RESEARCH PROJECT

TITLE: Continuous monitoring of in-home turns: to better elucidate true mobility (dis)ability and fall risk in the older adult population

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BACKGROUND

Safely altering locomotor trajectory (i.e., turning) is essential for functional performance and independence, as it is ubiquitous during activities of daily living and becomes more difficult with age due to increasing sensorimotor impairments. Difficulty turning during gait significantly contributes to mobility disability, which is one of the most common causes of dependence, reduced quality of life, and falls, a leading cause of injury and subsequent death for older adults [1, 2]. Falls during turning are especially dangerous and result in 8-times more hip fractures than falls during linear gait since they often result in femur-to-ground contact [3, 4]. Yet, the quantity and quality of turns resulting in falls remain unknown since turns have yet to be assessed during activities of daily living and in the natural environment of one’s home.

Turning is more complex and demanding than linear gait as it requires more neural resources to plan and coordinate postural transitions, more coupling between the postural and gait control systems, and more spatial coordination between limbs. It is suggested that because of this, turning-related neural systems may be more vulnerable than linear gait to impairment and decline [5, 6]. Recent studies have also shown turning measures to be more sensitive to mobility disability (as determined by clinical mobility measures in patients with mobility disorders) compared to gait measures (e.g., gait speed) [7, 8]. Although clinicians look to turning performance as a sensitive index of postural decline [9] and studies have found certain turning features capable of differentiating elderly fallers from non-fallers [1], no clinical system exists to efficiently and effectively measure turns. We believe that characterizing functional turning during daily activities in the home via continuous monitoring methods will address a critical barrier to clinical practice: our end-goal is to identify a sensitive, early marker of mobility disability that may enable early detection of postural decline and fall risk and, in turn, yield opportunities for intervention, treatment, compensation, coping, sustained independence, and prevention of irreversible damage.

The social, societal and economic impacts of aging motivate the proposed research. Preserving independence, increasing quality of life, and providing proper medical care for older adults has become a multifaceted challenge. Approximately one third of all older adults fall each year [10], and 20-30% of all falls cause moderate to severe injuries that result in disability, loss of independence, and an increased risk of early death [11]. Because the frequency of falls and fall-related injuries rise in parallel with the increasing population of older adults, the costs associated with falls are projected to be over $240 billion by 2020 in the US alone, which is a significant and increasingly unsustainable expense for our healthcare system [10, 12].

Continuous turning measures may better elucidate true mobility (dis)ability and may enable early detection of motor decline. Early detection of motor decline will likely predict future cognitive decline (since cognitive and motor decline tend to coincide), identify elevated risk of disease progression and other disease-related events such as falls, and enable early healthcare planning which allows time for both the older adult and the care provider (family or professional) to make proper arrangements/adjustments. Early detection may also yield the development and implementation of therapeutic interventions. Timely intervention is integral because treatment during the initial stages of disease state may prevent subsequent neurodegeneration and progressive motor and/or cognitive decline. The proposed research will lay the
foundation for an integrated turning assessment system capable of extracting frequent, longitudinal, objective measures of turning in the natural home environment. In turn, the proposed research will create potential for a future decrease in healthcare costs and an increase in quality of life and care for our older adults.

The proposed research will be conducted as a follow-up of the European Union FARSEEING Project, a collaborative European Commission funded research project that aims to “promote better prediction of falls and to support older adults with a focus on information and communication technology devices and the unique proactive opportunities they can provide to older adults to support them in their own environment” [13-15]. In synergy with the InCHIANTI study (ClinicalTrials.gov, NCT01331512), a population-based epidemiologic study investigating age-related decline in mobility [16], the FARSEEING Project has acquired a unique dataset (the FARSEEING-InCHIANTI dataset) that can provide novel evidence on the possible role of wearable sensors in profiling motor behavior in community dwelling older subjects and in linking this with prospective adverse events such as falls. The FARSEEING group will also take advantage of its access to a rich, annotated dataset acquired within the framework of the ADAPT Project, a project funded by the Norwegian National Research Council whose directive is to validate sensor placement and specifications for future use of wearable sensors in profiling motor behavior in older adults.

The specific aims of the proposed research are as follows:

- **Aim I**: to develop and validate the accuracy and reliability of a new turn detection algorithm.
- **Aim II**: to assess both the quantity and quality of turns in healthy, community-dwelling older adults.
- **Aim III**: to assess the relationships between in-home turning, in-laboratory turning, and falls.

**WORKING PLAN**

The duration of the proposed research is 12 months. The working plan is as follows:

**Month 1**: to get acclimated with the University of Bologna’s Personal Health System’s Laboratory and to familiarize oneself with the FARSEEING project, the FARSEEING-InCHIANTI dataset, and the ADAPT dataset.

**Months 2-5**: completion of Aim I, to develop and validate the accuracy and reliability of a new turn detection algorithm. Collaborating researchers from the Oregon Health & Science University and the University of Bologna have developed and validated a turn detection algorithm that requires input from 3 wearable inertial sensors (1 mounted on the lower back and 1 mounted on each foot) [17]. Our team is now in the preliminary stages of modifying the algorithm to rely on information from just the sensor mounted on the lower back. First, our new turn detection algorithm will be validated in the University of Bologna’s Personal Health System’s Laboratory using a camera-based Motion Analysis system as ground truth. The algorithm will then be tested and validated in the home with the ADAPT dataset, composed of wearable sensor data from 21 older adults tracking motor behavior in both the laboratory and in-home environments, using video as ground truth.

**Months 6-9**: completion of Aim II, to assess both the quantity and quality of turns in healthy, community-dwelling older adults. We will apply our validated turn detection algorithm from Aim I to the rich FARSEEING-InCHIANTI dataset. During the 12-year follow-up of the InCHIANTI Study, smartphones were used to continuously monitor mobility in the home for a 7-day period in 334 healthy, community-dwelling older adults (219 over the age of 65). The cohort wore the smartphone for an average of $7.3 \pm 1.6$ days (range of 1-9 days), with 94.5% of the cohort wearing the device for at least 5
days. Our new turn detection algorithm from Aim I will be used to assess both the quantity and quality of turns during activities of daily living in the natural home environment.

Months 10–12: completion of Aim III, to assess the relationships between in-home turning, in-laboratory turning, and falls. Our in-home turning data will first be analyzed against prospective falls (occurring within 1 year of the in-home continuous monitoring period) to assess whether the quantity and/or quality of turning in the home can be used as a predictor of future falls. Then, we will compare our in-home turning data to the in-laboratory turning data (derived from instrumental mobility tests such as the Timed Up and Go Test and the 400 Meter Walk Test) acquired prior to in-home monitoring. Specifically, we will objectively quantify the differences between turning in the home (i.e., natural turning bouts) and in the laboratory (i.e., prescribed turning bouts). Perhaps assessing turning in the natural environment of one’s home will be more telling of true mobility (dis)ability than that assessed in the unnatural environment of a clinic or laboratory. We hypothesize that in-home mobility assessments will be more predictive of future falls than clinical and/or laboratory mobility assessments.

REFERENCES

7. Spain, R., St George, R., Salarian, A., Boudrette, D., Horak, F. Validation of an Instrumented Test of Mobility, iMOBILITY, in Multiple Sclerosis. in American Academy of Neurology. 2010. Toronto, ON, Canada.