05$).

balance during challenging motor activities such as single-leg stance, anticipatory and compensatory postural adjustments, gait stability, and multitasking.

A similar trend was evident on the ABC Scale, where older adults with higher proprioceptive performance had a decreased self-reported fear of falling; however, this difference was not statistically significant in our sample. Surprisingly, the mean ABC Scale score for the older adult sample did not statistically differ from mid-aged and younger adults. However, this is consistent with the similarity in the number of falls experienced across groups. It is possible that both ABC Scale score and number of falls are underreported here and do not accurately reflect the actual fear level and fall number of older adults in this study since both measures relied on self-report.⁵³ A less independently ambulatory older adult sample with greater motor impairments would likely demonstrate a relationship between proprioceptive error and fear of falling.

Taken together, these data show an age-associated decline in hip proprioception acuity for both JPS and kinesthesia. Decreased hip proprioception did not relate to increased sway in stance, perhaps because of the relative simplicity of the force-plate tasks and adequate sensory input from other sources. However, hip proprioception loss did disrupt performance in more complex motor tasks requiring higher levels of balance, such as anticipatory and compensatory postural adjustments and gait stability. Therefore, these data are the first to link hip proprioception declines with decreases in clinical measures of dynamic balance. Since fall-related injuries tend to occur during dynamic activities,²¹⁻²⁴ minimizing lower extremity proprioception errors in older adults may be an important therapeutic fall prevention strategy. Previous studies have suggested that lower extremity proprioception can be increased with physical activity,⁵⁴⁻⁵⁷ and that proprioceptive training can improve balance.^{54,55} However, this is not yet established for hip proprioception.

Study limitations

Although statistically significant correlations were found between proprioception error and age, elucidating causal effects of age on proprioception is limited by the cross-sectional design of this research.

The results of this research are generalizable to relatively healthy, independently ambulatory older adults. Even greater proprioceptive loss may be observed in older adults with lower physical ability levels. Furthermore, stronger relationships between hip proprioception error, postural sway, and fear of falling in older adults with greater mobility impairments may be observed. Future studies should investigate proprioceptive contributions to balance in older adults with diagnoses known to affect somatosensation, such as peripheral neuropathies.

Finally, the proprioception findings in this study are limited to the hip in the transverse plane. Also important is proprioception performance in the frontal and sagittal planes and whether proprioception loss in those planes relates to postural sway and dynamic balance. Additionally, the effect of weight-bearing in stance on hip proprioception is unknown since both the current study and Pickard et al¹⁶ tested participants in non-weight-bearing conditions. Future research should include other planes and test hip proprioception in weight-bearing stance to provide clinicians with further specific information about age-related lower extremity proprioception changes and the role of hip proprioception in postural control.

Conclusions

The definitive hip proprioception deficits in older adults observed in this study are in contrast to prior findings for the hip but are consistent with previous findings of age-related proprioception loss in other joints. Interestingly, these losses in hip proprioception were not related to increases in stance postural sway. However, an important relationship between hip proprioception loss and decreased dynamic balance performance was established by this research, as evidenced by significantly decreased mini-BESTest scores in older adults with greater proprioception error. This research provides evidence supporting the importance of accurate hip proprioceptive input for maintenance of balance. Therefore, rehabilitation of people with balance impairments should target improvement of hip proprioceptive accuracy.

Suppliers

- Advanced Mechanical Technology Inc, 176 Waltham St, Watertown, MA 02472.
- The MathWorks, 3 Apple Hill Dr, Natick, MA 01760-2098.

Keywords

Aging; Kinesthesia; Postural balance; Proprioception; Rehabilitation

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