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Validity of Clinically Derived Cumulative Somatosensory Impairment Index

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Abstract

Objective—To develop a Cumulative Somatosensory Impairment Index for the lower limbs and evaluate its construct validity for discriminating relevant groups and predictive validity for predicting global postural control over time.

Design—Prospective cohort study.

Setting—Population-based cohort.

Participants—InCHIANTI (“Invecchiare in Chianti” or aging in the Chianti area) study participants (N=960; age, 21–91y, 51.8% women).

Interventions—Not applicable.

Main Outcome Measures—The Cumulative Somatosensory Impairment Index was derived from baseline performance on clinical tests of pressure sensitivity, vibration sensitivity, proprioception, and graphesthesia. Global postural control was assessed using Frailty and Injuries Cooperative Studies of Intervention Techniques (FICSIT) balance test, time to complete 5 repeated chair stands, and fast walking speed, at baseline and at 3-year follow-up.

Results—In participants without neurologic conditions (n=799), the Cumulative Somatosensory Impairment Index was significantly different in age groups classified by decades ($P<.001$). Compared with participants without prevalent conditions, the Cumulative Somatosensory Impairment Index was significantly higher in persons with diabetes ($P=.017$), peripheral arterial disease ($P=.006$), and a history of stroke ($P<.001$). In the overall population (N=960), in the fully adjusted multiple regression models, the Cumulative Somato-sensory Impairment Index independently predicted deterioration in FICSIT scores ($P=.002$), time for 5 repeated chair stands ($P<.001$), and fast gait speed ($P=.003$) at 3-year follow-up.

Conclusions—The Cumulative Somatosensory Impairment Index is a valid measure that detects relevant group differences in lower limb somatosensory impairment and is an independent predictor of decline in postural control over 3 years.

Keywords

Aging; Rehabilitation

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RESEARCH STUDIES HAVE independently shown that information from isolated somatosensory modalities from the lower limbs is critical for postural control.¹⁻³ Experimental work has shown that even a partial loss of foot cutaneous information not only results in increased postural sway during standing⁴ but also leads to slowing of gait speed⁵ and maladaptive postural changes during termination of gait.⁶ Further, studies involving patients with peripheral neuropathy suggest that a deficit in ankle proprioception is a primary contributor to their balance problems,⁷ and it explains more than 50% of the variance in performance on the timed standing test.⁸ Similarly, the role of foot vibrotactile sensitivity in stepping recovery response for regaining stability after perturbation during standing has been demonstrated.⁹ Overall, it is evident that information from multiple somatosensory modalities from lower limbs can contribute significantly to postural control.

Recent evidence demonstrates that different somatosensory modalities show minimal agreement in impairment within the same body areas.¹⁰⁻¹² Therefore, testing any one modality may not be sufficient to obtain a complete clinical picture of somatosensory deficits. Furthermore, because information from multiple somatosensory inputs is integrated for maintaining postural control,¹⁻⁹ it is suggested that there is a possibility of redundancy.⁷ Thus, it is apparent that overall somatosensory deficit, rather than a deficit on an individual modality, should be taken into consideration while examining the relation between somatosensory function and postural control.

A comprehensive somatosensory assessment is a part of a routine clinical neurologic examination. However, the utility of clinically derived lower limb somatosensory information for independently predicting postural control is not known. Therefore, the 3 objectives of this study were (1) to develop a Cumulative Somatosensory Impairment Index for the lower limbs from clinical assessment; (2) to evaluate the discriminant validity of the Cumulative Somatosensory Impairment Index by its ability to differentiate groups defined by age (in persons without prevalent neurologic conditions) and pathologic disorder (diabetes without overt peripheral neuropathy, PAD, and history of stroke); and (3) to examine predictive validity of the Cumulative Somatosensory Impairment Index by its ability to predict a decline in standing or dynamic balance performance over 3 years.

METHODS

Participants

The InCHIANTI (“Invecchiare in Chianti” or aging in the Chianti area) Study is an epidemiologic study conducted to understand factors contributing to the decline in mobility in late life. The study population is a representative sample of the population living in 2 towns of the Chianti countryside of Tuscany, Italy. The study design and data collection have been described previously elsewhere.¹³ In 1998, of the 1453 adults who participated, 1317 completed the clinical examination session at baseline. From those who completed lower limb somatosensory testing (n=1209), only cognitively intact (Mini-Mental State Examination score ≥ 24)¹⁴ participants were included in the present study to minimize errors in responses (N=960). Persons with diabetes were identified by a fasting blood glucose level of 126mg/dL or greater.¹⁵ PAD was diagnosed from the Rose criteria.¹⁶ First, participants were asked if they had pain in their calf/calves while walking. If the answer was affirmative, they were asked if the pain was relieved within 15 minutes by standing or sitting. PAD was recorded if the answer to this question was affirmative and if it was not accompanied by nighttime leg/foot pain. The history of stroke was recorded from participants’ self-report and medical records. Follow-up data were collected after 3 years. The study protocol was approved by the ethical committee of the Italian National Institute of Research and Care of Aging and complies with the Declaration of Helsinki. All participants received a detailed description of the study purpose and procedures, and all signed the informed consent.

Outcome Measures

Cumulative Somatosensory Impairment Index—The Cumulative Somatosensory Impairment Index was derived at the baseline. Participants assumed a supine position with their eyes closed. The Cumulative Somatosensory Impairment Index for the lower limbs was derived from clinical tests of pressure and vibration sensitivity, ankle proprioception, and graphesthesia. Pressure sensitivity was tested using 4.31 and 4.56 Semmes-Weinstein monofilaments applied to the skin of the external malleolus. The 4.31 Semmes-Weinstein monofilament provides 2.04g of force, and the 4.56 monofilament provides 3.63g of force. The monofilament testing was not performed on the sole of the foot because in older persons, callus formation may prevent testing or may result in an incorrect assessment. Therefore, particularly in older persons, clinical protocols have recommended monofilament testing on the external malleolus.¹⁷ Each filament was applied twice, and the sensitivity for that filament was considered absent if it was not sensed on at least one trial. Pressure sensitivity was recorded as follows: 0, normal (both filaments sensed); 1, reduced (only 4.56 filament sensed); and 2, absent (neither filament sensed). For testing proprioception, the examiner positioned the reference ankle randomly at 10° dorsiflexion and 20° plantar flexion, from the neutral position. The participant was asked to place the test ankle in the same position. The proprioception was considered absent if in both positions the error of the tested ankle was greater than 5° of the reference ankle. It was considered reduced if this error occurred only for 1 of the 2 positions. Proprioception was rated as follows: 0, normal; 1, reduced; and 2, absent. The vibratory stimulus was created with a 128-Hz diaphon on the bony prominence of the first metatarsal bone. The participants were asked to report if they perceived the vibration. If the vibration was perceived, they were asked to indicate when they no longer perceived the vibration. Vibration sensitivity was graded as follows: 0, normal (≥ 10 s); 1, reduced (1–9s); and 2, absent. Graphesthesia was evaluated by asking participants to recognize 3 simple symbols (line, circle, plus sign) that were drawn on their sole. Graphesthesia was rated as follows: 0, normal (all 3 correct); 1, reduced (1 error); and 2, absent (≥ 2 errors). All tests were performed bilaterally, and worse scores of the 2 lower limbs were considered in the Cumulative Somatosensory Impairment Index. Total Cumulative Somatosensory Impairment Index scores ranged from 0 to 8, with 8 being the worst. This cluster of 4 somatosensory tests was chosen in the InCHIANTI study for 2 reasons. First, they represent or encompass all the aspects of somatosensory function such as exteroception, proprioception, and hemispheric or cortical sensation. Second, these noninvasive tests are commonly performed during neurologic clinical assessment.

Global postural control—Balance and postural control underlie every mobility function. Therefore, balance and postural control are imperative for efficient and timely performance of any mobility function.¹⁸ Global postural control is assessed by grading an overall output—for example, gait speed during walking or time to complete a certain task—rather than some specific measures such as step width or step length analysis, center of mass analysis, or center of pressure analysis. Three protocols were used to determine global postural control at baseline and at 3-year follow-up.

Frailty and Injuries Cooperative Studies of Intervention Techniques balance test.¹⁹—Participants were asked to maintain balance for 10 seconds in a series of positions characterized by progressive reduction of the base of support in the frontal plane. The performance was rated from the most difficult position that the participant was able to maintain for at least 2 seconds (score range, 0–24, higher score denotes better performance (appendix 1)).

Time to complete 5 repeated chair stands—Participants were asked to stand up from a sitting position 5 times consecutively without using support through upper extremities and/or an assistive device. Time to complete the task was recorded.

Fast walking speed—From a standing position participants were asked to walk a distance of 7m at their fastest possible speed. The total time to complete the walking task was measured and was converted to gait speed (m/s).

These 3 postural control tests were specifically chosen because they represent 3 different mechanisms of postural control. During standing, the center of gravity is maintained within a constant base of support defined by the feet.²⁰ Therefore, the standing balance test of FICSIT was included to represent static or standing postural control. During sit to stand, the base of support drastically changes from a large base of support provided by the area delineated by the buttocks and the feet to a very small base of support defined by the feet only. In addition, the center of mass needs to be controlled within this changing base of support against its acceleration, initially in the forward direction and then immediately in the vertical direction.²¹ During walking, except for the double-support phase (ie, when both feet are on the ground), the center of gravity is not within the base of support (provided by the foot that is on the ground), but it must be maintained at the manageable distance on the medial side of the supporting foot (ie, the foot that is on the ground).²² Overall, the base of support is constantly changing during walking, and the center of gravity must be manipulated with respect to the rhythm of “double support–single support.” During fast walking, the duration of the double-support phase decreases even further, thus further increasing the challenge to balance and postural control. Sit to stand and fast walking tests were included to represent 2 different mechanisms of postural control during the changing base of support, what is also called dynamic postural control.²⁰

Covariates

Potential confounding factors were included as covariates. These comprised knee extensor strength, visual acuity,²³ contrast sensitivity,²⁴ depression,²⁵ cognition,¹⁴ and demographic parameters of age, weight, height at baseline, and sex.

Knee extensor strength was measured with a hand-held dynamometer.^{26, a} The participant was asked to assume a lateral decubitus position. The dynamometer was placed on the anterior surface of the leg 10cm above the proximal margin of the external malleolus. The measurement was repeated 3 times, and the maximum value was noted.

Visual acuity was tested using a standard Snellen eye chart that was placed at a distance of 3m.²³ Visual acuity scores of 0/0 to 11/10 were graded from 0 to 11. A standard Pelli-Robson chart²⁴ test was used to measure contrast sensitivity. The last correctly identified letter was noted, and the associated log contrast sensitivity was recorded. The vision testing was completed using binocular vision with the participant's usual corrective lenses.

The Center for Epidemiological Studies Depression Scale, a 20-item self-report questionnaire, was used to assess depression.²⁵ Scores can range from 0 to 60, with higher scores indicating more depressive symptoms. Cognitive function was evaluated by the Mini-Mental State Examination (range, 0–30; higher scores indicate better cognitive functioning).¹⁴ A score below 24 points is used to indicate impaired cognitive function.

^aNicholas Manual Muscle Tester, model BK-5474; Fred Sammons, 145 Tower Dr, Burr Ridge, IL 60521.

Descriptive Variable

The number of falls in the previous years was recorded at baseline only for the purpose of describing the population.

Statistical Analysis

Variables not normally distributed were log-transformed for analyses (Cumulative Somatosensory Impairment Index, Center for Epidemiological Studies Depression Scale, Mini-Mental State Examination, Snellen chart scores). Peripheral sensory functions are known to deteriorate with increasing age. Therefore, we expected the Cumulative Somatosensory Impairment Index scores to differ by age groups. Thus, with the use of analysis of variance, the discriminant validity of the Cumulative Somatosensory Impairment Index was determined by its ability to discriminate age groups (by decades) in participants without prevalent neurologic conditions (n=799). The age- and sex-adjusted analyses of covariance separately examined Cumulative Somatosensory Impairment Index differences between the participants with diabetes without overt diabetic neuropathy, PAD, or a history of stroke, and those without prevalent neurologic conditions.

Although it is known that somatosensory information from multiple modalities is integrated for both standing and dynamic postural control, the ability of the somatosensory information to predict either standing or dynamic postural control over time has not been tested. Therefore, multiple linear regression analyses were performed to determine the predictive ability of the Cumulative Somatosensory Impairment Index. Follow-up scores of FICSIT, repeated chair stand, and fast gait speed were separately regressed on Cumulative Somatosensory Impairment Index scores of the baseline session, adjusting for respective performance at baseline and potential confounders. Statistical analyses were conducted using SPSS.^b A *P* value less than .050 was considered statistically significant. Data are presented as mean $\pm$ SD, unless mentioned otherwise.

RESULTS

The study population comprised 960 participants (age 21–91y, 51.8% women). Table 1 describes the study population according to Cumulative Somatosensory Impairment Index quartiles. The participants in higher quartiles were older and slightly shorter. A significantly higher number of persons in higher quartiles had diabetes, PAD, and a history of stroke and at least 2 falls in the previous year. Those in higher quartiles also performed worse on FICSIT, 5 repeated chair stands, and the fast walking test (see table 1).

Of the 960 participants, 799 (age 21–91y, 53.8% women) were without prevalent conditions that included diabetes (n=66), Parkinson's disease (n=7), PAD (n=70), stroke (n=31), and neuropathies of any origin (n=4). Their Cumulative Somatosensory Impairment Index ranged from 0 to 8 (mean $\pm$ SD, 1.7 $\pm$ 1.5). The distribution of the 960 participants by age group was as follows: In the age group 30 to 39 years (n=64), there was 1 person with diabetes and 1 person with PAD. In the age group 40 to 49 years (n=50), there was 1 person with diabetes and 2 persons with PAD. In the age group 50 to 59 years (n=65), 3 persons had diabetes, 3 had PAD, and 2 had a history of stroke. The age group 60 to 69 years (n=295) had 17 persons with diabetes, 19 with PAD, 5 with a history of stroke, and 3 with Parkinson's disease. The age group 70 to 79 (n=347) had 36 persons with diabetes, 32 with PAD, 18 with a history of stroke, and 3 with Parkinson's disease. In the age group 80 to 89 years (n=78), 6 persons had diabetes, 13 had PAD, 5 had a history of stroke, and 1 person had Parkinson's disease. In those 90 years or older (n=10), 2 persons had diabetes and 1

^bVersion 15.0; SPSS Inc, 233 S Wacker Drive, 11th Fl, Chicago, IL 60606.

person had a history of stroke. Participants younger than 30 years ($n=51$) did not report any of these pathologic disorders.

Cross-Sectional Analysis

The Cumulative Somatosensory Impairment Index was significantly different in age groups classified by decades ($F=82.031$, $P<.001$). Post hoc analysis showed that the Cumulative Somatosensory Impairment Index was significantly higher for every decade after the fifth decade (fig 1). Adjusting for age and sex, compared with participants without prevalent conditions ($n=799$), the Cumulative Somatosensory Impairment Index was significantly higher in persons with diabetes (mean $\pm$ SD, 2.7 ± 1.5 ; $F=5.759$, $P=.017$) and in persons with PAD (mean $\pm$ SD, 2.8 ± 1.7 ; $F=6.928$, $P=.006$) and stroke (mean $\pm$ SD, 3.4 ± 1.5 ; $F=13.720$, $P<.001$).

Longitudinal Analysis

The attrition rate at follow-up was 19.9%. The participants who did not attend follow-up were older ($P<.001$), had a worse Cumulative Somatosensory Impairment Index at baseline ($P<.001$), and also performed worse in FICSIT ($P<.001$), repeated chair stand test ($P<.001$), and fast walking test ($P=.026$) at baseline. The data of the participants who attended the follow-up session were included in the longitudinal analysis. Results of a paired sample t test showed that the performance on all 3 postural control tests declined at the follow-up ($P<.001$ for all 3 tests). In multiple regression analysis, the Cumulative Somatosensory Impairment Index independently predicted deterioration in FICSIT balance scores ($\beta \pm$ SE, $-1.380\pm.441$; $P=.002$), time for 5 repeated chair stands ($\beta \pm$ SE, $2.754\pm.581$; $P<.001$), and fast walking speed ($\beta \pm$ SE, $-.129\pm.044$; $P=.003$) at 3-year follow-up even after adjusting for baseline performance and multiple other potential confounders (table 2). These models explained 45%, 44%, and 61% variance in the performance at the 3-year follow-up in FICSIT, repeated chair stand, and fast walking speed, respectively (fig 2). Average Cumulative Somatosensory Impairment Index scores according to quintiles of performance on each postural control task at the 3-year follow-up are demonstrated in figure 3.

DISCUSSION

Our results demonstrate that the Cumulative Somatosensory Impairment Index can detect differences between age groups delineated by decades, and show a consistent increase in the Cumulative Somatosensory Impairment Index particularly after the fifth decade even in persons without neurologic conditions. To our knowledge, this is the first study to demonstrate the validity of clinically derived cumulative information about somatosensory impairment for detecting age-related differences. These results indicate that identifying age-appropriate baseline for interpreting clinically derived somatosensory information may be necessary. After adjusting for age and sex, Cumulative Somatosensory Impairment Index scores were also significantly higher in persons with diabetes without overt neuropathy or PAD, or in those with a history of stroke, further supporting the discriminant validity of the Cumulative Somato-sensory Impairment Index.

The role of independent somatosensory modalities in postural control has been extensively investigated in research environments by using animal as well as human models.¹⁻⁹ The longitudinal analysis demonstrated that the Cumulative Somatosensory Impairment Index can predict deterioration in global postural control in static as well as in dynamic tasks, independent of baseline performance and multiple potential confounders, supporting the predictive validity of this clinically derived index. Furthermore, even after including multiple confounding variables, the standardized beta values demonstrate that the relative weighting of the Cumulative Somatosensory Impairment Index in predicting the global

postural control in all 3 tasks is one of the highest. Preliminary results of binary logistic regression analysis that was adjusted for multiple confounders suggested that those with a Cumulative Somatosensory Impairment Index score greater than 3 are twice as likely to report more than 2 falls in the previous year and almost 4 times more likely to report mobility disability. Similarly, those with a Cumulative Somatosensory Impairment Index score greater than 3 are more than 2 times as likely to report incident mobility disability after 3 years (data not reported). These findings suggest that the record on this scale can be particularly critical in older populations that are at risk for balance problems or mobility disability.

The Cumulative Somatosensory Impairment Index targets multiple facets of the lower limb somatosensory functions, including exteroception, proprioception, and cortical sensation, that may be relevant for postural control. Therefore, the utility of the Cumulative Somatosensory Impairment Index in the older population could be beyond available sensory scales that have been primarily developed for specific pathologic disorders. Scales designed for peripheral neuropathy (eg, Neuropathy Impairment Scale²⁷ and the Utah Early Neuropathy Scale²⁸) or those designed for central nervous system manifestations such as stroke (eg, Rivermead Assessment of Somato-sensory Performance²⁹ and Nottingham Sensory Assessment³⁰) only partially assess somatosensory function relevant for postural control. For example, the Rivermead Assessment of Somatosensory Performance²⁹ and the Nottingham Sensory Assessment³⁰ lack assessment of vibration sensitivity, which has been shown to be strongly associated with postural control during challenging tasks.^{3,9} However, direct comparison with these established tests could not be performed because these tests were not included in the assessment repertoire of InCHIANTI.

The advantage of the Cumulative Somatosensory Impairment Index is that the tests used in the Cumulative Somato-sensory Impairment Index are established clinical tests that are routinely performed by clinicians. Clinicians will only be required to maintain a systematic grading record of the performance on these tests that will allow them to derive the Cumulative Somatosensory Impairment Index. The limitation of the study is that the reliability of the Cumulative Somatosensory Impairment Index was not tested directly in this study. However, the individual tests that comprised the Cumulative Somatosensory Impairment Index have been extensively tested for their reliability and are widely used in clinical settings.³¹⁻³³

Available evidence suggests that age- or disease-related impairment in different somatosensory modalities does not occur in parallel.¹⁰⁻¹² When probed further, the performance on the 4 clinical tests used in this study showed minimal correlation (Spearman $\rho = .189-.212$), supporting the suggestion that these modalities are independent of each other and all should be assessed.

CONCLUSIONS

The Cumulative Somatosensory Impairment Index is a valid measure that detects relevant group differences in deterioration of lower limb somatosensory function even in persons without specific pathologic disorders. These results suggest that identifying age-appropriate baseline for interpreting clinically derived somatosensory information may be necessary. Fully adjusted regression models showed that the Cumulative Somatosensory Impairment Index is one of the strongest independent predictors of decline in standing and dynamic postural control over time. Our findings emphasize the importance of a systematic record of a comprehensive clinical somatosensory examination, particularly in older persons. The findings suggest that the Cumulative Somatosensory Impairment Index could be quite useful in the assessment of older persons who are at risk for balance and mobility problems.

Further studies in epidemiology and clinical populations should be done to confirm these findings.

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APPENDIX 1: FRAILITY AND INJURIES CO-OPERATIVE STUDIES OF INTERVENTION TECHNIQUES BALANCE TEST

The participant was asked to maintain an erect standing position for 10s in a series of positions characterized by progressive reduction of the base of support in the frontal plane.

The series of foot positions was as follows:

ASIS: Feet were placed under the respective anterior superior iliac spine; Free Base: If participants were unable to maintain ASIS position for more than 1s, they were asked to choose their comfortable feet position; SBS: Feet together; SemiTandem: Heel of one foot touching the base of the big toe of the other foot; Tandem: Heel of one foot touching the tip of the big toe of the other foot; One Leg: Standing on one leg only.

The standing balance performance was scored as follows:

- 0, ASIS <1s
- 2, ASIS 2–9s, Free Base 2–9s
- 3, ASIS 2–9s, Free Base 10s with sway
- 5, ASIS 10s with sway
- 6, ASIS 10s still
- 9, SBS 2–9s, ASIS 2–9s, Free Base 2–9s
- 12, SBS 2–9s, ASIS 10s with sway
- 13, SBS 2–9s, ASIS 10s still
- 14, SBS 10s with sway, SemiTandem <1s
- 15, SBS 10s still, SemiTandem <1s
- 16, SemiTandem 2–9s
- 17, SemiTandem 10s with sway, Tandem <1s
- 18, SemiTandem 10s still, Tandem <1s
- 19, Tandem 2–9s
- 20, Tandem 10s with sway, One Leg <1s
- 21, Tandem 10s still, One Leg <1s
- 22, One Leg 2–9s
- 23, One Leg 10s with sway
- 24, One Leg 10s still

List of Abbreviations

FICSIT	Frailty and Injuries Cooperative Studies of Intervention Techniques
PAD	peripheral arterial disease

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Fig 1.

The graph denotes mean (95% confidence interval) Cumulative Somatosensory Impairment Index score of each age group (by decade) for cognitively intact participants. Participants with prevalent conditions that may impact peripheral neural function (eg, diabetes mellitus, peripheral arterial disease, stroke, Parkinson's disease, neuropathy) were excluded from this analysis (n=799). Cumulative Somatosensory Impairment Index was significantly higher for each decade after the fifth decade. The group-wise distribution of participants was as follows: >30y, 50; 30–39y, 60; 40–49y, 47; 50–59y, 58; 60–69y, 252; 70–79y, 270; 80–89y, 55; and >90y, 7. Abbreviation: CSII, Cumulative Somatosensory Impairment Index.

Fig 2.

The scatterplots demonstrate the relation between performance on the postural control task at 3-year follow-up and regression standardized predicted values obtained from fully adjusted models. (A) FICSIT scores. (B) Repeated chair stand time. (C) Fast walking speed.

Fig 3.

The bar graphs demonstrate average Cumulative Somato-sensory Impairment Index (standard error of the mean [SEM]) scores at baseline for quintiles of the performance on the postural control tasks at 3-year follow-up. (A) FICSIT scores. (B) Repeated chair stand time. (C) Fast walking speed. Abbreviation: CSII, Cumulative Somatosensory Impairment Index.

Table 1
Participant Characteristics According to Cumulative Somatosensory Impairment Index Quartiles (N=960)

Variable	1st	2nd	3rd	4th	F or χ^2	P
Age (y)	46.9±17.1	64.6±12.3	69.6±8.9	73.7±7.1	250.626	<.001
Sex (women)	24.9	20.7	24.1	30.3	0.671	.880
Height (cm)	165.2±9.1	161.8±9.5	161.0±9.9	159.3±9.1	17.392	<.001
Weight (kg)	71.1±13.2	70.2±12.7	72.2±13.1	70.1±12.3	1.388	.245
Diabetes	7.6	18.2	24.2	50.0	16.215	<.001
PAD	8.6	12.9	28.6	49.9	19.118	<.001
History of stroke	3.2	12.9	9.7	74.2	28.343	<.001
History of >2 falls	7.4	14.8	27.8	50.0	14.528	.002
FICSIT	23.3±1.3	22.4±2.1	22.0±2.0	20.8±3.5	43.561	<.001
Five repeated chair stand (s)	9.1±2.4	9.8±2.5	10.7±3.8	11.4±4.6	18.843	<.001
Fast-walking speed (m/s)	1.75±.31	1.60±.32	1.51±.36	1.40±.35	44.733	<.001

NOTE. Values are mean ± SD, percentages, or as otherwise indicated. 1st quartile: CSII=0; 2nd quartile: CSII=1; 3rd quartile: CSII=2; 4th quartile: CSII≥3.
Abbreviation: CSII, Cumulative Somatosensory Impairment Index quartiles.

Table 2
Results of Multiple Linear Regression Analyses Demonstrating Predictive Validity of Cumulative Somatosensory Impairment Index

Variables	FICSIT				Repeated Chair Stands				Fast Walking Speed			
	B ± SE	Std β	t	P	B ± SE	Std β	t	P	B ± SE	Std β	t	P
CSII	−1.380±.441	−.115	−3.132	.002	2.754±.581	.185	4.738	.000	−.129±.044	−.098	−2.936	.003
Age	−.021±.009	−.105	−2.409	.016	.024±.012	.097	2.041	.042	−.003±.001	−.121	−3.012	.003
Sex	.360±.247	.058	1.457	.146	1.283±.333	.169	3.854	.000	−.041±.025	−.062	−1.639	.102
Weight (kg)	.000±.009	.001	.019	.985	.013±.012	.041	1.090	.276	−.001±.001	−.023	−.689	.491
Height (cm)	.002±.015	.005	.110	.913	.006±.020	.015	.309	.757	.002±.001	.062	1.483	.139
Maximum knee extension (kg)	.054±.018	.116	3.037	.002	.039±.024	.069	1.611	.108	.004±.002	.087	2.292	.022
Cognition	1.878±3.353	.018	.563	.573	2.158±4.436	.016	.486	.627	.112±.336	.010	.332	.740
Depression	−.015±.011	−.039	−1.330	.184	.008±.015	.017	.541	.589	.000±.001	−.005	−.169	.865
Visual acuity	.242±1.089	.007	.222	.824	1.714±1.507	.039	1.138	.256	.009±.111	.002	.085	.932
Contrast sensitivity	.482±1.091	.014	.442	.658	−3.928±1.669	−.083	−2.354	.019	.162±.118	.041	1.375	.169
Baseline performance	.645±.041	.501	15.852	.000	.690±.050	.479	13.760	.000	.478±.035	.494	13.774	.000
(Constant)	3.712±5.761	NA	.644	.520	−2.026±7.644	NA	−.265	.791	.206±.571	NA	.361	.718

NOTE. CSII independently predicted global postural control over 3 years, in standing as well as during dynamic tasks, even after controlling for multiple confounding variables (N=960). Abbreviations: Cognition, Mini-Mental State Examination (log10 transformed); Contrast sensitivity, Pelli-Robson chart score; CSII, Cumulative Somatosensory Impairment Index (log10 transformed); Depression, Center for Epidemiological Studies Depression Scale (log10 transformed); NA, not applicable; Std, standard; Visual acuity, Snellen chart score (log10 transformed).