Accepted Article

Journal of Frailty, Sarcopenia and Falls

Research Protocol

A Wearable Sensor-Informed Approach to Evaluating Fall Risk in Community-Dwelling Older Adults: A Cross-Sectional Study Protocol

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Abstract

Falls are a significant concern for older adults but can be difficult to predict due to their multifactorial nature. Current fall risk assessment tools have been developed for specific populations and are challenging to implement in practice. Wearable sensors may offer additional information during mobility assessments which can be used to predict falls. The aim of the study described in this protocol will be to collect preliminary data to inform the development of a fall risk prediction tool in older adults. The proposed study will recruit adults aged ≥65 through a local falls assessment clinic, separated into high-risk (n=30) and intermediate-risk (n=30) groups based on the World Falls Guidelines. A low-risk group of community-dwelling older adults aged ≥65 who have not experienced a fall in the preceding 12 months will be recruited as controls (n=30). All participants will complete a battery of mobility assessments (Five Times Sit-to-Stand Test, Timed-Up-and-Go test, standing postural sway assessment, Two-Minute Walk Test) while wearing a full-body set of wearable sensors (Clario, Portland, USA). Exploratory analyses will be conducted to determine which variables may best predict falls. Collecting data from clinical settings allows for development of pragmatic fall risk prediction tools using wearable sensors.

Keywords: Falls, Balance, Fall Risk Assessment, Wearable Sensors, Geriatric Medicine

Introduction

Falls are the leading cause of injury, hospitalization, and loss of independence in adults aged 65 and older, contributing significantly to morbidity, mortality, and healthcare costs[1]. With this demographic projected to make up approximately 25% of Canada's population by 2035[2], the need for effective fall prevention and treatment strategies targeting the older adult population is becoming increasingly urgent.

Fall risk is inherently multifactorial, influenced by a wide range of both extrinsic and intrinsic factors[1]. Extrinsic factors include environmental hazards such as poor lighting, uneven or slippery surfaces, and cluttered walkways[3]. In contrast, intrinsic factors include diverse physiological and cognitive impairments, ranging from gait and sensory deficits to medication side effects and cognitive decline[3]. While certain extrinsic risks can be mitigated through environmental modifications, intrinsic contributors are often more complex and persistent, requiring targeted evaluation and intervention. Reduced strength can impair a person's ability to recover from imbalance or navigate stairs and inclines[3]. Abnormal gait patterns may signal compensatory strategies, instability, or even neurological

The authors have no conflict of interest.
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***Edited by:** Dawn Skelton*
***Accepted** 31 July 2026*

impairment[4]. Impaired proprioception can lead to missteps or poor foot placement, ultimately increasing the risk of falling[4]. Slower reaction time may reduce a person's ability to correct their posture during a loss of balance, while diminished peripheral sensation, often associated with age-related conditions such as peripheral neuropathy, can further compromise coordination and walking safety[5]. Cognitive impairment, including executive dysfunction and impaired attention, may interfere with hazard perception, judgment, or dual-task walking, all of which elevate fall risk[6].

Traditional fall risk assessment tools found in the literature, both of the self-report and performance-based varieties, tend to focus predominantly on hospitalized patients or individuals in long-term care facilities, retirement homes, or nursing homes[7]. Despite their widespread use, traditional fall risk assessment tools are difficult to implement in routine practice, in part because they are frequently developed in selected populations, are time-consuming to administer, and show limited reproducibility between assessments[8]. There is a need to develop structured protocols which are capable of being utilized in a variety of settings with heterogenous populations of older adults.

As technology improves, an increasing number of clinics and research centers are turning to instrumented assessments to enhance the objectivity and precision of fall risk evaluation. Instrumented assessments can allow clinicians to collect biomechanical data during standardized tasks, offering more accurate, reliable, and reproducible insight into balance, gait, and mobility, when compared to traditional non-instrumented observational approaches[9]. Conventional technologies, such as force plates and optical motion capture systems, have long been used to assess gait, balance, and postural control in clinical and research settings[10]. Though these systems can detect subtle and dynamic indicators of fall risk (e.g. gait variability, acceleration patterns, and postural stability)[11], they can be costly, stationary, and often require highly controlled environments, which can alter natural movement patterns, thus limiting their utility[12]. Moreover, these systems fail to capture important clinical contributors to fall risk, such as the effects of medication use[13], cognitive impairment, or a heightened fear of falling following an initial incident[14].

To address these limitations, newer wearable sensor-based technologies have emerged as promising tools for assessing fall risk in more ecologically valid settings[15]. Wearable sensors, particularly Inertial Measurement Units (IMUs), offer a portable and unobtrusive alternative for collecting movement data with minimal interference to natural performance[16]. By preserving natural gait patterns and daily movement behaviors, IMUs enable more ecologically valid assessments of mobility[12,17]. Additionally, these tools facilitate the early detection of biomechanical changes associated with increased fall risk as they capture acceleration, angular velocity, and spatial orientation, offering detailed insights into postural control and stability[18]. Using technology can allow for a more nuanced approached to gait and fall risk assessment, allowing for evaluation of gait parameters in conditions that preserve natural gait patterns. IMUs can enhance fall risk evaluation by providing objective, quantitative measurements of gait, balance, and mobility, complementing traditional clinical assessments[16,19].

While previous studies have demonstrated the feasibility of IMU-based sensors for capturing gait, balance, and mobility metrics in older adults, this work has largely been conducted in laboratory settings[20] or within a single risk category[21], limiting applicability to the heterogenous populations seen in routine clinical practice. Comparatively fewer studies have evaluated IMU-derived metrics directly within an existing geriatric falls-assessment pathway, alongside internationally recognized risk stratification frameworks such as the World Falls Guidelines. This protocol addresses this gap by evaluating the added value of IMU-derived movement metrics, in combination with traditional performance-based assessments and clinical/demographic data, across the full spectrum of clinical fall risk (low, intermediate, and high risk) within a single clinical protocol.

The Falls, Fractures, Frailty and Mobility (3FM) Clinic at St. Joseph's Health Care London - Parkwood Institute utilizes IMUs to obtain objective, high-resolution kinematic data during standardized mobility assessments for older adults. This instrumentation addresses the limitations of subjective recall and traditional stopwatch measures by providing a precise, non-redundant characterization of multiple mobility domains. As such, the 3FM Clinic provides a specialized environment to examine how IMU-driven data can be integrated into clinical protocols to enhance the accuracy of fall-risk detection. This data can then be further integrated into a Comprehensive Geriatric Assessment (CGA), a multidimensional, interdisciplinary diagnostic process used to determine the medical, psychological, and functional capabilities of a frail older adult. Embedding objective gait metrics into the CGA would aid clinicians in obtaining objective and personalized insights into the multitude of factors that could possibly contribute to future falls[22].

This study aims to address current limitations in fall risk evaluation by collecting preliminary data from a clinical population to inform the future development of a sensor-informed fall risk prediction tool. Specifically, it will integrate sensor-derived movement metrics captured via IMUs and instrumented gait mats, with clinical and demographic variables to evaluate their combined utility in assessing fall risk in older adults.

Materials and Methods

Study Design and Participants

This is a cross-sectional observational study taking place primarily out of the 3FM Clinic at Parkwood Institute. The 3FM Clinic is a specialized geriatric clinic that utilizes comprehensive assessments to evaluate key biomechanical risk factors in adults aged 65 years and older referred by health care providers due to concerns regarding fall risk and/or mobility decline, and a history of one or more falls within the past twelve months. Individuals for whom fall risk is primarily attributable to a neurological condition (e.g. Parkinson's disease, stroke, multiple sclerosis), as determined by the referring clinician or clinic physician, are ineligible. Peripheral conditions secondary to systemic disease (e.g. diabetic peripheral neuropathy) will not, on their own, result in study exclusion. Patients referred to the clinic will be categorized into risk groups based on the World Falls Guidelines[22]; those with a history of two or more falls in the past 12 months, or a single fall resulting in injury, are classified as high-risk, while those individuals with a single, non-injurious fall are considered intermediate risk. Data for the intermediate and high-risk cohorts will be captured during routine clinical assessments at the 3FM Clinic. Individuals who have not experienced a fall in the preceding 12 months are classified as low-risk[22]; as these individuals are not eligible for the 3FM Clinic, they will be recruited from the community to serve as a control group for comparison. Community-dwelling controls who are 65 years and older and have not experienced a fall in the past year will be recruited through local community activity groups. To support comparability across groups, controls will be frequency-matched to the clinic-recruited cohorts on age and sex. All procedures will be conducted following written informed consent and in compliance with institutional research ethics board approval and applicable privacy regulations. The researchers aim to recruit a total of 90 participants, with an even distribution of 30 individuals per risk category. The target of 30 participants per group was determined based on feasibility rather than a formal calculation, consistent with common recommendations for exploratory or pilot-stage studies[23]. As this is preliminary work, the resulting sample size is intended to generate estimates of effect size and association in hopes of guiding the design of a future, adequately powered study rather than to support definitive statistical inference.

Study Procedures

Demographic and clinical information, including age, sex, comorbidities, medication, and cognitive status, will be collected from the medical charts of participants attending the 3FM Clinic or using questionnaires for participants in the low-risk group. Frailty status will be assessed using the Frailty Index completed within the CGA. A screening log will be maintained throughout recruitment, documenting the number of patients assessed for eligibility at the 3FM Clinic and the reason(s) for exclusion where applicable, in order to characterize the proportion of clinic patients eligible for study participation. Participants will undergo a series of functional mobility evaluations using a full body set of Opal V2R® IMUs (Clario, Portland, OR, USA). Sensors are secured at the lumbar spine (L5/S1), sternum, bilateral wrists, and midfoot bilaterally. Participants will wear the full IMU array for the duration of the assessment battery, approximately 20 minutes, completing (in order) the 5xSTS, TUG, standing postural sway assessments (eyes open trial, followed by the eyes closed trial), and the 2MWT during a single clinic or community visit.

Five Times Sit-to-Stand Test (5xSTS)

Participants will be instructed to stand up and sit down five times as quickly and safely as possible. Poor performance on the 5xSTS may indicate weakness or impaired control in the lower extremities; both of which are associated with a higher risk of falls[24]. This test has been established as a reliable and valid tool for measuring lower-limb functional strength and balance control in older adults[24].

Timed Up and Go (TUG) Test

Participants will begin seated, then stand, walk 3 meters, turn, return, and sit again. The TUG test is widely used in fall risk screening, and deviations in performance, such as hesitation or instability during turning can offer insight into real-world fall risk[25]. The TUG is a validated measure for identifying community-dwelling older adults prone to falls, demonstrating high clinical sensitivity and specificity for this population[25].

Standing Postural Sway

To assess postural control and balance, patients will complete two standing balance tasks under different sensory conditions. Each test involves standing quietly for 30 seconds while wearing IMUs that can track sway, center of mass movement and postural variability[26]. First, participants will be instructed to stand with their eyes open and hands on their hips if feasible. To ensure a standardized base of support, a foot placement template, provided by the IMU manufacturer, will be used to set a consistent minimum distance between the feet of each participant. This will serve as a baseline measure of postural stability under normal visual input and will provide a reference point for comparison with the eyes-closed condition[27], which immediately follows. The use of wearable inertial sensors to assess standing balance has been validated against laboratory standards for providing objective characterization of postural sway in clinical populations[26].

Two-Minute Walk Test (2MWT)

Participants will walk continuously at a comfortable, self-selected pace for two minutes along an approximately

8-meter pathway[28]. While a 30-meter straight path is recommended as the gold standard for the 2MWT to ensure steady-state gait, and a 15-meter path is considered a viable alternative for capturing consistent temporal parameters[29], clinical environments often necessitate shorter distances due to spatial limitations. An 8-meter path aligns with standardized clinical protocols, such as the 6-meter and 10-meter walk tests, which have been validated as reliable indicators of gait performance in older adults[30], offering a practical balance between laboratory precision and real-world clinical applicability. The assessment of spatiotemporal gait markers via IMUs has been validated against electronic walkways specifically in older adult populations[28].

Data Analysis

Prior to formal data analysis, an extensive exploratory data analysis will be conducted. Visualizations, including boxplots, histograms and scatterplot matrices, will be used to assess data distributions, identify outliers, and observe potential trends between sensor metrics and fall-risk categories. These plots will guide the selection of appropriate statistical models and ensure that the mathematical assumptions of the planned tests are met. Descriptive statistics will be used to summarize the sample and sensor-derived variables across all study participants. Continuous variables will be reported using means and standard deviations or medians and interquartile ranges, as appropriate based on data distribution. Categorical variables can be summarized using frequencies and percentages.

Between-group comparison will be conducted to examine differences in sensor-derived movement metrics across fall-risk groups (low, intermediate, and high risk). Post hoc comparisons will be performed after significant findings to isolate specific group differences. To evaluate the relationship between independent domains of sensorimotor control, correlational analysis will be conducted between specific metrics collected by the IMUs. Correlation analyses will examine associations between sensor-derived movement metrics (e.g. gait speed, gait variability, double support time, turn velocity, centroidal frequency of sway, jerk, sway area, etc.). Pearson or Spearman correlation coefficients will be selected based on variable distribution to determine the strength and direction of these associations. Regression analyses will be conducted to further evaluate the relationship between sensor-based measures and fall-risk classification while adjusting for relevant demographic and clinical covariates, including age, sex, medication, and frailty status. Sensor-derived movement metrics can be analyzed as continuous variables throughout all descriptive, correlational, and regression analyses; pre-specified clinical cut-points will not be applied to these metrics. All statistical analyses will be conducted using R Foundation for Statistical Computing (The R Foundation, Vienna, Austria) with a statistical significance set at $\alpha = 0.05$.

Discussion

This study aims to demonstrate how integrating IMU-based kinematic data with movement-based clinical assessments enhances fall risk evaluation for older adults. Given the exploratory sample size, the regression and correlational analyses described in this protocol are intended to generate hypotheses and inform sample size estimation for future, adequately powered studies, rather than to provide definitive or generalizable estimates of association. Implementing this interdisciplinary model into routine geriatric practice is expected to streamline clinical decision-making, improve the consistency of fall prevention strategies, and contribute to a robust, anonymized dataset for ongoing predictive research in community-dwelling populations.

Ethics Approval

The study protocol will be submitted to the Western University Health Sciences Research Ethics Board for review and approval. Participant recruitment and data collection will not commence until Research Ethics Board approval has been obtained.

Consent to Participate

No participants have yet been enrolled. Written informed consent will be obtained from all participants prior to study.

Authors' Contributions

JU and JB led study conception and design. JU, JB, and JE led protocol development and methodology. AN led the statistical analysis plan and drafting of the manuscript. HJP, JB, JE, and JU performed critical revision of the manuscript. JU supervised the project. HJP and AN led project administration. All authors reviewed and verified the final text and accept responsibility for the integrity and accuracy of the article's content.

Funding

This study is supported/funded by a Catalyst Grant from the Bone and Joint Institute at Western University.

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