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BRIEF REPORT

Wrist-worn voice recorders capture the circumstances and context of losses of balance among community-dwelling older adults

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Abstract

Background: Most falls among community-dwelling older adults are due to a loss of balance (LOB) after tripping or slipping. Unfortunately, limited insight is available on the detailed circumstances and context of these LOBs. Moreover, commonly used methods to collect this information is susceptible to limitations of memory recall. The goal of this pilot observational study was to explore the circumstances and context of self-reported LOBs captured by wrist-worn voice recorders among community-dwelling older adults.

Methods: In this pilot observational cohort study, 30 community-dwelling adults with a mean (SD) age of 71.8 (4.4) years were asked to wear a voice recorder on their wrist daily for 3 weeks. Following any naturally-occurring LOB, participants were asked to record their verbal responses to six questions regarding the circumstances and context of each LOB abbreviated with the mnemonic 4WHO: When, Where, What, Why, How, and Outcome.

Results: Participants wore the voice recorder 10.9 (0.6) hours per day for 20.7 (0.5) days. One hundred seventy-five voice recordings were collected, with 122 meeting our definition of a LOB. Each participant reported 0–23 LOBs over the 3 weeks or 1.4 (2.1) per participant per week. Across all participants, LOBs were most commonly reported 3 p.m. or later (42%), inside the home (39%),

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while walking (33%), resulting from a trip (54%), and having induced a stepping response to regain balance (48%). No LOBs resulted in a fall.

Conclusions: Among community-dwelling older adults, wrist-worn voice recorders capture the circumstances and context of LOBs thereby facilitating the documentation of detail of LOBs and potentially falls, without reliance on later recall.

KEYWORDS

accidental falls, loss of balance, older adults, voice recorder

INTRODUCTION

An estimated 60% of falls among community-dwelling older adults are due to losses of balance (LOBs) precipitated by tripping or slipping.[1,2] An LOB can be defined as an event when the postural control of the body that resists gravity is momentarily lost and followed by either successful recovery of balance without a fall or a fall. Limited details are available on the circumstances and context of LOBs during the daily activity of older adults. Prior studies have obtained such contextual information for falls using medical records or incident reports,[3–5] self-reported logs or surveys,[2,6–9] and video or depth camera recordings.[10–12] Challenges associated with each of these methods include inadequate documentation in many medical records and incident reports,[3,13] recall bias, inaccuracies, or lack of detail,[14–16] and privacy concerns.[11]

Wrist-worn voice recorders offer a means to mitigate the limitations of other approaches and provide detailed contextual information on LOBs or falls.[17–19] The goal of this pilot observational cohort study was to explore the circumstances and context of self-reported LOBs captured by wrist-worn voice recorders in community-dwelling older adults.

Key points

- Wrist-worn voice recorders captured the circumstances and context of losses of balance among community-dwelling older adults.
- The use of these voice recorders reduces reliance on memory recall and therefore may result in more detailed information on these events.
- Losses of balance were most commonly reported 3 p.m. or later, inside the home, while walking, resulting from a trip, and having induced a stepping response to regain balance.

Why does this paper matter?

A better understanding of losses of balance and how they can lead to falls will help inform the development of new and/or improved fall prevention strategies.

METHODS

Participants were recruited for a larger study evaluating perturbation-based balance training. The current study focused on voice recorder data for documenting LOBs after the intervention. Participants were recruited from the university and local community via email listservs, flyers, word-of-mouth, and visits to local community organizations. Eligibility required: age 65–80 years old, no current back, leg, or foot pain that interfered with standing or walking, no lower limb amputation, no hospitalizations in the last 6 months, Montreal Cognitive Assessment score >18,[20] bone mineral density of the lumbar spine or proximal femur $t > -2.5$ (Lunar iDXA, GE Healthcare, Chicago, IL), no history of hip or vertebral fracture, not dependent on assistive device to walk, no regular engagement in exercise to improve balance, and willingness to wear a voice recorder and three inertial measurements units for 3 weeks. The study was approved by the Virginia Tech Institutional Review Board, and all participants provided written consent prior to participation.

Participants were asked to wear a voice recorder on their wrist (Mini Wrist Band Voice Activated Recorder, SpyCentre Security, Plano, TX) and inertial measurements units (APDM Wearable Technologies, Inc., Portland, OR) on their feet and sternum daily for 3 weeks (inertial measurement unit data to be reported elsewhere). This occurred after either 3 weeks of a perturbation-based balance training intervention designed to improve reactive balance upon tripping, or after no intervention. Participants first attended an

orientation session on recorder use and were provided an instructional manual developed by the investigators. Participants were asked to don the devices when starting their daily activities in the morning and remove them when they finished their activities in the evening (or during activities that might get them wet). At the end of each week, participants visited the laboratory for all voice recordings to be downloaded and to address any issues. Investigators also telephoned or messaged at least once during each of the 3 weeks. At the end of the third week, participants returned all devices.

For this study, an LOB was defined as "a sudden, unexpected change in body position that requires us to do something to regain our balance or else we will fall." After each LOB, participants were asked to use the voice recorder to document their responses to six questions derived from prior work[6,8,21] and for which we used the mnemonic 4WHO. These questions (and sample answers) included: When did the LOB occur? (e.g., time of day); Where were you when the LOB occurred? (e.g., in my kitchen; on the stairs to my basement); What were you doing when the LOB occurred? (e.g., walking down the driveway; reaching to the top shelf in the kitchen); Why do you think you lost your balance? (e.g., slipped on ice; tripped over a door threshold); How did you try to regain your balance? (e.g., grasped the railing; leaned on the wall); Outcome: Did you recover your balance or fall? A laminated credit card-size listing of these questions was also provided to participants.

All voice recordings were transcribed and reviewed by two investigators (YL and MM) to exclude those that did not meet the definition of an LOB. Recordings that mentioned an event resulting in a sudden, unexpected change in body position (e.g. trip), but did not clearly mention a corrective movement, were included. The level of agreement of this screening process was evaluated using 50 randomly-selected recordings and the Kappa statistic. Any disagreements were resolved using the independent review of a third investigator not involved in this study. To evaluate the quality of LOB recordings, investigators YL and MM independently rated each recording on the response to each of the six 4WHO questions as: 0 (no answer), 1 (answer was not clear and complete), or 2 (answer was clear and complete). These ratings were then summed across all six questions for each recording, and the interrater reliability of these summed ratings was evaluated using the 50 randomly-selected recordings and intraclass correlation coefficient (ICC [1, 2]). To evaluate usage of the voice recorder, we counted the number of days the voice recorder was worn and the number of hours worn each day. We considered a participant to have worn the voice recorder on any given day if a voice recording was made or if the right foot inertial measurement unit was worn (which was apparent from inspecting the inertial measurement unit data). Time stamps within the inertial measurement unit data indicated the time when they, and voice recorders, were donned and doffed. We used a Friedman test to compare the number of reported LOBs across the 3 weeks of data collection. We quantified each participant's activity level using the methodology of reference 22 by determining the mean of their daily root-mean-square (RMS) foot acceleration (minus gravity) using the inertial measurement unit worn on the right foot. We assessed unipedal stance time at the start of the study to assess balance.[23] We used Spearman's rank correlation coefficient (ρ) to determine whether the number of LOBs reported was associated with activity level or unipedal stance time.

RESULTS

Thirty community-dwelling older adults participated (12 M and 18 F, mean (SD) age of 71.8 (4.4) years, body height of 1.68 (0.10) m, body mass of 77.1 (16.8) kg, and unipedal stance time of 17.6 (12.3) s, with five participants reporting one or more falls over the prior 6 months). Data were collected between November 2022 and August 2023.

Participants wore the voice recorder for a mean (SD) of 10.9 (0.6) hours per day for 20.7 (0.5) days where 22 participants used the recorders for the full 21 days, seven used it for 20 days (returned the voice recorder on the 20th day to accommodate scheduling constraints), and one used it for 19 days (did not wear the voice recorder for 2 days while sedentary and recovering from illness). One hundred seventy-five recordings were collected across the 3 weeks of data collection (1.9 (2.9) per participant per week). Fifty-three (30%) of the 175 recordings were excluded from analysis due to not meeting our LOB definition (31% from Week 1, 25% from Week 2, and 35% from Week 3). Transcriptions of all voice recordings, including those excluded from further analysis, are included in Table S1. Interrater level of agreement for LOB exclusion was substantial (Kappa = 0.75). The mean (SD) ratings of quality of the responses to each of the 4WHO questions were 2.0 (0.1), 1.7 (0.6), 1.6 (0.7), 1.8 (0.4), 1.4 (0.9), and 1.7 (0.5) for When, Where, What, Why, How, and Outcome questions, respectively. The interrater agreement of these ratings indicated moderate reliability (ICC [1, 2] = 0.58).

Of the remaining 122 LOB recordings, there was a mean of 4.1 (5.5) and a range of 0–23 reported by each participant (see Figure S1) with a decrease in means across the 3 weeks: 1.8 (2.5) per participant during Week

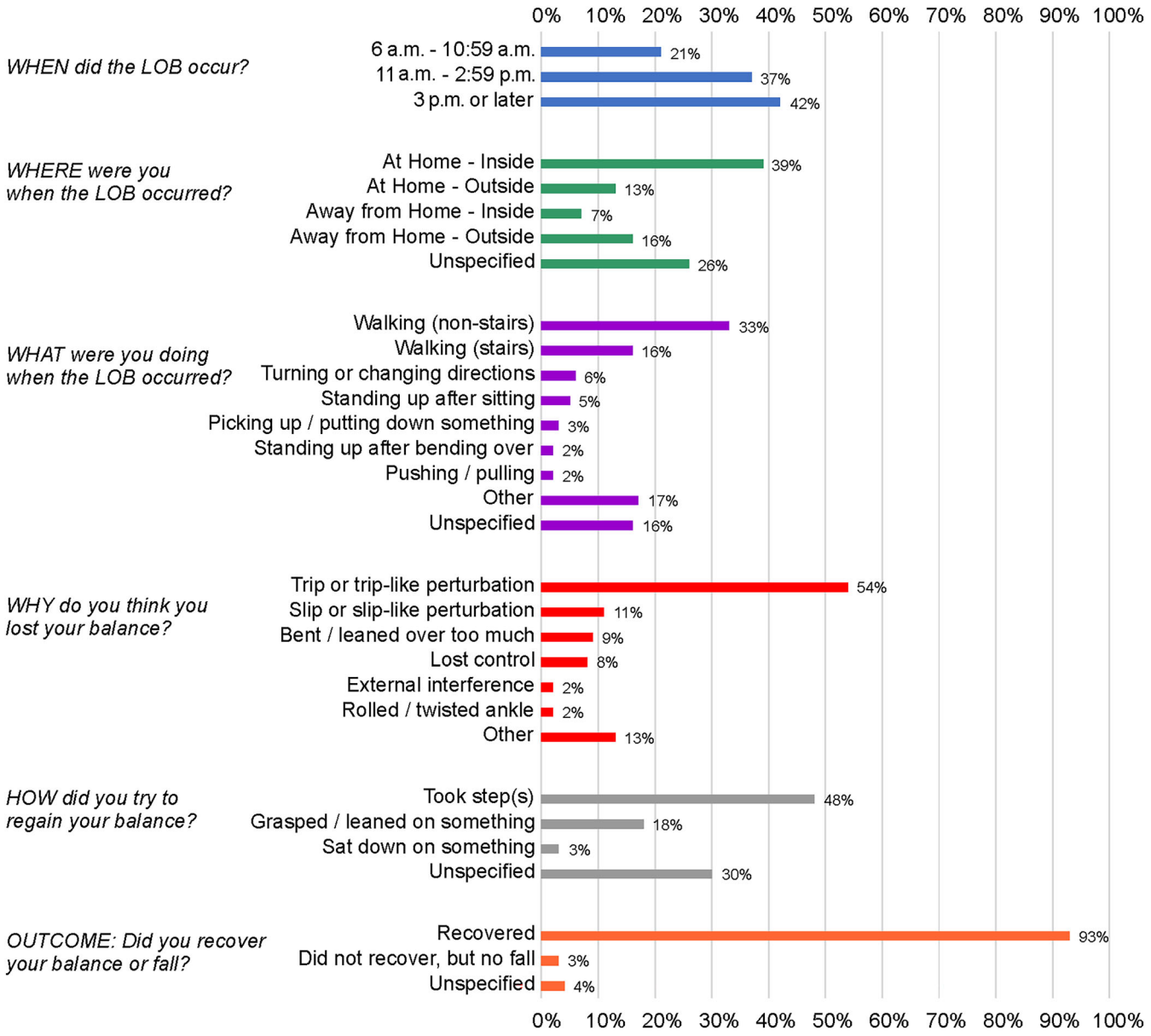

FIGURE 1 Percentage of responses to the six 4WHO questions from all participants combined.

1, 1.2 (1.9) per participant during Week 2, and 1.1 (1.9) per participant during Week 3 ($p = 0.366$). Activity level ranged from an RMS level of 1.34 to 4.56 m/s^2 with a mean of 2.99 (0.97) m/s^2 across all participants. Neither activity level ($\rho = 0.014$; $p = 0.941$) nor unipedal stance time ($\rho = -0.283$; $p = 0.130$) correlated with the number of LOBs reported.

Responses to the 4WHO questions were classified for all participants combined (Figure 1) and after categorizing participants into three groups to mitigate a disproportionate influence by participants reporting a large number of LOBs (see Table S2). The most common responses for all participants combined are summarized here. LOBs were most commonly reported to occur: 3 p.m. or later (42%), at home and inside (39%), while walking not on stairs (33%), and as a result of a trip or trip-like perturbation (54%). The most commonly reported action to try to regain balance was to take steps (48%), and two most common outcomes were balance recovery (93%) or no recovery but also not a fall (3%; e.g., "sat down bench" or "sat down on the bed"). Insufficient information was provided to classify 4%–30% of responses to each of the 4WHO questions. Because the balance training completed by some participants focused on responses to tripping, only the last two 4WHO questions were thought to be sensitive to the training. However, these two questions exhibited no meaningful differences in responses between the 20 participants who

did and the 10 participants who did not complete the training (see Table S3).

DISCUSSION

The current pilot observational study demonstrated that wrist-worn voice recorders capture the circumstances and context of LOBs among community-dwelling older adults. We believe voice recorders facilitate the documentation of additional detail and information of these events, and potentially falls, without reliance on later recall.

The reported number of LOBs experienced by community-dwelling older adults varies from 3.8 to 3.9 per participant per week,[17,19] 1.4 per participant per week found here, and 0.02–0.1 per participant per week[24,25] with the latter tracked using daily diaries. The lowest of these numbers were considered surprisingly small,[24] and might have been due, at least partly, on the use of daily diaries that are heavily dependent upon memory. These findings highlight the benefit of immediately documenting LOBs with a voice recorder to mitigate information loss due to challenges with recall.

Besides our prior small-scale studies capturing LOBs using inertial measurement units,[17–19] we are not aware of any studies that reported the circumstances and context of LOBs that did not result in falls. When comparing the circumstances and context of falls among independent community-dwelling older adults to those of LOBs reported here, some similarities were apparent including: both most commonly occurred in the afternoon[2,21,26]; both most commonly occurred while walking on level ground[2,6,26,27]; and the most common cause for both was tripping.[2,6,9,26] We are aware of only one study that described attempts to regain balance and avoid a fall in the real world such as reported here (13). Such information can be valuable for guiding future fall prevention interventions such as perturbation-based balance training (e.g., references 28,29).

It should be noted that, first, our relatively small sample size may limit the generalizability of our findings, but the methodology of using voice recorders appears useful for capturing detailed contextual information on LOBs and falls in the future. Second, voice recorder usage and its donning/doffing time were inferred from inertial measurement unit data, but participants were asked to don/doff all devices together. Third, while some participants expressed difficulty using the recorders and the number of LOB recordings with insufficient information was as high as 30% for one 4WHO question, we believe additional training on recorder usage would have mitigated these issues.

CONCLUSION

Among community-dwelling older adults, wrist-worn voice recorders capture the circumstances and context of LOBs thereby facilitating the documentation of detail of LOBs and potentially falls, without reliance on later recall.

AUTHOR CONTRIBUTIONS

YL: study concept and design, acquisition of subjects and data, analysis and interpretation of data, preparation of manuscript; NBA: study concept and design, interpretation of data, preparation of manuscript; LP: study concept and design, interpretation of data, preparation of manuscript; LVN: study concept and design, interpretation of data, preparation of manuscript; MLM: study concept and design, analysis and interpretation of data, preparation of manuscript.

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The corresponding author affirms that we have listed everyone who contributed significantly to the work.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

SPONSOR'S ROLE

The sponsor had no role in the design, execution, or reporting of this research.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. LOB recordings collected over 3-week voice recorder use.

Table S2. Percentage of responses within each participant group and all participants to the six 4WHO questions.

Table S3. Percentage of responses to the six 4WHO question from participants who received or did not receive balance training.

Figure S1. LOBs reported per day for each participant.

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