Communication

Air-Sequr Prototype, an Inflatable Intelligent Hip Protector: Acceptance Evaluation for Fall Injury Prevention Among Older Adults

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Air-Sequr Prototype, an Inflatable Intelligent Hip Protector: Acceptance Evaluation for Fall Injury Prevention Among Older Adults

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Abstract: This study evaluates acceptance parameters for *Air-Sequr*, an intelligent inflatable hip protector prototype. Using a structured questionnaire, data on ease of use, comfort, and perceived protection were gathered from 16 older adults in a retirement home. Results showed high acceptance rates, with positive feedback on user experience metrics. These findings highlight *Air-Sequr*'s potential in preventing fall-related injuries among older adults and support its advancement to pre-clinical studies.

INTRODUCTION

Fall-related injuries (FRIs) are a prevalent cause of hospitalization among adults over 65 years of age [1]. In this population, falls are associated with psychological distress, health complications, decline in quality of life, and even death [2–5]. Currently, FRIs are the second-largest contributor to hospitalization costs, with significant implications for directly or indirectly affected parties (e.g., families, caregivers, …) [6,7].

Potential solutions include nutritional strategies [8], hip fracture protectors (HPs) [9,10], fall risk detection systems [11], and adapted routines or living spaces [12]. Recent statistics from both Canada and the United States indicate an increase in FRIs, with a projected upward trend [13,14]. Based on these findings, we hypothesize that existing solutions may not adequately address the current challenges posed by FRIs in North America.

Among FRIs, hip fractures are associated with a higher risk of death, disability, and substantial healthcare costs [15,16]. Inflatable HPs represent a unique class of HPs relying on an airbag deployment system that provides enhanced impact absorption [17]. Although theoretically effective, the adoption of inflatable HPs by older adults is crucial for evaluating their practical applicability and potential to prevent FRIs in society [18,19].

We hypothesize that the successful adoption of our prototype, *Air-Sequr* – an intelligent inflatable hip protector (IIHP) – into the lifestyles of older adults is contingent upon its acceptance [20]. Early in our program, we incorporated a human-centered design approach [21] and now aim to evaluate the acceptance of our prototype among older adults to validate future practical studies. To this end, we developed a 20-minute questionnaire based on established acceptance evaluation literature [22]. The questionnaire was administered by interviewers to a random sample of older adults in a retirement home.

MATERIAL & METHODS

Distaste, discomfort, side effects, and relative complexity of use are common barriers to the acceptance of HPs [23]. We hypothesized that similar factors would affect the acceptance of inflatable HP garments, such as our *Air-Sequr* prototype. To investigate these barriers, we developed a questionnaire focused on ease of use and comfort, utilizing a Likert scale as a psychometric tool [24]. Esthetics were excluded as an evaluation category, since previous investigations not presented in this study indicated generally positive feedback. Questions related to perception and utility were formulated for "yes" or "no" responses.

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Participants

All participants were new to our technological garment. They were recruited on-site if they expressed a willingness to participate, without compensation. All participants were aged 65 or older, except for one participant who was 55. Each participant was assessed by a healthcare professional as physically and cognitively capable of participating and familiar with FRIs and their health consequences.

Data Collection

After explaining the study's objective and obtaining oral consent, an online survey was administered to collect anonymized questionnaire responses. A preliminary section of the survey inquired about participants' perceptions of falls, including direct or indirect experiences, to ensure sample uniformity, since fall perceptions are linked to acceptance of protective devices [20]. Participants rated their agreement on a 5-point Likert scale, where 5 indicated "strongly agree" and 1 indicated "strongly disagree." As no sensitive information was collected, the study we funded was not subject to committee review.

Three questions assessed perceived ease of use – putting on, removing, and the weight of the *Air-Sequr* IIHP prototype. Weight was primarily considered in terms of ease of use due to potential movement impairment, though it might also impact comfort. Four questions addressed perceived comfort, focusing on the garment fabric, as well as comfort while sitting, standing, and walking. Finally, perceived utility was assessed through questions on perceived effectiveness and purchase intentions.

Data Analysis

Data were collected from 18 participants; however, two were excluded for refusing to wear the IIHP, leaving 16 completed questionnaires for analysis. The majority of participants were female (87.5%), with an average age of 82.4 years (median = 85.5, mode = 89, SD = 9.5). No communicated participant data were verified.

The collected data were analyzed by calculating means, medians, standard deviations, and 95% confidence intervals for each Likert scale metric.

Study Setting

The study was conducted in a private senior care home (Les Habitations Bordeleau) located in a remote area of Montreal (Quebec, Canada). This location was selected based on the relevance of its residents to our study, ease of communication with the management, and the level of independence among the residents.

Interviews followed a standardized protocol to ensure consistent question formulation, a uniform user experience, and ease of data collection. We set up five stations in an adapted setting inspired by a previously published acceptance study [22]. Participants were interviewed using a 20-minute questionnaire administered by trained interviewers. The setup and atmosphere were designed to be professional yet comfortable, providing a pleasant experience for participants.

A typical interview process is summarized in **Figure 1**. A volunteer first welcomed each participant and directed them to the interviewer. The interviewer explained the study and obtained consent to collect data, including questionnaire responses, age, and sex. Participants were asked about their fall experiences and relevant personal characteristics. Next, participants put on the garment, adjusted it to their size over their clothing, and answered the questionnaire using a 5-point Likert scale [24]. Finally, participants were asked to remove the garment, watch a 20-second video demonstrating the *Air-Sequr* IIHP prototype, and evaluate ease of removal, purchase intention, and perceived effectiveness.

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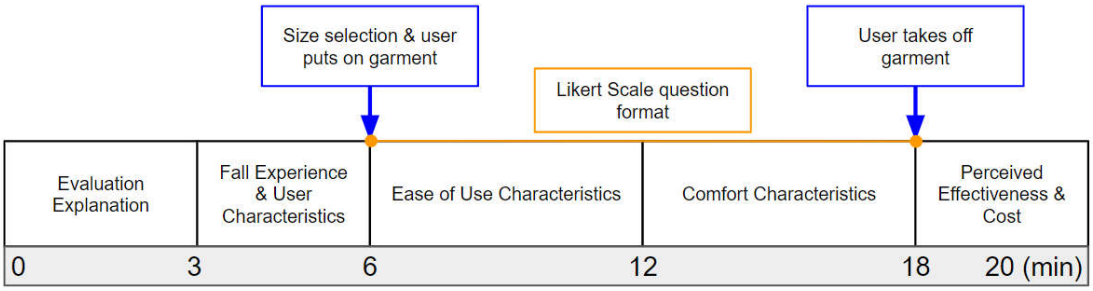

Figure 1. Experimental protocol workflow for hip airbag evaluation.

Upon completing the interview, participants provided feedback outside the scope of the study to a volunteer and received a low-value participation gift, regardless of the feedback quality or information shared during the interview.

Device

The system used in this study is the *Air-Sequr* IIHP prototype. It consists of an outer cover that serves as the garment and includes an integrated airbag system. This cover houses gas cartridges and electronics designed to predict falls using machine-learning algorithms.

Figure 2. Back view and lateral view of *Air-Sequr* IIHP prototype.

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RESULTS

We compiled the 9-question Likert scale feedback from participants into means, medians, and range values, as shown in **Table 1**. Perceived ease of use was assessed through Likert scores for ease of removal, putting on, and the weight of the *Air-Sequr* IIHP prototype. Perceived comfort was evaluated based on garment fabric, comfort while sitting, standing, and walking. Finally, we validated these acceptance metrics by evaluating perceptions of the IIHP's utility in fracture protection effectiveness and purchase intention, as summarized in **Table 2**.

Table 1. Summary score and statistics [mean, median, Standard Deviation (SD)] of questionnaire metrics evaluated by a Likert scale.

Variable Description	Mean	Median	ST
Perceived ease of use			
Putting on	4.31	4.50	0.70
Removing it	4.44	5.00	0.81
Weight	3.22	3.50	1.06
Perceived comfort			
Garment fabric	4.59	5.00	0.51
Sitting	4.36	4.00	0.63
Standing up	4.60	5.00	0.51
Walking	4.57	5.00	0.51

Table 2. Summary percentage of questionnaire utility metrics using Yes/No questions.

Questions	Yes (%)
Utility	
Would you feel protected in case of a fall?	100
Would you buy the inflatable hip protector?	75

DISCUSSION

Ease of Use

Participants rated the ease of putting on and removing the *Air-Sequr* IIHP prototype with mean scores of 4.31 and 4.44, respectively, and median scores of 4.5 and 5.0. These positive ratings indicate that most users found the IIHP convenient to handle. The relatively low standard deviations of 0.70 and 0.81 for putting on and removing, respectively, reflect a consistent user experience across the sample, suggesting that the design of the *Air-Sequr* IIHP prototype accommodates a wide range of abilities and minimizes the risk of user error or difficulty. Although the additional mass from the inflatable modules increases the perceived weight, as indicated by an above-neutral score (mean: 3.22, median: 3.5), this trade-off may be necessary for enhanced protection and was not perceived negatively by users.

The findings on the ease of use of the *Air-Sequr* prototype are encouraging and suggest that this device could be a practical option for older adults seeking additional fall protection. The high ease-of-use scores likely stem from several design features, particularly the garment's ability to be worn like regular clothing.

Perceived Comfort

Participants rated the comfort of the garment fabric with a mean score of 4.59 and a median score of 5.0, reflecting a highly positive perception. The standard deviation of 0.51 indicates consistent comfort ratings among participants. These high scores suggest that the material used in the *Air-Sequr* prototype is soft, non-irritating, and well-received – essential qualities for a device intended for prolonged use.

Comfort ratings for specific activities were also positive, with sitting (mean = 4.36, median = 4.0), standing up (mean = 4.60, median = 5.0), and walking (mean = 4.57, median = 5.0) all scoring well. These scores imply that the *Air-Sequr* IIHP prototype does not impede movement or cause discomfort during these activities. The consistency in comfort ratings across various postures and movements,

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as shown by standard deviations of 0.63, 0.51, and 0.51 for sitting, standing up, and walking, respectively, suggests a similar user experience among participants. These positive and consistent comfort metrics indicate that our IIHP is suitable for everyday use, allowing users to engage in routine activities with minimal discomfort.

Perceived Protection & Purchase Intention

We assessed participants' perceived protection and purchase intention for the *Air-Sequr* IIHP prototype. All participants (100%) believed they would be protected in the event of a fall while wearing the *Air-Sequr* prototype. This unanimous response highlights the device's perceived effectiveness in providing impact protection following the demonstration video. High confidence in the IIHP's protective capability is crucial, as it directly influences the willingness to wear the device regularly, thereby enhancing overall acceptance [20]. Additionally, a majority (75%) of participants expressed a willingness to purchase the *Air-Sequr* IIHP prototype. This positive purchase intention may be linked to the favorable acceptance metrics observed in our study.

CONCLUSIONS

By focusing on a user-centered design approach, we developed a device that was well-accepted among the older adults in our study. The *Air-Sequr* IIHP prototype shows promising potential for reducing fall-related injuries if proven effective and widely adopted. Future evaluations should proceed with pre-clinical applications, assessing both acceptance and effectiveness in a larger and more diverse older adult population.

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Data Availability Statement: The protocol and data underlying this study are available upon request.

ASSOCIATED CONTENT

Notes

NS declares no conflicts of interest. NMM, MB, and PL have financial interests in the Air-Sequr IIHP prototype. All authors have approved the final version of this manuscript.

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