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Introducing a new definition of a near fall: Intra-rater and inter-rater reliability

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Abstract

Near falls (NFs) are more frequent than falls, and may occur before falls, potentially predicting fall risk. As such identification of a NF is important. We aimed to assess intra and inter-rater reliability of the traditional definition of a NF and to demonstrate the potential utility of a new definition. To this end, 10 older adults, 10 idiopathic elderly fallers, and 10 patients with Parkinson's disease (PD) walked in an obstacle course while wearing a safety harness. All walks were videotaped. 49 video segments were extracted to create 2 clips each of 8.48 minutes. Four raters scored each event using the traditional definition and, two weeks later, using the new definition. A fifth rater used only the new definition. Intrarater reliability was determined using Kappa (K) statistics and inter-rater reliability was determined using ICC. Using the traditional definition, three raters had poor intra-rater reliability ($K < 0.054$, $p > 0.137$) and one rater had moderate intra-rater reliability ($K = 0.624$, $p < 0.001$). With the traditional definition, inter-rater reliability between the four raters was moderate ($ICC = 0.667$, $p < 0.001$). In contrast, the new NF definition showed high intra-rater ($K > 0.601$, $p < 0.001$) and high inter-rater reliability ($ICC = 0.815$, $p < 0.001$). A priori, it is easy to distinguish falls from usual walking and NFs, but it is more challenging to distinguish NFs from obstacle negotiation and usual walking. Therefore, a more precise definition of NF is required. The results of the present study suggest that the proposed new definition increases intra and inter-rater reliability, a critical step for using NFs to quantify fall risk.

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Keywords

fall risk; near falls; gait; aging

INTRODUCTION

Self-reported near falls (NFs) are related to fall risk¹⁻⁴, are more frequent than falls^{1, 3, 4}, and indeed may precede falls^{2, 3}. One can assume, therefore, that NFs are clinically relevant markers of fall risk and that measuring their frequency may help to provide a broader, more robust estimate of fall risk. The traditional definition (Table 1)³⁻⁵ is pragmatic, has face validity, and is useful for self-report. To date, this definition has been used in most studies of NFs.

With the advent of small, light-weight body-worn sensors that can be applied in the home and community settings and with the push for mobile- mHealth solutions⁶, automatic detection of NFs with devices worn continuously may be feasible⁶. This possibility has potential advantages of improved sensitivity, accuracy, and reliability. Before this can be achieved, it is important to re-consider the traditional definition of a NF. Several protocols have been developed to produce NFs in the laboratory setting, a necessary step towards continuous monitoring of NF⁶. Negotiating obstacles, for example, is used to provoke NFs. During obstacle negotiation, adjustments of the gait pattern such as changes in speed, step length, and rhythm may occur⁷⁻⁹. Assessing these changes may not be trivial as the gait pattern may be altered with aging and disease¹⁰⁻¹². These alterations may look similar to a NF, challenging identification. Additionally, during a NF, compensatory mechanisms may be utilized, further increasing the challenge. To address these issues, we propose a new definition that extends the traditional definition by including several possible compensatory mechanisms that may be activated to avoid a fall (Table 1). This study aims to assess intra and inter-rater reliability of the traditional NF definition and demonstrate the potential use of this new definition in the development of methods for automatically detecting and quantifying NFs objectively.

METHODS

Evaluators

Five raters participated in this study: (1) a senior physical therapist researcher, (2) an experienced neurologist, (3) a senior research engineer, and two (4, 5) physical therapists. Three raters were familiar with the topic of falls and therefore represent “experienced assessors”, while the other two raters were new to this topic and represented a more “naïve” viewpoint. All five raters were not involved in the development of the new definition.

Procedures

To provoke NFs under laboratory conditions, we created an obstacle course that included two types of obstacles: 10 meters of an uneven surface covered with a carpet and two transparent wires one meter before and after the carpet. Three groups of subjects were included: 10 healthy older adults, 10 idiopathic fallers, and 10 patients with Parkinson’s disease (PD) (Table 2). After providing informed written consent as approved by the local ethics committee, the participants walked up and down a 30 meter long corridor while wearing a safety harness under three conditions: 1) comfortable walking, 2) obstacle course walking, and 3) obstacle course walking while simultaneously subtracting serial 3s. During the protocol, the examiner walked behind the subject to assure safety and to document the

timing and occurrence of any events (e.g., NFs). The protocol was videoed with one frontal plane camera.

Forty-nine video segments, each of 5 seconds, were extracted: 4 of obstacle negotiation, 3 of falls, and 42 possible NFs. An 8.48 min movie was created from these segments: 23 segments from healthy older adults, 14 from fallers, and 12 from patients PD, from conditions 2 and 3. To assess test retest reliability, the first four raters rated each segment using the traditional definition. Then they watched the movie again, this time with the order of the segments randomized to assess test re-test reliability. Two weeks later, the segments were rated again using the new definition. The fifth rater classified the segments only according to the new definition to assess the possibility that reliability was impacted by the repeated assessments. Eight video segments are included in the online supplementary material as examples of events that were reviewed and rated to assess reliability of the traditional and new definition.

Data analysis

Intra-rater analysis was performed for each definition separately by calculating the Kappa statistic (K) between the two clips. A K value over 0.75 was considered excellent, 0.40–0.75 as fair to good, and below 0.40 as poor¹³. Inter-rater reliability was determined by calculating the ICC for the four and five raters when the traditional and new definitions were used, respectively. Since the raters classified two movies for each definition, two ICCs were calculated, one for the first movie and one for the second. The average of these two ICCs was calculated for each definition. Scores between 0–0.2 indicated poor agreement; 0.3–0.4 fair agreement; 0.5–0.6 moderate agreement; 0.7–0.8 strong agreement; and >0.8 excellent agreement¹⁴. Statistical analysis was performed using SPSS version 17.

RESULTS

Reliability using the traditional definition

Intra-rater reliability of three raters was poor, $K = (-0.211)–0.054$, $p > 0.137$, while one rater had fair to good reliability, $K = 0.624$, $p < 0.001$. The inter-rater reliability between the participating four raters was moderate, $ICC = 0.67$, $p < 0.001$.

Reliability using the new definition

Intra-rater reliability of the five raters was high, $K = 0.601–0.959$, $p < 0.001$. The inter-rater reliability between the five raters was fair to good, $ICC = 0.815$, $p < 0.001$.

Comparison between the reliability of the traditional definition and the new definition

Intra-rater reliability increased from poor to good when the new definition was applied (Figure 1A). In addition, inter-rater reliability increased from moderate to strong when the new definition was applied (Figure 1B).

DISCUSSION

We examined whether a definition of a NF based on five possible compensatory mechanisms that commonly appear when recovering from a loss of balance improves the consistency and reliability of NF identification. The present findings demonstrate that the new definition increases intra and inter reliability among raters compared to the traditional definition¹⁵. To our knowledge, the reliability of the traditional definition was never explicitly tested. The present results indicate that this definition is not highly reliable and that a more precise definition is needed. The higher intra-rater reliability for the new

definition indicates that the use of specific criteria for a NF increases consistency across raters.

The evaluation of NFs is challenging. In laboratory conditions, NFs are difficult to provoke, may not necessarily imitate real life, and may vary across individuals, environmental conditions, and obstacle types. On the other hand, self-report of NFs, as has been done in the past^{3,4}, is subjective, relies on motivation and recall, typically requires a long observation period (e.g., weeks/months), and lacks sensitivity. New methods that can automatically detect and quantify NFs in a more objective way in the community and at-home settings may address the limitations of self-report and laboratory testing⁶. To progress in this direction, a critical first step is to improve the NF definition, as proposed here. Evaluating the role of the compensatory mechanisms involved in a NF seems likely to enhance the identification process. A better understanding will also help to guide the placement of the sensors on the body and the accuracy of NF identification. The new definition is an important step forward for augmenting the study of NFs in the laboratory and community settings and should help in the development of the automatic identification of NFs, ultimately, providing a more reliable tool for understanding and assessing fall risk.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

A) Intra rater reliability using the traditional definition and the new definition of a near fall.

B) Inter rater reliability using the traditional definition and the new definition of a near fall.

Table 1

Near falls definitions

	Definition	Additional components to assist with identification
Traditional definition	A stumble event or loss of balance that would result in a fall if sufficient recovery mechanisms were not activated	
New Definition *	A stumble event or loss of balance that would result in a fall if sufficient recovery mechanisms were not activated. At least two of the following compensatory mechanism should be activated to be determined as a near fall.	Possible compensatory mechanisms: (1) unplanned movement of arms or/and legs (2) unplanned change in stride length (3) lowering of the center of mass (4) unplanned change in stride velocity (5) trunk tilt

* The definition was based on careful review of video tapes that included near falls, falls, usual walking, and obstacle negations in healthy adults, elderly fallers, and patients with Parkinson's disease. The goal was to develop a simple-to-use, but more sensitive definition that could reliably distinguish these different events. During the review process, the key role of compensatory mechanisms in a near fall became evident. Since the presence or absence of specific compensatory mechanisms apparently helped to distinguish near falls from other events, they were included in the new definition.

Table 2

Participant characteristics

Subject Group	Age (years)	Gender (male/female)	Falls in the year prior to testing	Hoehn and Yahr stage	# of Fallers* in the Group	Gait speed (m/sec)
Healthy older adults* (n=10)	79.8±4.6	4/6	0.21±0.42 (range: 0–1)	Not applicable	0	1.23±0.22
Idiopathic fallers (n=10)	77.8±5.0	5/5	4.50±3.36 (range: 2–12)	Not applicable	10	1.02±0.23
Patients with Parkinson's disease (n=10)	60.7±9.2	8/2	0.16±0.39 (0–2)	2–3	1	1.18±0.1

* Older adults were classified as fallers if they reported falling 2 or more times in the past year. Otherwise, they were considered as healthy older adult, non-fallers.