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Experimental identification of potential falls in older adult hospital patients

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ABSTRACT

Patient falls within hospitals have been identified as serious but largely preventable incidents, particularly among older adult patients. Previous literature has explored intrinsic factors associated with patient falls, but literature identifying possible extrinsic or situational factors related to falls is lacking. This study seeks to identify patient motions and activities along with associated environmental design factors in a patient bathroom and clinician zone setting that may lead to falls. A motion capture experiment was conducted in a laboratory setting on 27 subjects over the age of seventy using scripted tasks and mockups of the bathroom and clinician zone of a patient room. Data were post-processed using Cortex and Visual3D software. A potential fall was characterized by a set of criteria based on the jerk of the upper body's center of mass (COM). Results suggest that only motion-related factors, particularly turning, pushing, pulling, and grabbing, contribute most significantly to potential falls in the patient bathroom, whereas only pushing and pulling contribute significantly in the clinician zone. Future work includes identifying and changing precise environmental design factors associated with these motions for an updated patient room and performing motion capture experiments using the new setup.

1. Introduction

Unintentional falls are the leading cause of unintentional injury in the United States (Centers for Disease Control and Prevention, 2015a). Among all age groups, the older adult population suffers the highest risk of falling and the highest risk of injury as a result of falling—nearly 2.5 million unintentional injuries were caused by falls in adults 65 or older in 2013 (Centers for Disease Control and Prevention, 2015a). Approximately 24,000 of these falls resulted in death (Centers for Disease Control and Prevention, 2015b), and 700,000 led to hospitalization, primarily due to a broken hip or head injury (Centers for Disease Control and Prevention, 2015c). Further, older adult falls cause significant financial strain on families and healthcare facilities with the direct medical cost of falls reaching $34 billion (Centers for Disease Control and Prevention, 2015d).

A significant percentage of patient falls are identified as preventable as evidenced by the Centers for Medicare and Medicaid's classification of certain falls as "never events," i.e. errors in medical care for which the risk of occurrence is significantly influenced by procedures of the healthcare organization. Consequently, hospitals no longer receive reimbursement for treating falls that occur within patient rooms (CMS, 2008). This decision, prompted by the serious physical and financial consequences of falls, indicates that it is essential to prevent patient falls whenever possible.

The causes of falls are complex and may primarily be categorized as intrinsic, those related to the characteristics of the patient, or extrinsic, those related to environmental conditions. Specific intrinsic and extrinsic factors affecting falls are identified in Hignett and Masud (2006). Other causes of falls include situational activities, such as leaning forward or reaching (Tinetti and Speechley, 1989), and organizational factors related to staffing, policies, and available equipment (Currie, 2008). Roughly 70% of falls are unwitnessed; thus, existing research on patient falls draws data from reports of patient falls (Lee et al., 2011) or creates assessments to determine the patient-specific risk of fall (Kato et al., 2013). Analysis is limited primarily to intrinsic factors (Haines and Waldron, 2011), and literature examining extrinsic factors and situational activities is lacking.

Preferable falls prevention solutions include those which minimize the risk of falling while limiting mobility restrictions on the patient (Tinetti and Speechley, 1989). Several previous studies aimed to develop devices for the detection and prevention of falls (Debard et al., 2012; Ferrari et al., 2012; Lockhart et al., 2010; Ni et al., 2012; Wang et al., 2004) or to assess biomechanical factors which may lead to falls (Robinson et al., 1998; Yang and Pai, 2011,

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2014; Yang et al., 2012). Others have focused on how specific extrinsic factors, such as the bed rail height (Van Leeuwen et al., 2001), floor type (Simpson et al., 2004), or lighting conditions (Heung et al., 2010) influence patient falls. It should be noted that significant differences have been observed between real-world and simulated falls (Klenk et al., 2011), and experimental protocols should be adapted to reflect real-world falls accurately.

This study aims to identify motions and activities, with associated environmental design factors, within the clinician zone and patient bathroom which may lead to falls. Motion capture data were collected on subjects performing a natural progression of tasks identified as high risk for falls. No subjects fell throughout the course of the experiment, but a set of criteria based on the jerk, i.e. the rate of change of acceleration, of the upper body center of mass (COM) was used to determine the start and end points for potential falls. Complementary information pertaining to study development and possible design solutions may be found in Pati et al. (under review).

2. Methods

2.1. Participants

27 Subjects over the age of seventy volunteered for this study (sex: 11 males, 16 females; age: 78.3 ± 5.16 years; height: 165.1 ± 11.3 cm; body mass: 80.8 ± 17.6 kg, where $\pm$ indicates standard deviation). Nine subjects were assigned to each of three scenarios: a clinician zone mockup or one of two bathroom mockups. The subjects were required to be physically and mentally sound, able to perform the scripted tasks without any assistance and not be on any medication that might hamper their performing the tasks. The experimental procedures were approved by the Institutional Review Board of Texas Tech University, and all subjects gave written informed consent.

2.2. Experimental protocol

At the beginning of each experiment day, the motion capture system (eight Eagle-4 camera system from Motion Analysis, capture volume of $3.048 \times 3.048 \times 2.438$ m^3, capture rate of 120 frames/s) was calibrated to minimize error from motion of the cameras due to building vibrations and slight tripod adjustments. Subjects were provided with tight-fitting clothing for the motion capture experiments. After putting on the clothing, height and weight measurements were taken along with traditional limb length measurements according to the conventional gait model (Davis et al., 1991). The in-house marker placement protocol from Cloutier et al. (2011) was modified for use in this experiment. A total of 62 reflective markers were placed on each subject's body as shown in Fig. 1. Subjects were strapped into a fall arrest harness system (McMaster-Carr, 181.437 kg capacity, 3.658×7.315 m^2 floor area covered) before beginning trials as an added safety measure in case a fall occurred. To prevent fatigue, subjects were instructed to take breaks as frequently as needed.

2.2.1. Patient bathroom trials

Due to the limited size of the motion capture volume, tasks were split into clinician zone tasks and bathroom tasks. Two different locations of the bathroom (to the right or left side of the bed) were tested as shown in Fig. 2. Mockups for each bathroom location were created independently, and nine subjects per mockup participated in the bathroom trials (Mockup 1—Subject 1–9, sex: 4 males, 5 females; age: 75.3 ± 5.17 years; height: 161.9 ± 10.2 cm; body mass: 79.4 ± 20.1 kg; Mockup 2—Subject 10–18, sex: 5 males, 4 females; age: 78.4 ± 4.45 years; height: 171 ± 13.4 cm; body mass: 84.7 ± 20.4 kg). Subjects began seated on the hospital

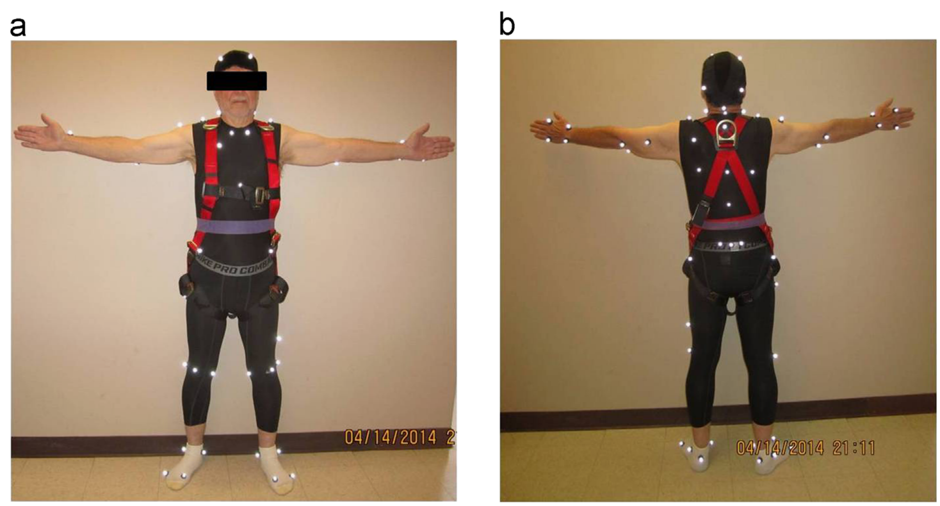

Fig. 1. (a) Marker placement protocol with harness (front view). (b) Marker placement protocol with harness (back view).

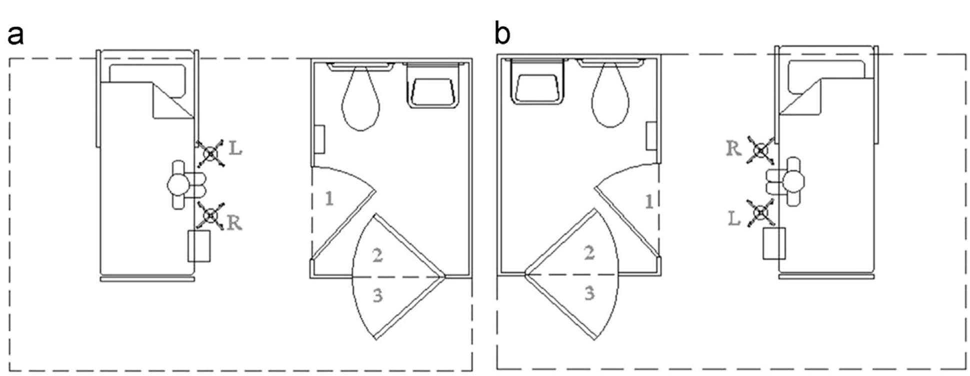

Fig. 2. (a) Bathroom layout to the right of bed, performed by subjects 1–9. (b) Bathroom layout to the right of bed, performed by subjects 10–18.