THE NEXT FRONTIER IN RISK FACTORS FOR FALLS IN THE OLDER POPULATION: 
Design and Methods of the MOBILIZE Boston Study

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ABSTRACT

Background

Falls are the sixth leading cause of death and primary cause of traumatic injury in elderly people in the U.S., accounting for nearly $20 billion in annual health care costs. Despite progress in understanding risk factors for falls in older persons, many suspected risk factors have not been adequately studied. Putative risk factors for falls such as pain, reductions in cerebral blood flow, somatosensory deficits, and foot disorders are poorly understood in part because they pose measurement challenges, particularly for large observational studies.

Methods

The MOBILIZE Boston Study (MBS), an NIA-funded Program Project, is being conducted to examine a unique set of risk factors for falls in seniors residing in the Boston area. Using a door-to-door population-based recruitment strategy, we have enrolled more than 750 persons aged 70 and older to participate in a longitudinal study of falls. The baseline assessment, nearly completed, was conducted in 2 segments: a 3-hour home interview followed within 4 weeks by a 3-hour clinic examination. Measures included pain, cerebral hemodynamics, and foot disorders as well as established fall risk factors. For the ongoing 24-month follow-up, participants return fall calendar postcards to the research center at the end of each month. Any reports of falls or missing calendars are followed-up with a telephone interview to assess circumstances and consequences of each fall. A second home and clinic assessment are performed at approximately 18 months following baseline.
Results

Results from the first 600 participants showed that participants are largely representative of seniors in the Boston area in terms of age, sex, race and Hispanic ethnicity. Many participants (39%) reported having fallen at least once in the year before baseline, and fallers had a higher prevalence of both traditional and the novel risk factors that are targeted in the MBS.

Conclusions

Our results demonstrate the feasibility of conducting comprehensive assessments, including rigorous physiologic measurements, in a diverse population of older adults to study non-traditional risk factors for falls and disability. The MBS will provide an important new data resource for examining non-traditional risk factors for falls and mobility problems in the older population.
BACKGROUND

Previous research on the causes of falls in older adults has uncovered numerous risk factors, but most epidemiologic studies of falls have focused generally on a common set of factors. Despite the progress in understanding the causes of falls in older persons, not all causes of falls are known and many suspected risk factors have not been adequately studied.[1, 2] Nonetheless, multifactorial interventions to prevent falls in older persons have met with moderate success, particularly when a targeted risk factor reduction strategy is employed.[3-5] Because falls are a leading cause of disability in the older population and because factors that contribute to falls are also risk factors for many other adverse consequences in older adults, fall prevention strategies may have the greatest impact overall in reducing disability in the older population.[6, 7] As the post-WWII Baby Boom generation approaches old age, there is an urgent need to improve our understanding of the causes of falls and enhance the multifactorial interventions with a more enriched knowledge base.

Selected risk factors for falls such as pain, changes in cerebral blood flow regulation, and foot disorders are poorly understood in part because they pose measurement challenges, particularly for large observational studies. Assessment of pain in previous cohort studies has generally targeted selected regions such as knee or back pain, or alternatively, summary measures have been used to assess overall pain severity using one or more numeric rating scale items. The few studies that have examined pain location using pain maps and other comprehensive approaches to pain assessment have shown that location of pain throughout the body is an important predictor of falls and disability.[8-11]
Although postural blood pressure declines are known to be associated with falls, [12, 13] it is not clear whether alterations in cerebral blood flow (CBF) regulation may contribute to falls in community-dwelling seniors. There is evidence that orthostatic hypotension and postprandial hypotension are associated with subcortical white matter abnormalities, presumably due to ischemic injury to watershed areas of the brain during periods of hypotension.[14] Increased blood pressure variability is also associated with white matter abnormalities in the brain.[15, 16] Furthermore, several case-control studies have demonstrated that ischemic white matter changes are associated with gait and balance abnormalities, which may lead to falls.[17-19] However, to our knowledge, no studies have shown a direct relation between cerebral blood flow abnormalities and falls in representative community-based populations. Cerebral blood flow and its regulation can be measured non-invasively and economically with good temporal resolution using Transcranial Doppler Ultrasonography (TCD). This technique is particularly suitable for population-based studies and offers the potential to better understand the role of CBF abnormalities as a cause of falls, syncope, and impairments in gait and balance.

Foot disorders are often overlooked as important potential causes of falls and little is known about how foot disorders influence important potential mediators of falls, such as balance or gait in older persons. Tinetti et al. found that elders with self-reported ‘serious foot problems’ were more likely to fall during the 1-year follow-up than those without foot problems.[20] Two retrospective studies found that self-reported foot disorders increased the risk of falling in elderly persons.[21, 22] These studies indicate that foot disorders are likely to be linked to falls, however, the definitions of foot problems used in these studies were often limited and based on
self-report. No studies to date have examined the relation between foot disorders and falls with empirical measures of balance and footwear, as well as measures of functional performance.

The MOBILIZE Boston Study (MBS), which stands for “Maintenance of Balance, Independent Living, Intellect, and Zest in the Elderly of Boston” is a major new cohort study designed to examine these novel risk factors for falls. It is likely to have a significant impact on our understanding of hazards posed by problems of pain, cerebral hypoperfusion, and foot disorders in the older population. In this paper, we present the design and an initial description of the MBS study cohort recruited from an urban population of older adults.

METHODS

MBS Project Overview

The MBS is funded by a program project grant from the National Institute on Aging. It was designed to efficiently address multiple project aims, by using core resources to recruit and study a large population of aged individuals. Furthermore, the identification and careful characterization of a diverse, elderly, community-based population has enabled us to create a valuable database to foster future research beyond the scope of the MBS, including the future study of other lifestyle factors, biomarkers and even genetic factors that may underlie risk for falls and disability in older populations.

Study Design

The MBS is a prospective observational study based in the Institute for Aging Research (IFAR) at Hebrew SeniorLife, a large geriatric housing, health care, and research organization. Study
operations are centralized in the Institute where the staff coordinates all aspects of participant enrollment, data collection and management, and participant follow-up. The MBS is a collaborative effort involving investigators at IFAR, Beth Israel Deaconess Medical Center, Harvard Medical School, the University of Massachusetts (UMASS) Boston, and Boston University. The population-based recruitment was conducted by the UMASS Center for Survey Research (CSR) in close collaboration with IFAR’s outreach staff. The recruitment strategy targeted older persons aged 70 years and older, living within a 5-mile radius of IFAR by using probability sampling from town lists and census information. Since the lists included approximately 90% of all people 70 or older in the area, all of these people had known probabilities of selection. Once recruited through home visits, elders were contacted by telephone by IFAR research staff to confirm eligibility and schedule the 2-part baseline data collection. The 2-part baseline assessment included an extensive 3-hour in-home interview, followed within 4 weeks by a 3-hour in-clinic examination. During the home visit, participants were given a set of monthly falls calendar postcards and instructed as to how they should be completed and mailed to IFAR at the end of each month during the 24-month follow-up. In the ongoing follow-up, reports of falls are followed up through telephone interviews. The data collection is repeated 18 months following enrollment, and uses the same 2-visit approach. The MBS was approved by the Institutional Review Boards of Hebrew SeniorLife and the collaborating institutions.

Within the program project, subgroups of the population-based cohort are being invited to participate in clinical projects that address specific questions related to the mechanisms and prevention of falls. One of these investigates the effect of subsensory mechanical "noise" applied
to the soles of the feet through a vibrating sandal on balance and gait.[23-25] This project examines healthy elderly fallers and non-fallers who have intact sensation in the feet, and those with peripheral neuropathy. A second project examines the anatomical and cerebrovascular regulatory changes of the brain associated with slow gait speed using MRI and TCD. Subjects with a gait speed of <0.6m/sec during the 4-meter walk and controls matched on age, gender and cardiovascular risk factors are targeted for this study.

Participant Recruitment

As of January, 2008, the MBS recruitment is nearly completed and 765 participants have enrolled. The sampling frame included households with one or more persons aged 70 years and older living in the community within a 5-mile radius of IFAR, located in Boston. The geographic boundary included most of Boston and sections of 5 nearby cities and towns. According to the U.S. Census 2000, among persons aged 70 and older in this locale, the minority representation was approximately 19%, which was lower than the general Boston population across all ages. Extra efforts were made to recruit in areas with large minority representation, but oversampling was not needed.

In preparation for recruitment, letters were sent to local police departments, fire stations, and churches informing them about the study, and informational newspaper articles and flyers were distributed to residents. Randomly selected households in the target area were sent letters informing them that a research assistant from the UMASS Center for Survey Research (CSR) would be visiting their home to discuss the study. During their first contact with potential subjects, staff explained the study and performed a rapid eligibility screen. Eligibility criteria
included age over 70 years, ability to speak and understand English, ability to walk across a small room, sufficient vision to read written material, and the expectation that they will be living in the area for at least 3 years. Companions or spouses who were aged 65 or older living with a participant also were allowed to join the study, as it was recognized early on that recruitment of one spouse or companion without the other would limit participation. Study participation was limited to English speakers because it was not feasible to translate the study instruments and conduct the interviews in the many languages that are spoken within Boston’s minority communities.

Subject Screening and Recruitment

Persons who expressed interest in participating after being contacted at home by the CSR were referred to IFAR research staff who conducted the initial screen by telephone. Eligibility criteria are shown in Table 1. Final eligibility was determined at the start of the home interview, including ascertainment of ability to walk across a small room without personal assistance and a screen for cognitive impairment. We excluded persons with a Mini-Mental State Exam (MMSE) score less than 18, indicative of moderate or severe cognitive impairment.[26, 27] In addition, at the home interview, the research assistant confirmed that there were neither serious language difficulties nor severe visual or hearing deficits. Severe sensory deficits and moderate or severe cognitive impairment precluded the participants’ ability to perform the various tasks and procedures that were part of the MBS protocol, including informed consent, cognitive and physical performance testing, and monthly falls calendars. Persons who scored 18 or greater on the MMSE but exhibited cognitive difficulties were eligible as long as they demonstrated that they could comply with the study requirements at baseline.
**Data Collection**

The in-home interview and clinic exams were designed to collect extensive information to meet the aims of the projects that comprise the MBS. During the baseline home visit, the interviewer obtained informed consent from the participant, reviewed the study procedures including instructions for completing the monthly fall calendars, and conducted the baseline interview, generally requiring 3 hours. The in-clinic appointment, conducted by research nurses, lasted approximately 3 hours and took place within 4 weeks of the in-home visit. Measures obtained in the 2-part baseline assessment are described in more detail below, and summarized in Table 2. Participants were given $15.00 for each in-home visit and $25.00 for the in-clinic appointment. Transportation to the MBS clinic using commercial transport vans was provided for all participants as needed or requested.

**Baseline Home Interview**

The baseline home interview, conducted by trained research assistants, included extensive information about health and functioning: chronic diseases (self-report of physician diagnosis and the Rose Angina and Claudication questionnaires[28]), health behaviors (smoking, walking activity[29], self-efficacy for pain and disease management[30, 31], social network and support[32], pain assessment (described below), fall history, fracture history, medication adherence[33], and sociodemographic characteristics. Three domains of disability were assessed, Activities of Daily Living (ADL: bathing, dressing, transferring, using the toilet, and eating[34]), Instrumental Activities of Daily Living[35] (IADL: shopping, preparing meals, and housework), and lower extremity mobility (walking and stair-climbing).[36] Response options
for the ADL, IADL, and mobility items included asking individuals to identify their level of difficulty (none, a little, some, or a lot) or inability in performing each ADL and IADL activity.

**Cognitive Tests:** Verbal memory functioning was assessed with the Hopkins Verbal Learning Test – Revised (HVLT-R). The HVLT-R is a 12-item word list learning test that has been identified as an ideal memory measure for elderly patients and those suspected of dementia.[37] Verbal fluency was assessed with phonemic and semantic fluency tasks.[38] Reliability and validity of the HVLT-R have been shown in both older adults and persons with frontal lesions.[39-41] The Trailmaking Test (parts A and B), requires the individual to connect encircled items in sequential order in a timed test. The Trailmaking Test, a measure of executive function, is frequently used in the clinical setting and has been shown to be sensitive to the presence of frontal lobe pathology and increased cerebrovascular risk.[42] The Clock-in-a-Box Test (CIB), a modification of the commonly used Clock Drawing test[43, 44], was designed as a cognitive screening measure for use in the medical setting and has increasingly been used as a measure of executive function.[45]

**Medications:** A medication review performed during the in-home visit included an examination of all containers of prescription and over-the-counter medicines used in the previous 2 weeks, and recording of name, strength and number taken per day, week or month.[46] At the end of the home interview, participants were given a questionnaire to complete and bring with them to the clinic visit. This self-administered instrument included a well validated measure of social networks[32], the anxiety subscale of the Hospital Anxiety and Depression Scale[47, 48], and the
Short Form-12 to measure self-rated health, bodily pain, limitations in social and physical activities, and emotional health.[49]

**Pain Assessment:** We used several measures to assess pain location, intensity and characteristics during the health interview. Participants were asked to identify sites of current pain that lasted more than a week or two, using the McGill Pain Map, a homunculus showing the front and back of a human figure.[50] The method was developed and validated for use in studies of older populations.[51] The multidimensional Brief Pain Inventory (BPI) consists of subscales for pain descriptors, pain-related quality of life, and pain relief.[52] The BPI and its subscales are well-tested and reliable instruments in patients with back pain, arthritis, and peripheral neuropathy.[53-55] Pain severity was measured using the 4-item BPI scale measuring pain intensity in the past week using a 0-10 numeric rating scale, where 0 is no pain and 10 is "severe or excruciating pain, as bad as you can imagine". The 7-item BPI pain interference scale measures level of pain interference with general activity, mood, walking, normal work including housework, relations with other people, sleep, and enjoyment of life. Response levels on the numeric rating scale ranged from 0 (not at all interferes) to 10 (completely interferes). Of note, reports from research staff indicated that participants had little or no difficulty using the BPI’s rating scales. To assess nonconventional pain management, we added several additional items to the BPI nonpharmacologic treatment assessment.

A second measure of pain location and severity was a modification of the pain assessment used in the Women's Health and Aging Study (WHAS).[56] The series of items on sites of chronic musculoskeletal pain addressed presence and severity of back and joint pain (feet, knees, hips,
shoulders, hands/wrists). Participants were asked to rate back or joint pain using the same numeric rating scale used in the BPI, described above. The questions were changed to match the American Pain Society's definition of chronic pain as pain lasting 3 or more months, rather than 1 month in the previous year.[56] The WHAS pain measures have been shown to predict falls and disability in older women.[8, 9]

*Falls history:* Standard questions regarding falls to the ground or lower surface occurring in the last year were used to ascertain fall history.[57] The Tinetti Falls Efficacy Scale (FES) is a 10-item instrument assessing degree of self-confidence in performing daily activities, such as carrying heavy objects, bathing and housekeeping, without falling. The FES has been found to be associated with falls and disability in older adults.[58, 59]

*Depression:* Depression symptomatology was measured using a modification of the 20-item Centers for Epidemiologic Studies Depression (CESD) scale.[60] The instrument has been shown to be valid, reliable and sensitive to change in older populations [61, 62] Recently, Eaton and colleagues at the Johns Hopkins University developed a revision of the CES-D, adding symptoms and a response option that together satisfy symptom and duration criteria for DSM-IV Major Depression.[63] In the MBS, we used a modification of the Hopkins Revision of the CES-D (CESD-R). We calculated depressive syndrome burden scores using item response theory [64, 65] and the metric was set relative to the mean and variance of the MBS sample aged 70-74 years at baseline interview using a mean of 50, standard deviation of 10. To classify minor and major depression, we applied a diagnostic algorithm following DSM-IV. Persons with minor or major depression had to have either anhedonia or dysphoria. Persons with minor
depression had a total of two of nine symptom clusters (dysphoria, anhedonia, appetite disturbance, sleep disturbance, difficulty thinking, guilt, fatigue, psychomotor retardation, or suicidal ideation), major depression requires five of nine symptom clusters. Symptoms within clusters had to be present nearly every day for two weeks in the previous month to meet duration criteria. In an initial sample of 600 MBS participants, the items that comprise the CESD-R were highly internally consistent (coefficient alpha = 0.87).

Footwear: We collected information on typical footwear as worn currently and also historically (at ages 20-29, 30-44, 45-64, 65-74 and 75+ years), using a checklist derived in two other population-based studies.[66, 67] The focus of the assessment was to distinguish types of typical shoe wear that constrict or place strain on the foot (e.g., narrow toe boxes, elevated heels, absent fixation, excessively flexible heel counters or soles).

Baseline Clinic Examination
The baseline examination at the IFAR clinical research center was conducted by experienced research nurses trained in the administration of the complex battery of clinical and performance measures. The intensive assessment was carefully paced to allow rest periods, avoid rushing and prevent excessive burden to participants.

Musculoskeletal Examination: The primary purpose of the musculoskeletal exam was to assess the American College of Rheumatology’s clinical criteria for hip, knee, and hand osteoarthritis, and fibromyalgia, for subsequent adjudication by the study rheumatologist.[68-70] The assessment included observation and movement of hands, wrists, hips, knees, and feet for joint
tenderness and swelling, and pain on movement. In addition, we evaluated hip and knee range of motion using a goniometer and inclinometer and assessed for knee angular deformities. The manual tender point exam of 18 tender points assessed criteria for fibromyalgia.[71] Staff were trained by physician specialists (rheumatologist and physiatrist) and certified by demonstrating proficiency in conducting the assessments. An initial reliability study was conducted using 20 elderly volunteers, respectively, to assess inter-rater reliability of the musculoskeletal and tender point exams, and to determine areas of the exams that required further staff training and clarifications to the protocols. Following the additional training, a second reliability study was conducted using 29 volunteers; all measures generally showed good to very good agreement, with kappa statistics ranging from 0.40 to 0.76. Staff have been recertified annually by the trainers in each of the musculoskeletal exam measures.

**Foot and Shoewear Assessment:** Foot disorders and foot symptoms were assessed using the validated Foot Assessment Clinical Tool to capture the main features of 25 common clinical foot disorders. This instrument has been found to have excellent reliability in 2 cohorts, and validity tested against podiatry examination. [72, 73] The Foot questionnaire and examination has two components: the first part queries respondents about pain and specific location of foot pain over various time frames, while the second component consists of a physical examination of the participant’s feet. The foot pain questions are useful for global measures and the specific location of pain is used in the identification of specific foot pathology (e.g., plantar fasciitis). Common foot disorders that are examined include Structural Disorders (hallux valgus, pes planus, hammer toes, claw toes, overlapping toes, valgus/varus, Tailor’s bunion, amputated toes, other foot deformity), Skin or Nail Disorders (hyperkeratosis, maceration, fissuring, tinea pedis,
foot ulcer, ingrown toenail, nail disorders), Systemic Disorders (vascular insufficiency, ankle edema, hallux rigidus, foot infection, fat pad atrophy), and Sensory/Pain Disorders (foot vibratory sensation, Morton’s Neuroma, plantar fasciitis, heel spur, local foot pain symptoms).

During the Foot Examination, we also collected foot imprint data using a MatScan, a computer-driven foot pressure and imprint device (Tekscan, Boston, MA). This device provides timely measures of foot pressure concentrations, dynamic weight transfer and evaluation of foot function as a participant walks across a sensory mat. The data from this device provide information on foot disorders, such as valgus or varus foot and pes planus during static stance as well as a dynamic walk.

**Somatosensory Function Tests:** We used an abbreviated Semmes-Weinstein monofilament test (SWMT) to assess the threshold for light touch pressure using a buckling column, which imparts a known force to the skin on the dorsum of each great toe.[74] Touch sensation threshold was measured as a function of column size/buckling force using 2 monofilaments (sizes 4.17 and 5.07). The test results were categorized into sensory loss groupings of mild, moderate, and severe deficits. We also used a common clinical test, the brush test, applying a light touch cotton ball to the soles of the feet to test for hyperalgesia among participants who were found to have abnormal findings on the SWMT.

**Cerebral Blood Flow (CBF) Regulation:** CBF velocity was measured continuously in the middle cerebral artery using transcranial Doppler ultrasonography (TCD) while sitting in a chair.[75, 76] A 2 MHz pulsed flat transcranial Doppler probe (MultiDop, DWL) was placed over the right or left temporal bone with the best signal, and held in place during recordings using a Velcro
headband. Continuous arterial blood pressure (BP) measurements were obtained simultaneously using a Finometer photoplethysmographic system (Finapres Medical Systems, Arnhem, The Netherlands) on a finger and held at heart level with a sling. After baseline CBF and BP measurements were obtained, the CBF responses to posture change and CO₂ inhalation and cognitive activation were evaluated. For posture change, a sit-to-stand maneuver was performed.[77] Subjects sat with their legs elevated at 90 degrees in front of them on a stool. Measurements were obtained continuously during a 5-minute rest in the sitting position then while standing upright for 1 minute. The initiation of standing was timed from the moment both feet touched the floor. The response to CO₂ was assessed using the CO₂ rebreathing and hyperventilation method. Subjects were asked to inspire a gas mixture of 8% CO₂, 21% O₂, and balance nitrogen for 2 minutes and then mildly hyperventilate to an end-tidal CO₂ of approximately 25 mmHg for 2 minutes. Postural blood pressure (BP) measurements were obtained according to a standardized measurement technique.[78] In a substudy of subjects with slow gait speed and controls, cerebral blood flow changes in response to cognitive activation were measured as reported elsewhere.[79]

*Berg Balance Scale:* The Berg Balance Scale is a multi-component assessment of standing balance, consisting of 14 balance tasks with each task scored from 0 to 4, for a summed score of 0 to 56.[80] The scale has been well-validated and shown to predict risk falls in community-dwelling elders.[81] The unipedal stance, also a validated measure of standing balance and risk for falls, is part of the Berg Balance Scale.[82]
**Quiet Standing Balance and Dual Task:** Subjects were asked to stand on a Kistler force platform (Kistler Instrument Corp., Amherst, NY) to measure postural sway as the displacement of the center of pressure under their feet. Ten, 30-second quiet-standing trials were performed with each participant, half of which include a cognitive task (dual task challenge), randomized to the first or second half by computer. We chose this approach because we felt the protocol would be too confusing for participants and prone to carryover effects if we randomized each trial. Thus, either the first or last five of the ten balance trials included a cognitive task while the individual stood on the balance platform. The cognitive task was serial subtractions, described below. Rest breaks were provided as needed.

We sought to use a “dual task” that: 1) would load attention, 2) would reflect, to some degree, a familiar activity, 3) would not directly influence balance, and 4) would be fairly independent of educational background. We chose, therefore, a paradigm used widely in neuropsychological testing: “serial subtractions.” The subject was asked to subtract 3 from 500, when they said the answer, they subtracted 3 again, continuing until they reached the end of the trial. In subsequent dual task trials they continued the subtractions where they previously left off. Performance on the “dual task” was monitored by asking the subject to state the answers orally. If subjects were unable to perform subtractions by 3, the test was modified by having them count backward by 1 from 500, or count backward by 1 from 100, or identify items at a supermarket.

**Vision:** Distant vision was assessed using the Good-Lite Chart Model 600A light box. The letter chart used with the light box was designed for use at a 10-foot text distance.[83] For the test,
participants read from 9 rows of progressively smaller letters, with each line assigned a score of 10. Their total score was a sum of the successfully identified letters.

**Physical Performance:** The Short Physical Performance Battery (SPPB) was used to measure lower extremity mobility performance.[84] The SPPB includes measures of standing balance, 4-meter usual-paced walking speed, and ability and time to rise from a chair 5 times. The validity of this scale has been demonstrated by showing a gradient of risk for admission to a nursing home and mortality along the full range of the scale from 0-12.[85, 86] Leg strength and muscle power was measured using a double leg press (Keiser Pneumatic Leg Press, Fresno, CA). Participants performed 8 to 12 repetitions to determine the maximal leg muscle strength, referred to as 1 repetition maximum (1RM). Leg muscle power was then performed at 40% 1RM (low resistance). The highest of 5 repetitions was recorded as the maximal double leg press power. For the testing, participants were instructed to use the Borg Scale to rate their perceived exertion and to determine their need for rests between repetitions.[87]

**Laboratory Measures:** Baseline laboratory tests included hemoglobin, hematocrit, hemoglobin A1C, lipid panel and random glucose level. In addition, blood was stored for later evaluation of potential biomarkers and DNA was extracted and stored for future genetic analyses.

**Falls Ascertainment**

A fall was defined as unintentionally coming to rest on the ground or other lower level not as a result of a major intrinsic event (e.g. myocardial infarction or stroke) or an overwhelming external hazard (e.g. hit by a vehicle).[88] During the home visit, participants were instructed
about how to complete the monthly falls calendar on a postage-paid folding postcard and return it to the study center at the end of each month during the 2-year follow-up. This validated method has been used successfully in longitudinal studies of falls.[7, 57, 89, 90] Calendar postcards have been used as a gold standard in studies evaluating fall recall at 3, 6 and 12 months in elder cohorts.[57, 91] Based on the approach described by Tinetti and colleagues, participants were instructed to mark an "F" on the days that a fall occurred and an "N" for each day that no fall occurred.[90] In addition to the calendar, the monthly postcard included 4 questions. Two items from the SF-12 addressed self-rated mobility difficulty and bodily pain. The latter correlates well with visual analog scales for rating pain.[92, 93] Additional items assessed usual footwear during the calendar month, ER visits and overnight stays in a hospital.

During the follow-up, participants who do not complete the calendar or fail to return it within 10 days of the end of the month are contacted by telephone by study staff to determine whether a fall occurred in the previous month. With any participant who reports a fall, a research assistant conducts a structured telephone interview to determine the circumstances and location of the fall, injuries sustained, and the presence of external and internal factors that may have contributed to the fall. Using a detailed algorithm, falls are categorized as follows: nonsyncopal falls, syncopal falls (associated with loss of consciousness), falls due to an overwhelming external hazard, and falls caused by major medical events other than syncope (e.g. stroke, seizure).

**Study Follow-up**

The 2-part assessment including the home interview and the clinic exam is repeated 18 months following baseline. Thus far, 87% of persons seen at baseline who are due for their 18 month
follow-up remain in the study (10% have withdrawn or dropped out and 3% died in the first 27 months of the study), and of those, 98% have completed at least partial follow-up.

Statistical Analysis

Baseline data were available for the first 600 participants enrolled in the study. Baseline characteristics were presented using descriptive statistics, primarily frequency distributions and percentages. Baseline prevalence of falls was determined according to the percentage of participants who reported having had a fall in the previous year. Recurrent fallers were identified as those who reported more than 1 fall in the year before the baseline assessment. We examined prevalence of traditional and novel fall risk factors according to baseline fall prevalence. Continuous variables were dichotomized based on their distributions except for blood pressure and cerebral blood flow measures, which were analyzed as continuous variables. Slow gait and low self-efficacy were based on the lowest quartiles of the distributions. Balance was very skewed toward higher function, thus for the unipedal stance we dichotomized at the lowest quintile to identify those with the poorest balance. Widespread pain was defined using the American College of Rheumatology Criteria and classified as pain in the upper and lower extremities, on the right and left side of the body, and axial pain.[71] Differences between fallers and non-fallers were tested using chi-square tests for dichotomous variables and t-tests for continuous measures.

RESULTS

The median length of the home interview (timed) was 2:42 hours (inter-quartile range, 2:24 to 3:00 hours). The estimated average length of the clinic exam was 2:45 hours. In general, there
has been very little missing information in either the home interview or the clinic exam. For example, fewer than 1% of the first 600 participants had missing pain information in the home interviews. All participants performed the 4-meter walk test, and only 2 participants had missing data for the standing balance test. Several participants (16%) were excluded from the leg press testing due to medical conditions such as acute or severe back or leg pain, systolic blood pressure>200, or recent cataract surgery. An additional 8% were unable to complete the leg press testing because of safety or other concerns by the participant or tester. Transcranial Doppler testing was completed in 63% of the sample, and partially completed in another 11% of participants. A common barrier to TCD testing is the absence of a suitable temporal window to isonate the middle cerebral artery. Nonetheless, the large number of successfully completed tests is unprecedented in an elderly population-based study and will provide sufficient statistical power for studying the relationship between CBF and falls.

No participants have reported a serious adverse event as a result of participation in any aspect of the research. In the follow-up calls conducted by research assistants 3 to 5 days following the clinic visit, a few participants reported minor muscle soreness (n=11), back or joint pain (n=11), or headaches (n=3), all of which resolved quickly. All events were reported to the MBS Safety Monitoring Board.

Baseline Characteristics

The average age of the first 600 study participants was 77.9 years (s.d. 5.5) and nearly two-thirds were women. The study cohort was 78% white and 17% black (Table 3). In comparison with US Census data for the population aged 65 and older in the Boston Metropolitan Statistical Area
shown in Table 3, the study sample was generally representative of elders in the Boston area. In part related to study eligibility criteria and geographic boundaries of the recruitment area, study participants had greater educational attainment than elders in the general community (45% and 24% college graduates, respectively).

The study cohort had a high prevalence of obesity (26%) and low levels of physical activity, with 40% reportedly walking less than 1 mile per week (Table 4). In general, participants reported good to excellent health (85%). Moderate to severe depressive symptoms were infrequent, reported by 8% of participants, and 14% reported having a lot of difficulty or inability to walk ¼ mile (2-3 blocks).

**Fall Prevalence and Risk Factors**

Many participants (39%) reported that they fell at least once in the 12 months prior to the baseline interview, and 17% reported falling 2 or more times in the previous year. There was a high prevalence of risk factors for falls in the study cohort, and a number of these risk factors were more common among those who reported having fallen in the previous year (Table 5). Several traditional risk factors were associated with having a single fall, compared to no falls in the previous year: slow gait speed, balance impairment, low falls self-efficacy, use of bifocal or multifocal glasses, mobility difficulty, and depression. Only 2 traditional risk factors, low falls self-efficacy and depression, were associated with recurrent falls. Self-reported arthritis and mobility difficulty were somewhat more common among those with recurrent falls compared to those with no falls but the difference was not statistically significant.
Among the novel risk factors for falls, widespread pain and high pain interference with daily activities were associated with recurrent falls (Table 5). There was a weak relationship (p=0.06) between high pain interference and having a single fall in the previous year. Among the hemodynamic measures, the fall in arterial blood pressure when changing from supine to standing was higher in recurrent fallers compared to non-fallers (p=0.001). Similarly, recurrent fallers had the greatest orthostatic change in cerebral blood flow velocity from sitting to standing, however the difference was not statistically significant.

While no association was observed for current shoewear and falls in the previous year (Table 5, all types of shoes, p>0.61), participants who reported that their shoes hurt their feet had more single as well as recurrent falls in the previous year (p<0.001). However, those reporting that they experienced foot pain on most days did not report more falls than participants without foot pain (p=.35). Having 3 or more foot disorders was associated with recurrent falls in the previous year (p <0.03).

DISCUSSION

Our results demonstrate the feasibility of a population-based study of community-living persons aged 70 and older to examine a novel set of risk factors for falls. Participants routinely report positive experiences from their participation, resulting in high retention rates. Excellent information has been obtained in the monthly fall calendar postcards that are routinely returned by the majority of participants (approximately 70% fully completed each month), with the
remainder contacted by telephone for completion of the calendars at the end of each month. Although several of our methods have not been used in large cohort studies of elders, our findings demonstrate that the lengthy and complex set of study measures have not been overly burdensome to older and frail participants of the MBS. An important element has been the careful attention paid to the comfort and safety of participants. In addition, all study visits with participants have been organized to provide regular breaks and rest periods in order to limit participant burden and fatigue.

Rubenstein recently reviewed several studies describing reasons for falls and found that up to half of falls were attributed to “accidental or environmental” causes.[2] These reports examined many known risk factors such as gait and balance limitations, dizziness, vision problems, confusion, and “drop attacks”. This later category often included poorly defined problems such as weakness or unexplained loss of stability. The role of cerebral blood flow in such problems has not yet been explored in other fall studies but are prominent measures in the MBS. Also, the careful assessment of pain and lower extremity impairments in the MBS offers a new opportunity to explain many falls that were previously attributed to vague categories of risk factors. Initially, the MBS research will determine the role of pain, cerebral blood flow, and a number of lower extremity impairments as causes of falls in older persons. Foot disorders will be examined as a possible cause of balance difficulties that could contribute to falling. In addition, serum biochemical abnormalities and genetic polymorphisms can be assessed from the MBS blood samples.
The combined set of assessments of cerebral blood flow, pain, cognitive and physical function, balance and other performance measures, and monthly falls ascertainment, will provide an exceptional new resource for future studies of functional change in the aging population. The availability of DNA will allow for the examination of genetic hypotheses. The rich medication inventory is an important resource for examining questions related to chronic disease prevalence and treatment.

Use of the population-based approach in the MBS rather than a more limited clinical sample will allow us to generalize our findings to comparable populations of older adults. Our study cohort is representative of English-speaking older adults living in the community who are without significant cognitive impairment and are able to walk at least short distances in their homes. The latter 2 criteria resulted in a slightly lower proportion of participants aged 85 and older compared to the Census information. However, the primary reason for ineligibility to participate was language. In Boston, the large immigrant population has lower educational attainment than the non-immigrant population.[94] Thus, our English-speaking study participants have higher educational levels than the general Boston population based on the US Census data. Most importantly, from the eligible population, we have enrolled a study cohort at high risk for falls, with comparable fall rates to previous population-based studies.[20, 95]

Our findings regarding the association between traditional fall risk factors and history of falls in the MBS are generally consistent with the established epidemiology of falls from other population-based studies.[1] However, in our preliminary investigation, differences emerged according to whether falls were single versus recurrent events in the year prior to baseline.
Traditional risk factors of gait and balance impairments, and mobility difficulty were more common in those who reported a single fall in the previous year. Novel risk factors of widespread pain, pain interference, and orthostatic change in arterial blood pressure were most strongly associated with recurrent falls, and only weakly or not at all related to single falls. Foot disorders were linked with recurrent falls in the previous year, while persons reporting that their shoes caused foot pain had more single as well as recurrent falls. These provocative associations will be examined carefully using the prospective data of the MBS.

CONCLUSIONS

Although previous epidemiologic studies have explored multiple risk factors for falls, the new set of proposed risk factors assessed in depth for this project combined with excellent falls information will advance our understanding of the causes for falls and will lead to new advances in fall prevention. Our results attest to the feasibility of conducting an innovative population-based study of non-traditional risk factors for falls and disability in the older population. Despite the complexity and potential subject burden in this population of seniors, many of whom have activity limitations, our success demonstrates that such studies are feasible and have the potential to yield important findings in previously under-studied areas related to aging. Many participants have expressed enthusiasm for the research and report that they enjoy their participation. The MBS will provide a valuable and extensive new data resource for examining non-traditional risk factors for falls and mobility problems in the older population.
Author Contributions

SL helped conceive and design the study, contributed to the data analyses, and led the preparation of the manuscript.

DK helped conceive and design the study, directed the study operations, and contributed to the preparation of the manuscript.

RJ helped conceive and design the study, directed the data management and analyses, and contributed to the preparation of the manuscript.

AR directed the study sampling and recruitment, helped with the design of the study, reported the initial recruitment results, and contributed to the preparation of the manuscript.

MTH contributed to the design and operations of the study, directed the foot disorders study, and contributed to the preparation of the manuscript.

FAS: Contributed to the design, implementation and analysis of cerebral blood flow studies and manuscript preparation.

HK helped design and supervise the subsensory threshold study and contributed to the manuscript preparation.

EJS helped conceive and design the study, helped direct study operations, and contributed to the preparation of the manuscript.

MG contributed to all phases of the participant enrollment and study data collection, supervised the day-to-day operations, and contributed to the preparation of the manuscript.

MF contributed to all phases of the participant recruitment and enrollment, supervised the day-to-day screening and enrollment, and contributed to the preparation of the manuscript.

LL directed the conceptualization and design of the study, provided oversight to all aspects of the study implementation, and contributed to manuscript preparation.
All authors read and approved the final manuscript.

Acknowledgements

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Declaration of Competing Interests

All authors of this manuscript declare that they have no conflicts of interest.
References


59. Tinetti ME, Richman D, Powell L: **Falls efficacy as a measure of fear of falling.** 

60. Radloff L: **The CES-D Scale: A self report depresion scale for research in teh general population.** *App Psych Meas* 1977, **1**:385-401.


64. Jones RN, Fonda SJ: **Use of an IRT-based latent variable model to link different forms of the CES-D from the Health and Retirement Study.** *Social Psychiatry and Psychiatric Epidemiology* 2004, **39**(10):828-835.


Figure legend

Figure 1. Recruitment and enrollment flowchart as of January, 2008, MOBILIZE Boston Study.
Table 1. Study eligibility criteria for the MOBILIZE Boston Study

**Inclusion criteria**

- Age $\geq 70$ years (or age $\geq 65$ if living with an MBS participant)
- Able to understand and communicate in English
- Plans to be in area for 2 years
- Able to walk 20 feet without personal assistance (walking aids permitted)

**Exclusion criteria**

- Terminal disease
- Severe vision or hearing deficits
- Cognitive impairment (Mini-Mental State Examination $<18$)[26, 27]
Table 2. Summary of data collection and equipment.

<table>
<thead>
<tr>
<th><strong>Domain</strong></th>
<th><strong>In-home interview:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronic Conditions</td>
<td>Medical history</td>
</tr>
<tr>
<td>Pain</td>
<td>Pain location &amp; characteristics (McGill Pain Map, BPI)</td>
</tr>
<tr>
<td>Falls</td>
<td>Falls, fractures, and syncope history</td>
</tr>
<tr>
<td>Cognition</td>
<td>Mini-Mental State Exam ; Neuropsychological Battery: HVLT-R, Clock-in-the-Box, Verbal fluency, Trails A &amp; B</td>
</tr>
<tr>
<td>Depression</td>
<td>Depression (CESD-R)</td>
</tr>
<tr>
<td>Medications</td>
<td>Medication Inventory (prescription and OTCs)</td>
</tr>
<tr>
<td></td>
<td>Self-efficacy for self-management (CPSS; PEPPi)</td>
</tr>
<tr>
<td>Footwear</td>
<td>Footwear/ shoewear</td>
</tr>
<tr>
<td>Demographics</td>
<td>Socio-demographic information</td>
</tr>
<tr>
<td>Behaviors</td>
<td>Health behaviors</td>
</tr>
<tr>
<td>Environment</td>
<td>Perceived neighborhood walkability;</td>
</tr>
<tr>
<td></td>
<td>Observational environmental assessment</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Clinic Exam</strong></th>
<th><strong>Equipment</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobility performance</td>
<td>Height and weight measured</td>
</tr>
<tr>
<td>Muscle Strength</td>
<td>Physical performance tests (SPPB)</td>
</tr>
<tr>
<td></td>
<td>Stadiometer; balance scale</td>
</tr>
<tr>
<td></td>
<td>Stopwatch</td>
</tr>
<tr>
<td>Balance</td>
<td>Leg muscle strength (1 RM) and muscle power</td>
</tr>
<tr>
<td></td>
<td>Keiser Leg Press</td>
</tr>
<tr>
<td></td>
<td>Standing balance +/- divided task, Berg balance, Center of pressure and sway</td>
</tr>
<tr>
<td></td>
<td>Stop watch;</td>
</tr>
<tr>
<td></td>
<td>Kistler force plate</td>
</tr>
<tr>
<td>Cerebral Blood Flow</td>
<td>Transcranial Doppler measures</td>
</tr>
<tr>
<td></td>
<td>Doppler</td>
</tr>
<tr>
<td></td>
<td>Ultrasonography</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>Musculoskeletal exam; manual tender point exam</td>
</tr>
<tr>
<td>Peripheral Neuropathy</td>
<td>Modified Semmes Weinstein neuropathy assessment</td>
</tr>
<tr>
<td>Foot disorders</td>
<td>Monofilaments</td>
</tr>
<tr>
<td>Blood specimens</td>
<td>Non-fasting blood tests &amp; DNA banking</td>
</tr>
<tr>
<td>Vision</td>
<td>Foot exam, foot pressure tests</td>
</tr>
<tr>
<td></td>
<td>MatScan Foot pressure mat, tuning fork</td>
</tr>
<tr>
<td></td>
<td>Phlebotomy equipment</td>
</tr>
<tr>
<td></td>
<td>Good-Lite Chart™</td>
</tr>
</tbody>
</table>
Table 3. Baseline sociodemographic characteristics of MBS participants and the older population in the Boston area.*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>MSA population, Census 2000*</th>
<th>MBS participants (N=600)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Percent</td>
</tr>
<tr>
<td>Age (years)§</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-69</td>
<td>n/a</td>
<td>---</td>
</tr>
<tr>
<td>70-74</td>
<td>22020</td>
<td>32.41</td>
</tr>
<tr>
<td>75-79</td>
<td>18980</td>
<td>27.93</td>
</tr>
<tr>
<td>80-84</td>
<td>13319</td>
<td>19.60</td>
</tr>
<tr>
<td>≥85</td>
<td>13625</td>
<td>20.05</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>43240</td>
<td>63.64</td>
</tr>
<tr>
<td>Men</td>
<td>24704</td>
<td>36.36</td>
</tr>
<tr>
<td>Marital status†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married/lives as married</td>
<td>31941†</td>
<td>47.01</td>
</tr>
<tr>
<td>Widowed</td>
<td>22082</td>
<td>32.50</td>
</tr>
<tr>
<td>Not married</td>
<td>13,921</td>
<td>20.49</td>
</tr>
<tr>
<td>Missing</td>
<td>4</td>
<td>0.67</td>
</tr>
<tr>
<td>Education‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>20361</td>
<td>29.96</td>
</tr>
<tr>
<td>High school</td>
<td>31258</td>
<td>46.01</td>
</tr>
<tr>
<td>College graduate</td>
<td>16325</td>
<td>24.03</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>54419</td>
<td>80.09</td>
</tr>
<tr>
<td>Black or African American</td>
<td>8102</td>
<td>11.93</td>
</tr>
<tr>
<td>Asian</td>
<td>3166</td>
<td>4.56</td>
</tr>
<tr>
<td>Category</td>
<td>Count</td>
<td>Mean</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>Other</td>
<td>2257</td>
<td>3.32</td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Hispanic or Latino ethnicity</td>
<td>2008</td>
<td>2.96</td>
</tr>
</tbody>
</table>

* First 600 participants of the MBS compared with the population aged ≥70 years in the Metropolitan Statistical Area of Boston, US Census 2000.

§ Age eligibility was 70 years and older except for spouses of participants, who were eligible if aged 65 years or older.

† Census 2000 information did not include "lives as married"; same sex adults could not legally marry in Massachusetts until 2003.

‡ Mutually exclusive groups: high school category includes high school equivalence and college attendance but not graduated.
Table 4. Baseline health characteristics of MOBILIZE Boston Study participants

<table>
<thead>
<tr>
<th>Health Characteristics</th>
<th>N</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Mass Index (kg/m2)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;21</td>
<td>42</td>
<td>7.2</td>
</tr>
<tr>
<td>21-24.9</td>
<td>137</td>
<td>23.4</td>
</tr>
<tr>
<td>25-29.9</td>
<td>252</td>
<td>43.0</td>
</tr>
<tr>
<td>≥30</td>
<td>155</td>
<td>26.4</td>
</tr>
<tr>
<td><strong>Self-rated health</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Good to Excellent</td>
<td>510</td>
<td>85.0</td>
</tr>
<tr>
<td>Fair or Poor</td>
<td>90</td>
<td>15.0</td>
</tr>
<tr>
<td><strong>Walking 2-3 blocks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No difficulty</td>
<td>433</td>
<td>72.7</td>
</tr>
<tr>
<td>Little or some difficulty</td>
<td>82</td>
<td>13.7</td>
</tr>
<tr>
<td>A lot of difficulty</td>
<td>46</td>
<td>7.7</td>
</tr>
<tr>
<td>Unable to do</td>
<td>35</td>
<td>5.9</td>
</tr>
<tr>
<td><strong>Minor or major depression</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CESD-R)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>45</td>
<td>7.5</td>
</tr>
<tr>
<td>No</td>
<td>555</td>
<td>92.5</td>
</tr>
<tr>
<td><strong>Cognitive function (MMSE)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-23</td>
<td>72</td>
<td>12.0</td>
</tr>
<tr>
<td>24-28</td>
<td>302</td>
<td>50.3</td>
</tr>
<tr>
<td>29-30</td>
<td>226</td>
<td>37.7</td>
</tr>
<tr>
<td><strong>Amount of walking per week</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;1 mile</td>
<td>153</td>
<td>25.5</td>
</tr>
<tr>
<td>1-3.9 miles</td>
<td>180</td>
<td>30.0</td>
</tr>
<tr>
<td>&gt;= 4 miles</td>
<td>24</td>
<td>4.0</td>
</tr>
<tr>
<td>------------</td>
<td>----</td>
<td>-----</td>
</tr>
<tr>
<td>missing</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5. Prevalence of fall risk factors according to falls history in previous 12 months, MOBILIZE Boston Study.§

<table>
<thead>
<tr>
<th></th>
<th>No falls (n = 364)</th>
<th>1 fall (n = 131)</th>
<th>≥2 falls (n = 101)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Traditional Fall Risk Factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gait deficit (speed &lt;0.79 m/sec)</td>
<td>82 (22.5)</td>
<td>43 (32.8)*</td>
<td>25 (24.8)</td>
</tr>
<tr>
<td>Balance diff. (1 leg st. &lt;1.32 sec)</td>
<td>63 (17.3)</td>
<td>36 (27.5)*</td>
<td>19 (18.8)</td>
</tr>
<tr>
<td>Falls self efficacy (lowest quartile)</td>
<td>76 (20.9)</td>
<td>42 (32.3)*</td>
<td>36 (35.6)*</td>
</tr>
<tr>
<td>Bifocal or multifocal glasses</td>
<td>173 (47.5)</td>
<td>75 (57.3)*</td>
<td>52 (51.5)</td>
</tr>
<tr>
<td>Arthritis (self-reported)</td>
<td>158 (43.4)</td>
<td>42 (32.1)</td>
<td>53 (52.5)</td>
</tr>
<tr>
<td>Mobility difficulty</td>
<td>104 (28.6)</td>
<td>61 (46.6)*</td>
<td>37 (36.6)</td>
</tr>
<tr>
<td>Minor or major depression</td>
<td>18 (4.9)</td>
<td>13 (9.9)*</td>
<td>14 (13.9)*</td>
</tr>
<tr>
<td>Decreased cognitive function †</td>
<td>40 (11.0)</td>
<td>22 (16.8)</td>
<td>9 (8.9)</td>
</tr>
<tr>
<td><strong>MBS Risk Factors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic widespread pain</td>
<td>55 (15.1)</td>
<td>21 (16.0)</td>
<td>24 (23.8)*</td>
</tr>
<tr>
<td>High pain interference</td>
<td>64 (17.6)</td>
<td>33 (25.2)</td>
<td>29 (29.0)*</td>
</tr>
<tr>
<td>Sit-to-stand Δ cerebral blood flow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>velocity</td>
<td>-3.80 (5.29)</td>
<td>-4.05 (4.24)</td>
<td>-4.24 (5.90)</td>
</tr>
<tr>
<td>Supine-to-stand Δ arterial BP</td>
<td>-14.7 (8.8)</td>
<td>-15.5 (9.3)</td>
<td>-18.7 (10.4)*</td>
</tr>
<tr>
<td><strong>Footwear</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Athletic shoes</td>
<td>131 (36.0)</td>
<td>50 (38.2)</td>
<td>31 (30.1)</td>
</tr>
<tr>
<td>Tied/Buckle shoes</td>
<td>101 (27.8)</td>
<td>32 (24.4)</td>
<td>26 (25.7)</td>
</tr>
<tr>
<td>Slip-on shoes</td>
<td>81 (22.2)</td>
<td>26 (19.8)</td>
<td>22 (21.8)</td>
</tr>
<tr>
<td>Category</td>
<td>No Falls</td>
<td>1 Fall</td>
<td>2+ Falls</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>Sandals, slippers, flip-flop</td>
<td>35 (9.6)</td>
<td>13 (9.9)</td>
<td>16 (15.8)</td>
</tr>
<tr>
<td>Boots</td>
<td>4 (1.1)</td>
<td>2 (1.5)</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>High heels, pumps</td>
<td>4 (1.1)</td>
<td>3 (2.3)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Barefoot, stockings</td>
<td>8 (2.2)</td>
<td>5 (3.8)</td>
<td>3 (2.9)</td>
</tr>
<tr>
<td>Shoes cause foot pain</td>
<td>135 (37.3)</td>
<td>63 (48.8)*</td>
<td>55 (54.5)*</td>
</tr>
<tr>
<td>Foot pain on most days</td>
<td>83 (22.8)</td>
<td>31 (23.7)</td>
<td>30 (29.7)</td>
</tr>
<tr>
<td>3 or more foot disorders</td>
<td>184 (50.5)</td>
<td>76 (58.0)</td>
<td>64 (63.4)*</td>
</tr>
</tbody>
</table>

§ Based on data from the first 596 participants of the MOBILIZE Boston Study; 4 participants were missing fall history information.

* p-value <0.05 in pairwise comparison with no falls (reference) category, using chi-square test for binary variables and t-tests for continuous variables.

† Defined as MMSE score 18-23.
Eligible at CSR Screen N=2383

Home Visit Complete N=810

Clinic Visit Complete N=765

590 declined/deferred participation
145 ineligible on screening call
69 never reached

41 withdrawn/declined
4 clinic visit pending/not complete

CSR Referral to MOBILIZE Boston team N=1614

948 no age eligible person
320 vacant households
418 cannot confirm age/vacancy

1440 ineligible* at CSR screen
217 eligibility undetermined
280 refused unknown eligibility

768 refused referral; 1 lost to contact

Center for Survey Research (CSR) contacts:
5655 Households

Age eligible Persons N=4320

Eligible at CSR Screen N=2383

Reasons for ineligibility at CSR Screen (N=1440)

632 language
262 nursing home resident
222 illness
120 unable to walk twenty feet
123 impaired cognition
43 anticipating moving
38 impaired hearing