Journal of Exercise Science & Fitness 22 (2024) 152–158

Contents lists available at ScienceDirect

Journal of Exercise Science & Fitness

journal homepage: www.elsevier.com/locate/jesf

Tai Chi counteracts age-related somatosensation and postural control declines among older adults

Teng Zhang [a], Li Li [b], Jan M. Hondzinski [c], Min Mao [d], Wei Sun [e], Qipeng Song [e,*]

[a] Department of Graduate School, Harbin Sport University, Harbin, 150006, China
[b] Department of Health Sciences and Kinesiology, Georgia Southern University, Statesboro, GA, 30460, USA
[c] School of Kinesiology, Louisiana State University, Baton Rouge, LA, 70803, USA
[d] School of Nursing and Rehabilitation, Shandong University, Jinan, 250012, China
[e] Department of Sports and Health Science, Shandong Sport University, Jinan, 250102, China

ARTICLE INFO

Keywords:
Tai chi chuan
Elderly adults
Sensorimotor integration
Plantar sensitivity
Balance control

ABSTRACT

Objective: To investigate the effect of a 16-week Tai Chi practice on strength, tactile sensation, kinesthesia, and static postural control among older adults of different age groups.
Methods: This is a quasi-experimental study. Thirteen participants aged 60–69 years (60–69yr), 11 aged 70–79 years (70–79yr), and 13 aged 80–89 years (80–89yr) completed 16 weeks of 24-form Tai Chi practice. Their ankle and hip peak torque, tactile sensation, ankle and knee kinesthesia, and the root mean square of the center of pressure (Cop-RMS) were measured before (week 0) and after (week 17) practice.
Results: 80–89yr showed less ankle plantar/dorsiflexion and hip abduction peak torques ($p = 0.003$, $p < 0.001$, $p = 0.001$), and a greater ankle plantar/dorsiflexion kinesthesia ($p < 0.001$, $p = 0.002$) than 60–69yr and 70–79yr. Greater ankle plantar/dorsiflexion and hip abduction torques ($p = 0.011$, $p < 0.001$, $p = 0.045$), improved arch and heel tactile sensation ($p = 0.040$, $p = 0.009$), and lower knee flexion/extension kinesthesia ($p < 0.001$, $p = 0.044$) were observed at week 17. The significant group*practice interaction for the fifth metatarsal head tactile sensation ($p = 0.027$), ankle plantar/dorsiflexion kinesthesia ($p < 0.001$, $p = 0.004$), and the CoP-RMS in the mediolateral direction ($p = 0.047$) only in 80–89yr revealed greater improvement at week 17.
Conclusion: Tai Chi practice increased strength, tactile sensation, kinesthesia, and static postural control among older adults. Tai Chi practice improved tactile, kinesthesia sensations, and static postural control among older adults over 80, who presented with worse strength and kinesthesia than their younger counterparts. Tai Chi practice offers a safe exercise option for those aged over 80 to encourage improvements in sensorimotor control.

1. Introduction

Falls lead to fractures and head injuries among older adults, resulting in significant medical expenditures.[1] One-third of older adults aged 65 and older had a fall at least once a year, and fall rates increased with age.[2]

Strength, tactile sensation, and proprioception contribute to postural control,[3] and their reduction may help explain why balance impairment is one of the greatest risk factors for falls among older adults.[4] Postural control requires the motor system (muscle strength) and precise coordination of inputs from the somatosensory system, including tactile sensation and proprioception.[5]

Age-related functional declines in muscle strength,[6] tactile sensation,[7] proprioception,[8] and postural control[9] are accompanied by atrophy of muscle fibers,[10] reduced density and elasticity of tactile receptors,[11] and decreases in spindle diameter and the number of intrafusal fibers,[12] which increased fall risks among older adults.[3] These functional declines do not necessarily inform researchers and clinicians about the age-specific differences among older adults.

Tai Chi, often described as "moving meditation," also proved effective in improving strength,[13] tactile sensation,[14] proprioception,[15] and static postural control.[16,17] Age is one of the main risk factors for falls among older adults, and fall risk increases with age.[18] Furthermore, the lack of physical activity among the aging population is alarming and needs to be addressed.[19] Seventy-five percent of people aged 75 and over do not meet the recommended physical activity level[20] yet few studies

* Corresponding author.
E-mail addresses: Zteng0523@163.com (T. Zhang), lili@georgiasouthern.edu (L. Li), Jhondz1@lsu.edu (J.M. Hondzinski), mindy_m@163.com (M. Mao), sunwei841024@163.com (W. Sun), songqipeng@sdpei.edu.cn (Q. Song).

https://doi.org/10.1016/j.jesf.2024.02.004
Received 26 November 2023; Received in revised form 17 February 2024; Accepted 19 February 2024
Available online 24 February 2024

involving physical activity include data on older adults over 80 years and differentiate participant ages by decades. To our knowledge, no existent published studies include comparisons of the differences in Tai Chi's effects on strength, tactile sensation, kinesthesia, and static postural control among older adults of different age groups. This leads to the question of whether Tai Chi produces the same effects among older adults compared with younger counterparts. Relevant information may increase the confidence and willingness of older adults to practice Tai Chi and prescribe targeted exercises for older adults aged over 80 years and most prone to falls.

In this study, we aimed to investigate the effect of 16 weeks of Tai Chi practice on strength, tactile sensation, kinesthesia, and static postural control among older adults of different age groups. We hypothesized that 1) compared to the younger counterparts, those over 80 would present with less strength and worse tactile sensation, kinesthesia, and static postural control, and 2) 16 weeks of Tai Chi practice would improve strength, tactile sensation, kinesthesia, and static postural control relatively equally among older adults of different age groups.

2. Methods

2.1. Sample size estimation

An *a priori* power analysis (G*Power Version 3.1) indicated that a minimum of 30 participants was required to achieve an alpha level of 0.05 and a statistical power of 0.80. Based on a previous study, in which the ankle dorsiflexion kinesthesia was compared among three groups of older adults (Tai Chi, Brisk walking, and no-exercise control) before and after 16-week interventions (Tai Chi group, Week 0: 1.94 ± 0.40°, Week 16: 1.15 ± 0.20°; Brisk walking group, Week 0: 2.12 ± 0.47°, Week 16: 1.63 ± 0.53°; Control group, Week 0: 2.13 ± 0.30°, Week 16: 1.90 ± 0.34°, η_p^2 (group*practice interaction) = 0.092).[15]

2.2. Participants

Thirty-nine older adults were recruited by distributing presentations in the local communities, with 13 participants aged 60–69 years (60–69yr), 11 participants aged 70–79 years (70–79yr), and 13 participants aged 80–89 years (80–89yr). The inclusion criteria were: 1) aged over 60 years and 2) no Tai Chi experience. The exclusion criteria included: 1) self-reported history of neuro-musculoskeletal disorders, 2) self-reported diseases that could dramatically impact gait or postural control, 3) having a cardiac pacemaker or history of sole foot ulcers, and 4) cognitive impairment determined by the Mini-Mental State Exam (MMSE) score of 24 or less.

Human participation was approved by the Institutional Review Boards of the local University (2019005) and following the Helsinki Declaration.

2.3. Tai Chi practice

From August to December 2019, participants from three age groups practiced the 24-form Tai Chi together under the supervision of a qualified Tai Chi instructor in four 1-h sessions per week for 16 weeks, with the assistance of three graduate students who frequently practice Tai Chi. The instructor wore a microphone and stood on a 25-cm-high platform to ensure that each participant could hear and see him clearly. Three graduate students assisted in correcting the participants' movements as they practiced and provided safety assistance when they performed difficult movements or were at risk of falling. Details of the practice are shown in Table 1.

2.4. Protocol

This is a quasi-experimental study. At week 0, the participants signed an informed consent form and gave supplementary information, along with the MMSE and Medical History form. Muscle strength, tactile sensation, kinesthesia, and static postural control were measured at weeks 0 and 17, respectively.

Table 1
The full routine of Tai Chi practice.

Time	10 min	20 min	20 min	10 min
Week 1	Warm-up	To learn new movements: Starting Posture; Part the Wild Horse's Mane on Both Sides; White Crane Spreads its Wings	Practicing	Relaxation
Week 2	Warm-up	Brush Knee and Twist Step on Both Sides; Hold the Lute; Grasp the Bird's Tail-Left Side	Practicing	Relaxation
Week 3	Warm-up	Rollings on Both Sides; Grasp the Bird's Tail-Right Side; Single Whip	Practicing	Relaxation
Week 4	Warm-up	Cloud Hands; Single Whip; High Pat on Horse	Practicing	Relaxation
Week 5	Warm-up	Kick with Right Heel; Twin Peaks; Turn and Kick with Left Heel	Practicing	Relaxation
Week 6	Warm-up	Push Down and Stand on One Leg-Left/Right Style; Work at Shuttles on Both Sides	Practicing	Relaxation
Week 7	Warm-up	Needle at Sea Bottom; Flash the Arms; Turning body, Pulling, Blocking and Pounding	Practicing	Relaxation
Week 8	Warm-up	Apparent close up; Cross Hands; Closing Form	Practicing	Relaxation
Week 9–16	Warm-up	Practicing		Relaxation

2.5. Muscle strength, tactile sensation, kinesthesia, and postural sway tests

A detailed description of muscle strength, tactile sensation, kinesthesia, and postural sway tests was previously reported.[3] Greater strength and smaller tactile sensation, kinesthesia, and CoP-RMS indicated better performance.

Strength of hip abduction and ankle plantarflexion/dorsiflexion was measured using the IsoMed 2000 strength testing system (D. & R. Ferstl GmbH, Hemau, Germany), which has good reliability.[21] Three trials were conducted in each direction at an angular velocity of 60°/s.[3]

Tactile sensation at the great toe, first and fifth metatarsal heads (M1 and M5, respectively), arch, and heel were performed by the Semmes-Weinstein monofilaments (North Coast Medical, Inc., Morgan Hill, CA, USA), which have good reliability.[22] One investigator applied filaments (bent at 90°) to the plantar surface on each of the five locations for 1 s in random order. The tactile sensation was determined by the minimum monofilament gauge.

Kinesthesia assessment of knee flexion/extension and ankle plantarflexion/dorsiflexion involved a proprioceptive testing device (Sunny, Jinan, Shandong, China), which has good reliability.[23] The device was composed of a box and a platform that rotated steadily at an angular velocity of 0.4°/s until the participant stopped it with a hand switch when they determined the movement. Participants closed their eyes and wore headphones with music playing to eliminate visual and auditory stimuli. In each direction, five trials were carried out.

Postural sway was measured to assess balance. The participant was instructed to look straight ahead and keep their arms beside the trunk in a comfortable posture with feet together, and stand still on a force plate for 60 s. Data from the force plate (KISTLER, 9287 B A, Bern, Switzerland), known for good test-retest reliability,[24] were collected at 1000 Hz and used to calculate the root mean square of the center of pressure in anteroposterior (CoP-RMS$_{ap}$) and mediolateral (CoP-RMS$_{ml}$) directions:

$$\mathrm{CoP} - \mathrm{RMS}_{ml} = \sqrt{\frac{\sum \mathrm{ML}[n]^2}{n}}$$

$$\mathrm{CoP} - \mathrm{RMS}_{ap} = \sqrt{\frac{\sum \mathrm{AP}[n]^2}{n}}$$

n is the number of data points; ML and AP are the COP displacement in the mediolateral and anteroposterior direction.

2.6. Data analysis

The Shapiro-Wilk test was used to determine the normality of all outcome variables. Evidence for the between-subject factor of group (60–69yr, 70–79yr, 80–89yr), within-subject factor test (pre/post practice), and group*practice interaction effects were assessed with a mixed-model two-way ANOVA (normally distributed data) or a Scheirer-Ray-Hare test (non-normally distributed data) while controlling for the covariates, sex, height, and weight. Stratified t-tests with Bonferroni adjustment were conducted for post-hoc testing when applicable. Cohen's d (d) values provided evidence of small (0.2), medium (0.5), and large (0.8) effect sizes.[25] All analyses were performed using SAS 9.4 (SAS Inst., Cary, NC, USA), and the significance level was set at 0.05.

3. Results

Shapiro–Wilk tests showed that the tactile sensation data were non-normally distributed, and the muscle strength, kinesthesia, and CoP-RMS data were normally distributed; hence, Scheirer–Ray– Hare tests and two-way ANOVA tests with repeated measures were applied.

Data of two participants with attendance rates <70% were excluded due to time commitment (Fig. 1), other participants completed all the sessions. No regular exercises other than Tai Chi were practiced and no adverse effects were reported during the intervention.

Thirty-seven participants remained: 13 in 60–69yr (female = 7; age = 65.6 ± 1.0 years; height = 162.6 ± 7.8 cm; mass = 63.3 ± 10.1 kg; BMI = 23.5 ± 2.7 kg/m^2), 11 in 70–79yr (female = 7; age = 73.0 ± 3.4; height = 158.7 ± 10.8; mass = 62.1 ± 9.0 kg; BMI = 24.2 ± 3.6 kg/m^2), and 13 in 80–89yr (female = 8; age = 85.3 ± 2.6 years; height = 155.3 ± 2.8 cm; mass = 61.1 ± 6.3 kg; BMI = 25.1 ± 2.6 kg/m^2).

The relative peak torques are shown in Fig. 2. No significant group by practice interaction was detected. Significant practice effects for ankle plantarflexion ($p = 0.011$, $\eta_p^2 = 0.47$, $F_{(34,2)} = 7.24$), dorsiflexion ($p < 0.001$, $\eta_p^2 = 0.176$, $F_{(34,2)} = 30.127$), and hip abduction ($p = 0.045$, $\eta_p^2 = 0.113$, $F_{(34,2)} = 4.325$) revealed an increase from week 0 to week 17. Significant group effects in ankle plantarflexion ($p = 0.003$, $\eta_p^2 = 0.293$, $F_{(34,2)} = 7.036$), dorsiflexion ($p < 0.001$, $\eta_p^2 = 0.436$, $F_{(34,2)} = 13.151$), and hip abduction ($p = 0.001$, $\eta_p^2 = 0.357$, $F_{(34,2)} = 9.458$) indicated that 80–89yr produced less peak torque for ankle plantarflexion ($p = 0.003$, $d = 0.932$), dorsiflexion ($p < 0.001$, $d = 0.965$) and hip abduction ($p < 0.001$, $d = 0.951$) than 60–69yr, and for ankle plantarflexion than 70–79yr ($p = 0.028$, $d = 0.894$). 70–79yr also produced less peak torques than 60–69yr for ankle dorsiflexion ($p = 0.024$, $d = 0.897$).

The tactile sensation thresholds are shown in Fig. 3. A significant

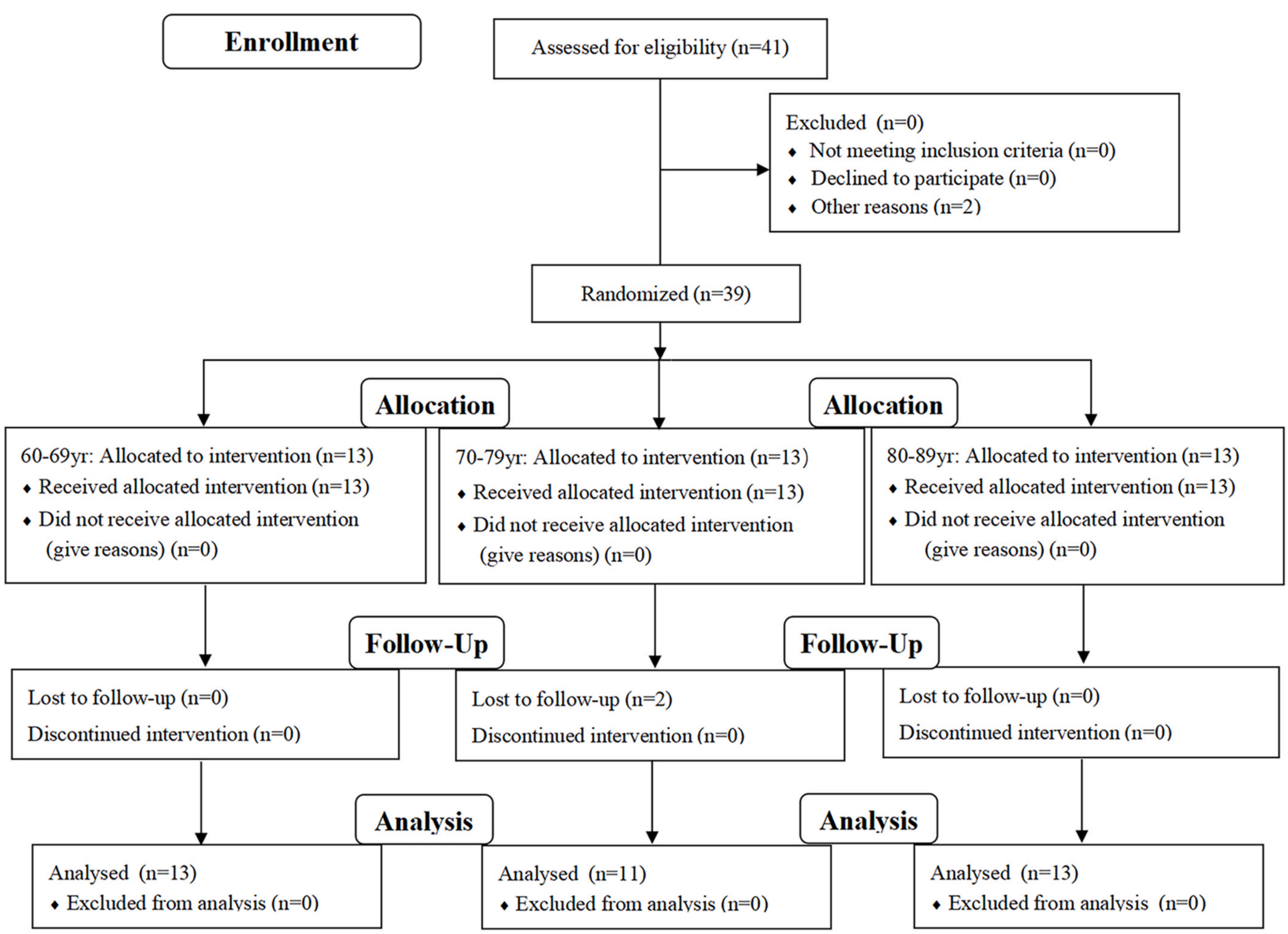

Fig. 1. The flowchart of assignment in the study.

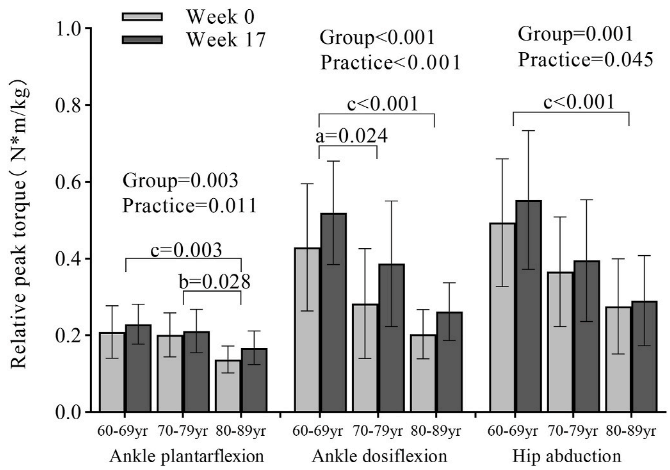

Fig. 2. Mean relative peak torque representing muscle strength of the ankle plantarflexion (left panel), dorsiflexion (middle panel), and hip abduction (right panel) are shown for each age group at weeks 0 and 17 (Practice). Error bars represent ±1 standard error. 60–69yr = participants aged 60–69 years, 70–79yr = participants aged 70–79 years, 80–89yr = participants aged 80–89 years. P-values representing significant differences for Group, Practice or a = between 60-69yr and 70–79yr, b = between 70-79yr and 80–89yr; c = between 60-69yr and 80–89yr are provided.

group by practice interaction ($p = 0.040$, $\eta_p^2 = 0.169$, $F_{(34,2)} = 2.526$) for M5 showed its thresholds decreased from week 0 to week 17 in 80–89yr ($p = 0.027$, $d = 0.837$, $F_{(34,2)} = 5.310$) with no changes detected in 60–69yr and 70–79yr. Significant practice effects were detected at arch ($p = 0.040$, $\eta_p^2 = 0.118$, $F_{(34,2)} = 4.541$) and heel ($p = 0.009$, $\eta_p^2 = 0.186$, $F_{(34,2)} = 7.755$) denoted that each decreased from week 0 to week 17. No group effect on tactile sensation threshold was detected.

The kinesthesia thresholds are shown in Fig. 4. Significant group by practice interaction for plantarflexion ($p < 0.001$, $\eta_p^2 = 0.395$, $F_{(34,2)} = 36.770$) and dorsiflexion ($p = 0.004$, $\eta_p^2 = 0.273$, $F = 25.093$) decreased from week 0 to week 17 in 80–89yr only (plantarflexion = $p < 0.001$, $d = 0.945$, $F_{(34,2)} = 31.912$; dorsiflexion = $p < 0.001$, $d = 0.946$, $F_{(34,2)} = 22.400$). Significant practice effects in kinesthesia thresholds for knee flexion ($p < 0.001$, $\eta_p^2 = 0.409$, $F_{(34,2)} = 23.498$) and extension ($p = 0.044$, $\eta_p^2 = 0.114$, $F_{(34,2)} = 4.382$) designated decreases from week 0 to week 17 for all groups. Significant group effects for plantarflexion ($p < 0.001$, $\eta_p^2 = 0.392$, $F_{(34,2)} = 10.957$) and dorsiflexion ($p = 0.002$, $\eta_p^2 = 0.313$, $F_{(34,2)} = 7.744$) revealed that plantarflexion and dorsiflexion for 80–89yr exceeded 60–69yr ($p < 0.001$, $d = 0.966$) and 70–79yr ($p = 0.020$, $d = 0.899$) plantarflexion and 60–69yr ($p = 0.002$, $d = 0.936$) and 70–79yr ($p = 0.023$, $d = 0.894$) dorsiflexion, respectively.

The CoP-RMS is shown in Fig. 5. Significant group by practice interaction ($p = 0.047$, $\eta_p^2 = 0.169$, $F_{(34,2)} = 3.354$) for CoP-RMS_{ml} showed its thresholds decreased from week 0 to week 17 in 80–89yr ($p < 0.001$, $d = 4.0$, $F_{(34,2)} = 16.782$) with no changes detected in 60–69yr and 70–79yr. No group main effect was detected.

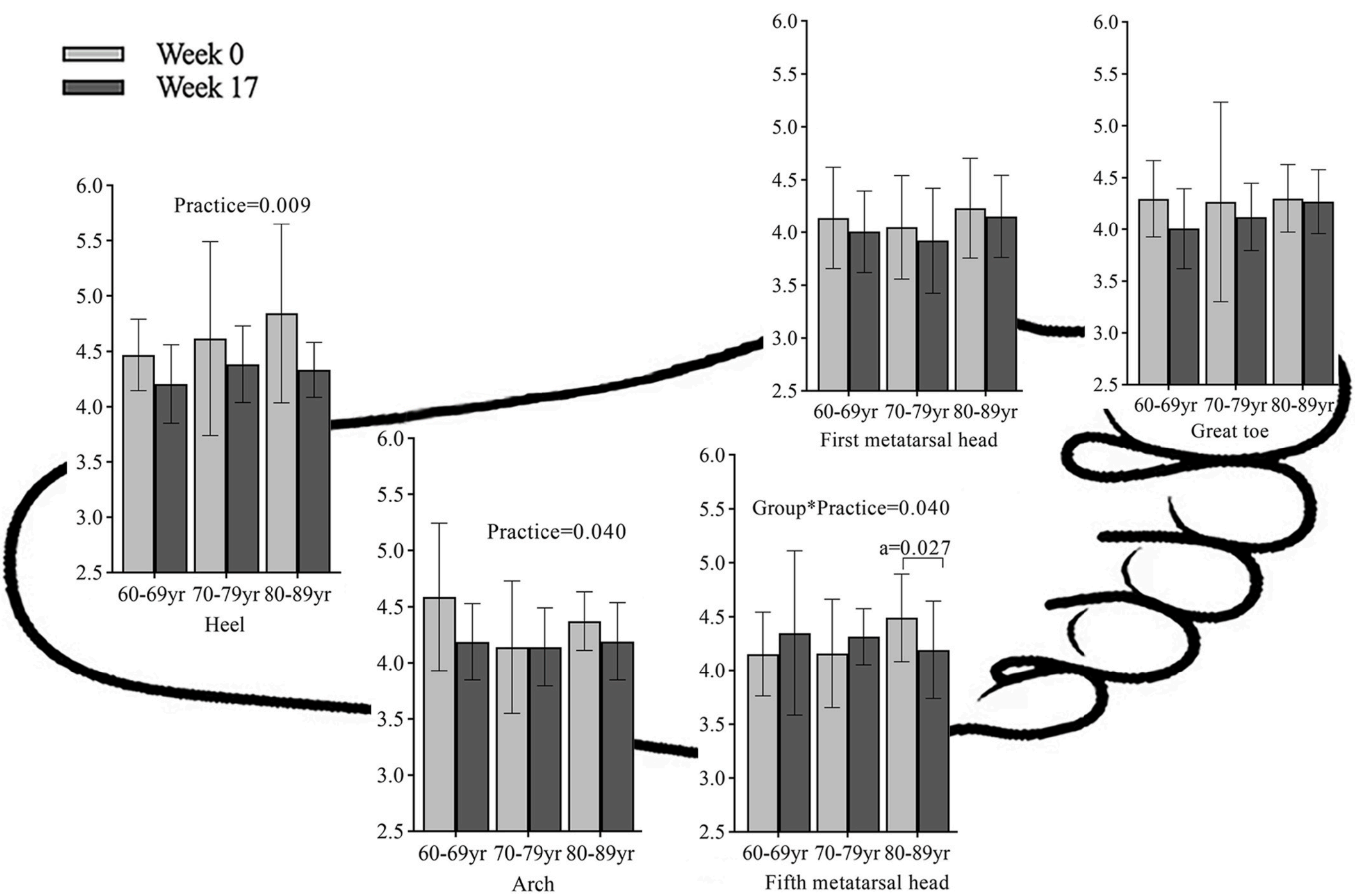

Fig. 3. Mean tactile sensation thresholds are shown for each age group at weeks 0 and 17 (Practice). Error bars represent ±1 standard error. 60–69yr = participants aged 60–69 years, 70–79yr = participants aged 70–79 years, 80–89yr = participants aged 80–89 years. The curvy black line represents the outline of a footprint, and the location of each bar chart matches the position on the foot. P-values representing significant differences for Practice, Group* Practice, or a = from week 0 to week 17 in 80–89yr are provided.

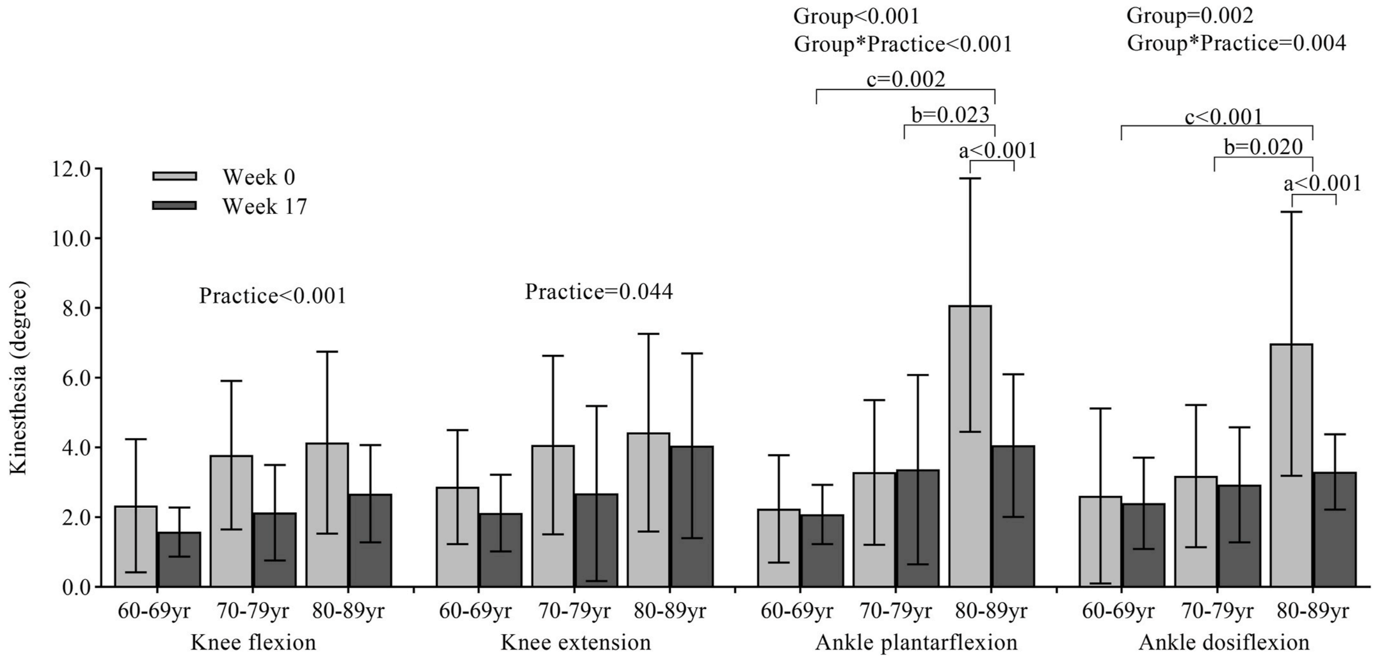

Fig. 4. Mean kinesthesia threshold for knee flexion (left panel), knee extension (middle-left panel), ankle plantarflexion (middle-right panel), and ankle dorsiflexion (right panel) are shown for each age group at weeks 0 and 17 (Practice). Error bars represent ±1 standard error. 60–69yr = participants aged 60–69 years, 70–79yr = participants aged 70–79 years, 80–89yr = participants aged 80–89 years. P-values representing significant differences for Group, Practice, Group* Practice, or a = from week 0 and week 17 in 80–89yr, b = between 70-79yr and 80–89yr, c = between 60-69yr and 80–89yr are provided.

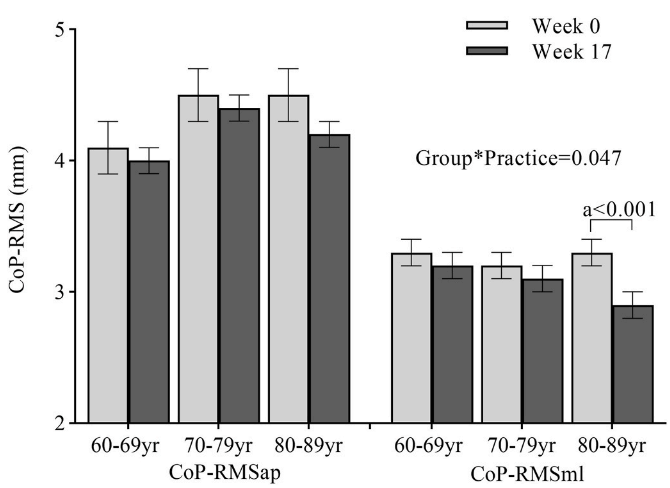

Fig. 5. Mean CoP-RMS (root mean square of the center of pressure) representing postural sway in anteroposterior (ap-left panel) and mediolateral (ml-right panel) directions are shown for each age group at weeks 0 and 17 (Practice). Error bars represent ±1 standard error. 60–69yr = participants aged 60–69 years, 70–79yr = participants aged 70–79 years, 80–89yr = participants aged 80–89 years. P-values representing significant differences for Group*-Practice or a = from week 0 to week 17 in 80–89yr are provided.

4. Discussion

The results indicated that 80–89yr was weaker, with less kinesthesia sensitivity, and worse static postural control than other groups. Tai Chi practice improved all participants' strength, tactile sensations, and kinesthesia. The most novel outcomes of the present study are that Tai Chi practice also produced superior effects on improving plantar tactile sensation in one-foot location, ankle kinesthesia, and CoP-RMS$_{ml}$ only in the 80–89yr, who had less ankle kinesthesia initially. We discuss how the results support previous research, how these novel results improve our understanding of peripheral lower limb sensorimotor control among older adults of different ages, and how Tai Chi may improve such control.

Compared with 70–79yr and 60–69yr, 80–89yr possessed less strength and worse ankle kinesthesia. The strength reduction among older adults agrees with previous reports that muscle strength declines progressively.[6] Explanations for less muscle strength in the 80–89yr likely accompany the loss of muscle mass and changes in the properties of muscle fibers with age.[26] The worse kinesthesia among older adults also agrees with previous work, in which older adults aged 75–90 years showed worse kinesthesia than younger counterparts.[8] Worse kinesthesia may relate to age-related morphological changes in the muscle spindle[27] and the structural modifications of the Golgi tendon organs.[11] However, there were no significant differences in tactile sensations and static postural control among the three age groups in the present study.

The study results indicated that Tai Chi improved strength, tactile sensation, and kinesthesia sensitivity among older adults. The improvement in strength through Tai Chi corresponds with results from previous studies.[13,28] Tai Chi involves practicing in a half-squat position with continuous movements, constantly shifting body weight from side to side. The knee flexions, squats, and other movements in Tai Chi require repeated concentric and eccentric contractions of the muscles surrounding the lower extremity,[29] which could improve lower extremity muscle strength. The improvement in tactile sensation through Tai Chi also matches results from a previous study.[14] Tai Chi might expand representation in the primary somatosensory cortex to amplify somatosensory information from the plantar mechanoreceptors.[30] The improved kinesthesia from Tai Chi matches the results from a meta-analysis.[31] Most Tai Chi movements are practiced in different directions and requiring various ankle movements,[32] which may enhance the function of mechanoreceptors located in the joint capsules, ligaments, tendons, and muscles to improve kinesthesia.[33] The improved postural control is in accordance with different systematic reviews that Tai Chi may be beneficial for improving postural control.[34,35] Practitioners were requested to shift their bodies in different directions, including forward, backward, sideways, and turning during Tai Chi.[36] The ability of older adults to control the shift of the center of mass was enhanced, reducing the oscillation range of CoP in mediolateral directions, thereby improving postural control for participants.

Sixteen weeks of Tai Chi practice for older adults over 80 revealed slightly greater improvements in tactile sensation than 60–69yr and 70–79yr (i.e., improvements in M5), which resemble those for older practitioners compared to younger practitioners.[37] Since Tai Chi may delay the structural and physiological deterioration of the somatosensory cortex with age,[38] it may also improve its cortical plasticity, which remains intact in older adults,[39] as tactile sensation strongly accompanies cortical plasticity in the primary somatosensory cortex.[37]

80–89yr improved ankle kinesthesia with Tai Chi practice more than 60–69yr and 70–79yr. The greater improvements likely resulted from worse pre-training kinesthesia perceptions than 60–69yr and 70–79yr. Support for this supposition comes from fewer relative numbers of large sensory neurons reported in cadaver ankles of older than younger counterparts.[8] That proprioceptive acuity decreased by 19.2% in older adults over 75 years compared to those aged 60–75 [8]. Muscle spindles, which contribute significantly to proprioception and kinesthesia,[40] undergo morphological and functional changes with age, like the increased fusiform bursa thickness and loss of total fibers within each fusiform,[41] which follow a decrease in sensory neuron innervation and associated alpha motor neuron denervation.[42] The greater age-related perception of position and movement declines associated with muscle spindle function explain the poorer ankle kinesthesia in 80–89yr compared to 60–69yr and 70–79yr. These findings offer insight into potential mechanisms underlying improvement.

The reduction in CoP-RMS_{ml} observed after Tai Chi practice in 80–89yr rather than 60–69yr and 70–79yr indicated that Tai Chi helped reduce standing mediolateral sway in 80–89yr. Maintenance of postural control requires interactions of orientation-related neural pathways from the somatosensory (proprioceptive, cutaneous) system.[43] Specifically, the sensory information from proprioceptive and cutaneous mechanoreceptors is transmitted to the central nervous system (CNS)[44] and used to detect changes in body position (kinesthesia) and contract specific muscles to restore balance.[45] Our data provided evidence that some strength impairments and kinesthetic sensory receptor deficits, observed in 80–89yr, can be remediated with Tai Chi practice. The improvements in kinesthesia and tactile sensations only observed in 80–89yr after practicing Tai Chi likely explained the improvements in postural sway observed for this group. Moreover, less sway, like that observed in the present study, may benefit participants in fall prevention as greater CoP-RMS_{ml} positively associations with future falls.[46]

Tai Chi practice may increase the efficiency of central regulation since evidence exists for its positive effects on CNS function and microstructure.[47] Tai Chi involves a somatosensory, attentional training exercise with meditative slow-motion components to sense the entire body.[37] Attentional training could explain the greater activation of various cortical areas in response to age-related somatosensory declines,[48] like those with poor kinesthesia, especially in the distal extremities.[12] The greater reliance on visual cues related to age-reduced somatosensory acuity used to maintain balance during an upright stance,[49] which improves with Tai Chi practice,[50] further supports the use of higher brain center activation with Tai Chi. However, greater reliance on visual cues also encourages greater attention on the environment (external focus) which encourages a more automated process of postural control, less attention on internal somatosensation, and less swaying.[51] The attentional training associated with Tai Chi can help people switch from an internal focus on somatosensation needed to perceive movement to an external focus on visual inputs to move less when needed. A physiologic complexity that arises from an affluent feedback loop network integrating subcortical, cortical, and peripheral motor circuitry to regulate posture control exists.[52] Although aging aggravates the decline of the physiologic complexity of the neuromuscular control system and coordination,[53] Tai Chi practice may improve physiologic complexity.[54]

All three groups can benefit from Tai Chi practice. However, 80-89y showed greater sensory improvements. Literature shows sensory loss is a more pronounced risk factor for this age group.[14] Therefore, the older people are, the more they benefit from Tai Chi practice; not only can they get stronger, but they also curb the loss of sensitivity that is detrimental later in life.

5. Limitations

We did not collect fall history data, which could help interpret the significance of the variable. The participants in this study represent community residents and caution is required in nursing homes. We did not have a control group. We did not measure gender differences since the sample size was not big enough to divide the participants into different gender groups. There was no follow-up with participants, so assessing long-term effects was impossible. Although our results met the normality standard for the mixed-model two-way ANOVA we used, more participants in each group could improve our confidence in the results.

6. Conclusion

People over 80 have less strength and worse kinesthesia than older adults between 60 and 80. Tai Chi practice increased strength, tactile sensation, kinesthesia, and static postural control, providing older adults over 80 with additional improvements in distal somatosensation that might reduce postural sway and potentially counteract some age-related declines. Tai Chi practice offers a safe exercise option for those aged over 80 to encourage improvements in sensorimotor control.

Authors' contributions

TZ designed the study and drafted the manuscript. LL was responsible for recruiting patients and collecting data. MM, WS, and QS analyzed data. LL, JH, MM, WS, and QS contributed to the manuscript content and revisions. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Funding information

This work was supported by the General Administration of Sport of China [grant number 23QN009]; the National Natural Science Foundation of China [grant number No.12102235]; the Natural Science Foundation of Shandong Province [grant number ZR2022MH163].

Data statement

The data presented in this study are available on request from the corresponding author.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors did not use AI.

Declaration of competing interest

The authors declare that they have no competing interests.

Acknowledgements

The authors would like to thank Xiao Gao, Hengshuo Zhang, Fang Liu, Xiu Hu, Xinrui Zhang, and Huifeng Zheng, graduate students at Shandong Sport University, for participating in this work's experiment and data acquisition.

References

1. Luigi F, Eleanor S, Ajoy K. Association between arterial stiffness and fatigability in well-functioning older adults. *Innov Aging*. 2021. Supplement_1.
2. Peng W, Mo C, Luo Y, Tang S, Liu M. Demographics moderated the association of symptom burden with falls and fall-related outcomes. *Arch Gerontol Geriatr*. 2024; 117, 105190.
3. Song Q, Zhang X, Mao M, et al. Relationship of proprioception, cutaneous sensitivity, and muscle strength with the balance control among older adults. *J Sport Health Sci*. 2021;10:585–593.
4. Muir SWKB, Chesworth Bert, Klar Neil, Speechley Mark. Balance impairment as a risk factor for falls in community-dwelling older adults who are high functioning: a prospective study. *Phys Ther*. 2010;90:338–347.
5. Li L, Zhang S, Dobson J. The contribution of small and large sensory afferents to postural control in patients with peripheral neuropathy. *J Sport Health Sci*. 2019;8: 218–227.
6. Boutin RD, Yao L, Canter RJ, Lenchik L. Sarcopenia: current concepts and imaging implications. *AJR Am J Roentgenol*. 2015;205:255–266.
7. Machado Á S, Bombach GD, Duysens J, Carpes FP. Differences in foot sensitivity and plantar pressure between young adults and elderly. *Arch Gerontol Geriatr*. 2016;63: 67–71.
8. Yang N, Waddington G, Adams R, Han J. Age-related changes in proprioception of the ankle complex across the lifespan. *J Sport Health Sci*. 2019;8:548–554.
9. Ambrose AF, Paul G, Hausdorff JM. Risk factors for falls among older adults: a review of the literature. *Maturitas*. 2013;75:51–61.
10. Wu R, Ditroilo M, Delahunt E, De Vito G. Age related changes in motor function (II). Decline in motor performance outcomes. *Int J Sports Med*. 2021;42:215–226.
11. García-Piqueras J, García-Mesa Y, Cárcaba L, et al. Ageing of the somatosensory system at the periphery: age-related changes in cutaneous mechanoreceptors. *J Anat*. 2019;234:839–852.
12. Shaffer SW, Harrison AL. Aging of the somatosensory system: a translational perspective. *Phys Ther*. 2007;87:193–207.
13. Xu DQ, Li JX, Hong Y. Effects of long term Tai Chi practice and jogging exercise on muscle strength and endurance in older people. *Br J Sports Med*. 2006;40:50–54.
14. Zhang T, Mao M, Sun W, Li L, Song Q. Effects of a 16-week Tai Chi intervention on cutaneous sensitivity and proprioception among older adults with and without sensory loss. *Res Sports Med*. 2021;29:1–11.
15. Zhang C, Sun W, Yu B, Song Q, Mao D. Effects of exercise on ankle proprioception in adult women during 16 weeks of training and eight weeks of detraining. *Res Sports Med*. 2015;23:102–113.
16. Tsang WWN, Hui-Chan CWY. Effects of tai chi on joint proprioception and stability limits in elderly subjects. *Med Sci Sports Exerc*. 2003;35:1962–1971.
17. Li JX, Xu DQ, Y H. Effects of 16-week Tai Chi intervention on postural stability and proprioception of knee and ankle in older people. *Age Ageing*. 2008;37:575–578.
18. *WHO. Falls. WHO*; 2021. https://www.who.int/news-room/fact-sheets/detail/falls.
19. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? *Lancet*. 2012;380: 258–271.
20. Welfare AioHa. *Australia's Health*; 2014. http://www.aihw.gov.au/australias-health/, *23 Oct 2014*). 2014.
21. Gonosova Z, Linduska P, Bizovska L, Svoboda Z. *Reliability of Ankle‑Foot Complex Isokinetic Strength Assessment Using the Isomed 2000 Dynamometer*. vol. 54. 2018. Medicina.
22. Collins S, Visscher P, De Vet HC, Zuurmond WW, Perez RS. Reliability of the Semmes Weinstein Monofilaments to measure coetaneous sensibility in the feet of healthy subjects. *Disabil Rehabil*. 2010;32:2019–2027.
23. Sun W, Song Q, Yu B, Zhang C, Mao D. Test-retest reliability of a new device for assessing ankle joint threshold to detect passive movement in healthy adults. *J Sports Sci*. 2015;33:1667–1674.
24. Meshkati Z, Namazizadeh M, Salavati M, Mazaheri M. Reliability of force-platform measures of postural sway and expertise-related differences. *J Sport Rehabil*. 2011; 20:442–456.
25. Statistical power analysis for the behavioral sciences. *Comput Environ Urban Syst*. 1990;14:71.
26. D'Antona G, Pellegrino MA, Adami R, et al. The effect of ageing and immobilization on structure and function of human skeletal muscle fibres. *J Physiol*. 2003;552: 499–511.
27. Liu JX, Eriksson PO, Thornell LE, Pedrosa-Domellöf F. Fiber content and myosin heavy chain composition of muscle spindles in aged human biceps brachii. *J Histochem Cytochem*. 2005;53:445–454.
28. Yang Y, Li JH, Xu NJ, Yang WY, Liu J. Meta-analysis of elderly lower body strength: different effects of tai chi exercise on the knee joint-related muscle groups. *Evid Based Complement Alternat Med*. 2021;2021, 8628182.
29. Lu X, Hui-Chan CW, Tsang WW. Effects of Tai Chi training on arterial compliance and muscle strength in female seniors: a randomized clinical trial. *Eur J Prev Cardiol*. 2013;20:238–245.
30. Liranisilva E, Vitório R, Barbieri FA, Orciolisilva D, Simieli L, Gobbi LTB. Continuous use of textured insole improve plantar sensation and stride length of people with Parkinson's disease: a pilot study. *Gait Posture*. 2017;58:495–497.
31. Zou L, Han J, Li C, Yeung AS, Hui SS. Effects of tai chi on lower limb proprioception in adults aged over 55: a systematic review and meta-analysis. *Arch Phys Med Rehabil*. 2019;100:1102–1113.
32. Xian LJ, Qing XD, Youlian H. Effects of 16-week Tai Chi intervention on postural stability and proprioception of knee and ankle in older people. *Age Ageing*. 2008;37: 575–578.
33. Xu D. Effect of tai chi exercise on proprioception of ankle and knee joints in old people. *Br J Sports Med*. 2004;38:50–54.
34. Zhong D, Xiao Q, Xiao X, et al. Tai Chi for improving balance and reducing falls: an overview of 14 systematic reviews. *Ann Phys Rehabil Med*. 2020;63:505–517.
35. Wang LC, Ye MZ, Xiong J, Wang XQ, Wu JW, Zheng GH. Optimal exercise parameters of tai chi for balance performance in older adults: a meta-analysis. *J Am Geriatr Soc*. 2021;69:2000–2010.
36. Lan C, Lai JS, Chen SY, Wong MK. Tai Chi Chuan to improve muscular strength and endurance in elderly individuals: a pilot study. *Arch Phys Med Rehabil*. 2000;81: 604–607.
37. Kerr CE, Shaw JR, Wasserman RH, et al. Tactile acuity in experienced Tai Chi practitioners: evidence for use dependent plasticity as an effect of sensory-attentional training. *Exp Brain Res*. 2008;188:317–322.
38. Hagiwara K, Ogata K, Okamoto T, et al. Age-related changes across the primary and secondary somatosensory areas: an analysis of neuromagnetic oscillatory activities. *Clin Neurophysiol*. 2014;125:1021–1029.
39. Muiños M, Palmero F, Ballesteros S. Peripheral vision, perceptual asymmetries and visuospatial attention in young, young-old and oldest-old adults. *Exp Gerontol*. 2016; 75:30–36.
40. Proske U, Gandevia SC. The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. *Physiol Rev*. 2012;92: 1651–1697.
41. Henry M, Baudry S. Age-related changes in leg proprioception: implications for postural control. *J Neurophysiol*. 2019;122:525–538.
42. Coletti C, Acosta GF, Keslacy S, Coletti D. Exercise-mediated reinnervation of skeletal muscle in elderly people: an update. *Eur J Transl Myol*. 2022;32, 10416.
43. Oku K, Kawahara I, Sugioka T, et al. Immediate effects of plantar vibration stimuli during static upright posture following total hip arthroplasty in females. *Somatosens Mot Res*. 2020;37:238–244.
44. Pasma JH, Engelhart D, Schouten AC, van der Kooij H, Maier AB, Meskers CG. Impaired standing balance: the clinical need for closing the loop. *Neurosci*. 2014; 267:157–165.
45. Sultan N, Najam Ul Islam M, Mughal AM. Nonlinear postural control paradigm for larger perturbations in the presence of neural delays. *Biol Cybern*. 2021;115: 397–414.
46. Piirtola M, Era P. Force platform measurements as predictors of falls among older people - a review. *Gerontol*. 2006;52:1–16.
47. Yao J, Song Q, Zhang K, et al. The effect of Tai Chi practice on brain white matter structure: a diffusion tensor magnetic resonance imaging study. *Res Sports Med*. 2019;27:121–130.
48. Lenhart L, Steiger R, Waibel M, et al. Cortical reorganization processes in meditation naïve participants induced by 7 weeks focused attention meditation training. *Behav Brain Res*. 2020;395, 112828.
49. Balestrucci P, Daprati E, Lacquaniti F, Maffei V. Effects of visual motion consistent or inconsistent with gravity on postural sway. *Exp Brain Res*. 2017;235:1999–2010.
50. Song Q, Wang S, Wong DP, et al. Long-term Tai Chi exercise increases body stability of the elderly during stair ascent under high and low illumination. *Sports BioMech*. 2018;17:402–413.
51. Wulf G, Mercer J, McNevin N, Guadagnoli MA. Reciprocal influences of attentional focus on postural and suprapostural task performance. *J Mot Behav*. 2004;36: 189–199.
52. Manor B, Lipsitz LA, Wayne PM, Peng CK, Li L. Complexity-based measures inform Tai Chi's impact on standing postural control in older adults with peripheral neuropathy. *BMC Complement Altern Med*. 2013;13:87.
53. Manor B, Lipsitz LA. Physiologic complexity and aging: implications for physical function and rehabilitation. *Prog Neuro-Psychopharmacol Biol Psychiatry*. 2013;45: 287–293.
54. Tang H, Pan J, Li L. Tai chi improves postural coordination during precision fitting task among elderlies. *Med Sci Sports Exerc*. 2022;54:611–612.