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# The Development and Testing of a Contemporary Co-Designed Mobility Support to Reduce Abandonment and Support Outdoor Fitness Adherence

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**Introduction**

Although in excess of 24% of individuals over the age of 65 and 40% over the age of 80 need mobility equipment in order to safely and comfortably move and engage in healthy physical activity, 30-50% of this large and growing population quickly abandon these devices and become unnecessarily sedentary[1]. Primary reasons for abandonment include difficulty of use, stooped posture, upper extremity pain and occurrence of upper extremity repetitive use injuries, and the stigma of being perceived as "crippled" or near death[1]. Further, while exercise and movement themselves are crucial to illness prevention and health maintenance in elders, recent research has identified the significant benefits of being in outdoor environments. Simply being outdoors has been shown to enhance healthy sleep patterns, promote social-emotional health thereby countering depression, contribute to cardiac health by lowering blood pressure, and mediating against cognitive deterioration[1]. Adding movement and exercise to regular outdoor exposure expands health benefits and adds cardiac, musculo-skeletal and endocrine health, and an additional 5-10 years of longevity to the list of advantages derived from being in green spaces [2,] Accordingly, adaptive equipment that focuses both on form and function is critically needed to improve device adoption that facilitates outdoor movement and exercise[3], [4] Of particular note is the importance of involving users in product design such that their objections to use are clearly understood and addressed. The study presented herein discusses a two-phase project examining the usability and selected outcomes of a mobility device co-designed by users and researchers.

Literature

Four areas of literature were synthesized to support this study; functional limitations of current adaptive mobility devices; importance of non-stigmatizing device appearance; reasons for mobility device abandonment, and value of co-design in promoting problem solving. These bodies of literature provide the theoretical and research rationale for device development and testing.

Functional Limitations of Adaptive Mobility Devices. Durable medical equipment, such as rollators, walkers, canes and crutches, comprises the bulk of current and available mobility devices[5]. And while some are well accepted due to the independence that they aim to create for the user, significant limitations exist when this adaptive equipment is used for activities other than time-limited walking on smooth surfaces[6].

A major deficit of walkers and rollators is that they position users in a stooped posture. Looking down and adopting a gibbose position when moving contributes to postural deterioration, pain, tripping, and falling[6]

Because of small wheels on rollators and wheeled walkers, limited or no active steering, and poor braking systems if they are included at all, Gell at al. [6] were unable to find any reduction in the rate of falling or in fear of falling on the part of those who use walkers and rollators compared to those who do not.

Secondary injury is also a major device use deterrent. The demands of rollator use, including weight bearing on wrists and elbows along with repetitive stress on all upper extremity joints, further impair balance, create tendinopathy, and exacerbate conditions such as osteoarthritis and carpal tunnel syndrome[7]. In investigating walker use for exercise, Mcquade, Finley and Oliveira[8] found that subjects excessively loaded upper extremities during ambulation (46.1% of total body weight), thereby eliminating the potential for safe engagement in prolonged movement necessary for exercise to improve or maintain cardiopulmonary and musculoskeletal health.

Third, walkers and rollators are not crafted for use on diverse surfaces, particularly uneven terrain[6]. While walkers and rollators provide a wider base of support than devices with a single ground contact point, bilateral grip and upper extremity strength are needed just for safe navigation of short distances on flat ground using this equipment. And although wheeled walkers are superior to stationary walkers[9] , neither is designed for prolonged or outdoor use necessary to participate in mild to moderate levels of activity for more than a few minutes. Stationary devices require the user to shuffle or pick up the equipment to advance. These activities require excessive energy and elevate the risk of falling[10] .

The Importance of non-stigmatizing device appearance. Stigmatized appearance is a major cause of device abandonment. Although there are numerous theories of stigma, the common definitional elements are: (1) pejorative labeling or branding a group on the basis of an essential characteristic[3] ; and (2) discrimination on the basis of the label. Goffman's work was seminal in positioning stigma as a field of study fundamental to understanding status, diversity, and discrimination[1]. Building on this work and more contemporary theory, NIH defines stigma as complex, affecting marginalized individuals and groups in diverse manners, from experiencing overt discrimination and disadvantage to internalized acceptance (self-stigma) and behavioral and health consequences of negative stereotypes [11]. Further,violation of expected norms is a major causal element of enacted and self-stigma. For elders, the stigmatized appearance of old age is powerful in itself in a youth oriented culture[12]. However, when compounded by mobility impairment and the need for adaptive mobility equipment such as walkers, stigma is one of the most critical barriers to eliminate if individuals are to participate in exercise and actualize the health benefits thereof [3].

A large body of research identifies stigma as a significant barrier to social, emotional, physical functioning, and productivity. As revealed by Resnik et al. [1], in a study of elders with mobility impairments, some said they did not want to use a device because they feared being seen as "crippled," "an old lady," "very sick", or even as "dying." Some feared that, after accepting a device, further decline would be inevitable. Also, the flexed spinal posture necessary to grip and advance a traditionally designed walker exacerbates the visual stereotype of debility, frailty, and dependence[3].

Device Abandonment. Stigmatizing equipment leads to its abandonment, and ultimate withdrawal from exercise and movement [3,7,13]. As discussed above, for elders with mobility impairments, the majority of mobility supports currently available and prescribed are stigmatizing in appearance. In a recent study [14], the walker was seen by users as a negative reflection of identity. Through meta-analysis research, Polgar [15] found that despite some functional benefits, mobility devices, and particularly walkers, were frequently abandoned because this equipment "reinforces a discrediting attribute and enhances the perception of stigma". (p.20).

Other investigators have approached abandonment research by examining the factors that promote adoption and continuation of regular exercise[16]. Of particular prominence in this large literature are the roles of social support and enjoyment of outdoor exercise environments in influencing adherence, particularly in aging when it is likely that physiological conditions such as pain and mobility impairment increase[17]. Embarrassment, perceived stigma, and limited functionality of durable medical equipment (DME) pose major barriers to the identified positive vectors necessary for fostering adherence to and continuation of fitness activity in social and outdoor settings[18].

Co-Design as Problem Solver

Advancing on older models of user-centered design, co-design genuinely engages service and product users as full collaborators in a collective intelligence and the invention process at the **conceptual fuzzy front end** of the design process. This empowerment model[19] involves end users in designing solutions to their own problems. Because laypersons tend not to be professionally educated designers and thus may not possess the knowledge and skill to initiate a viable design, Ventura and Talamo use prototypes which they define as, "incomplete but flexible communication tool{s} for a design idea, both manifesting and filtering interesting aspects of the original idea". Co-designers then examine, deliberate, and formally analyze the entity using a variety of approaches relevant to the design effort. Forensic analysis is a particularly potent strategy for device evaluation. This process, also referred to as failure analysis, identifies the attributes of a product that can make it fail or be rejected by the target user[2]. The process of activating and demonstrating creativity in user groups while also contributing to the production of a non-stigmatizing device design demonstrated significant potential to undermine negative stereotypes and complex stigma experienced by elders with mobility impairments and more expansively other similar groups [19,20].

**The AFARI Device: Synthesis, Design Principles, and Preliminary Data**

Based on a synthesis of the literature and validated by the co-design analysis, the AFARI shown in Figure 1 was developed and tested. It is a three-wheeled, aesthetically crafted device, designed to counter the visual and functional barriers to participation in safe and comfortable health producing outdoor movement and exercise.

Figure1

Six, well documented principles informed the design and development of AFARI:

1. To promote adherence to regular exercise, movement must be safe, convenient, and easily learned[13];

2. Stigma of the equipment must be absent in that it leads to device abandonment, and ultimate withdrawal from exercise and movement[1,2, 3,]

3. Feedback to users about progress increases motivation[21]

4.Feedback to users and health care providers enhances adherence, safety, and efficacy of use-related health outcomes[2];

5. Upright posture has health benefits and also reduces fall risk, pain, and secondary injury to upper extremities and other parts of the musculoskeletal system caused by ambulating with poor posture[22]; and

6. Unweighting can avoid damage to upper extremities from repetitive stress as may occur with traditional mobility devices[7] .

AFARI can be distinguished from current mobility supports by a number of design features. First the device is specifically crafted for upright movement (as shown in Fig. 1) including brisk walking and exercise in diverse outdoor environments, in contrast to walkers and crutches that are primarily used to support navigation over short distances. Second, AFARI supports safe and stable navigation at diverse speeds and levels of effort, which are key functional differentiators from other assistive devices. Third, it has an active steering mechanism and robust but easy to engage manual braking system. Active steering removes the “shopping cart” feel from the device to allow the user to precisely control direction and safely navigate on uneven terrain. Fourth, unlike plastic systems on many rollators, the disc braking system on AFARI is both effective and easy to activate even by users with hand weakness. Fifth, rather than gripping a device with both hands, AFARI is fitted with arm rests for unweighting using forearms. This feature removes direct impact from the wrist, elbow and shoulder joints, thereby reducing upper extremity and upper body injuries while allowing effective unweighting. Sixth, a force-measuring system developed for this device allows the user’s weight bearing reduction to be measured and displayed to the user and transmitted wirelessly to providers if indicated. This information is important in injury prevention and rehabilitation programs. The ability for patients and clinicians to know exactly how much weight is being unloaded improves the safety of ambulation, ability to set and attain rehabilitation goals, and thus provides motivation for users. If indicated by diagnostic condition, this feature also encourages early mobility, potentially leading to rapid and efficacious post-surgical outcomes. The hardware and software for the weight bearing measuring system is being developed and includes Bluetooth Smart (BLE) capability. It can be used in conjunction with activity trackers such as Fitbit or Jawbone. Seventh, AFARI is designed for natural posture, providing comfort and a healthy stance while eliminating the safety threats and secondary injury factors that result from walking in a stooped position and looking down. Natural posture is emphasized as a major physical and social benefit of the device, as affirmed in co-design sessions. Eighth, the design of AFARI is contemporary and deliberate. It does not look like a stigmatizing “medical device” but rather is crafted to appear like a piece of exercise equipment, mediating against one of the major reasons for abandonment; stigmatized, burdensome devices which people are embarrassed to use in public settings[1]. Lastly, AFARI is lightweight with component pieces being 10 lb. or less, and it is easily transportable.

**The Study**

Initial research on the benefits and usability outcomes of the AFARI device occurred in two phases, a preliminary testing phase and a usability study of the final design. Health and pain reduction benefits were not investigated in this phase but are planned. (Engineering research to test the integrity of the frame and component parts was also done, but is not detailed in this paper).

*Phase I*

The initial phase of the study employed a multiple holistic case study design (3) in which four individuals (30-63 yrs) with orthopedic and neurological conditions that impaired balance and/or mobility (Table 1) completed a standardized walking trial without assistance (CON) and with AFARI assistance. Selected relevant items from the Activities-Specific Balance Confidence Scale (ABC Scale) were administered following each trial session. The preliminary prototype wireless load sensor system measured the relative unloading achieved by the tester based on body weight (see Table 1). Walking speed and gait characteristics were also monitored. Results indicated that AFARI provided common and condition specific benefits to each of the four testers. A correlation between ABC score and % body weight unloading suggested that increased ABC score may lead to increased self-selected % of body weight unloading.

| User | Condition | Age (yr) | Weight (lbs) | ABC Balance Confidence (%)* | AFARI Weight Unloading (%) |
|---|---|---|---|---|---|
| A | Major knee surgery | 30 | 150 | 54 | 32 |
| B | Fused hip | 63 | 185 | 94 | 10 |
| C | Ataxia | 63 | 103 | 41 | 37 |
| D | Knee osteoarthritis | 57 | 220 | 86 | 23 |

*Activities-specific balance confidence (ABC) scale. >80% high level of physical function, 50-80% moderate level of physical function, <50% low level of physical function

*Phase 2*

To examine the usability of AFARI and its perceived benefits to a broad population of adults with mobility impairments, a mixed method study of adults with mobility impairments due to osteoarthritis was conducted. This population was selected due to the wide prevalence of the condition and the ease of obtaining testers. The following research question was answered in Phase 2:

1. What are the usability, fear of falling, and perceived stigma ratings of AFARI™ according to potential users?

*Population and Sample*

The sample was recruited from a population with the following inclusion criteria:

Over 55 years of age

Community dwelling or residing in assistive living settings

In active treatment for osteoarthritis in one or both lower extremities

Prescribed a mobility support device

Exclusion criteria were:

Non-ambulatory individuals

Individuals residing in nursing homes

Those with health conditions that would render testing unsafe

A total of 47 individuals meeting inclusion criteria and possessing none of the exclusion criteria consented and then participated. All participants had hip, knee, or ankle osteoarthritis. The average age was 64.4 years old (ranging from 58-73). Participants were recruited using flyers, brief verbal presentations, and/or participation request letters.

Data Collection and Analysis

Mixed methods [23] were used to obtain data on fear of falling, stigma, and usability.

*Fear of Falling*

The Falls Efficacy Scale - International (FES-I)[24], a self-report measure that assesses fear of falling (FOF) was selected. The scale lexically defines fear of falling as concern about falling which can limit the engagement in activities of daily living and has the potential to increase fall risk. The FES-I functioned in this study both to assess the FOF in the sample and to examine the extent to which AFARI was perceived as a device that could reduce this fear. A Likert-type four-point scale (not concerned=1 to very concerned=4) was used as the measurement strategy for each activity item. For a total FOF score, responses to all items were summed.

*The Stigma Scale for Chronic Illness (SSCI-8)*

This short scale tests perceived stigma with 5 items asking respondents to rate how they believe others react to them as a result of their condition[25]. Items were slightly revised to assure relevance to the population and device evaluation. A 5-point Likert-type scale (1-5) was used with ascending scores indicating increasing stigma perception on each of the items and then summed for a total stigma score. The five items were:

1. people seem uncomfortable around me,
2. people avoid being with me
3. I feel left out of things,
4. I feel embarrassed about my physical limitations
5. people avoid looking at me.

*Usability*

To examine usability, open-ended forensic analysis (2) and a closed-ended survey were accomplished in a group interview settings with no more than 8 respondents in each group.

**Findings**

On the FES-I, scores ranged from 16-64, with ascending scores indicating increasing fear of falling. Scores over 23 have been associated with moderate to high fall risk. The unaided mean FES-I score in this sample was 30.8 out of a possible total of 64 points, indicating a moderate risk of falls in this sample. When asked to rate the fear of falling while using AFARI, a significant decrease in fear was noted on three items: walking on a slippery surface, walking on uneven ground, and walking in a crowded environment. While other items did not reveal a significant difference, descriptive differences were noted suggesting that fall anticipation decreased on all but one activity.

Table 2- Paired Differences on the FES-I with and without AFARI

| | Paired Differences with and without AFARI | | | | | |
|---|---|---|---|---|---|---|
| | | | | 95% Confidence Interval of the Difference | | |
| | Mean Diff | Std. Deviation | Std. Error Mean | Lower | Upper | Sig. (2-tailed) |
| FOF5 - Shopping | .43 | .535 | .20203 | -.06578 | .92292 | .033* |
| FOF8 – Walking around the neighborhood | .43 | .535 | .20203 | -.06578 | .92292 | .033* |
| FOF10 –Gpong to answer the phone before it stops ringing | .40 | .894 | .40000 | -.71058 | 1.51058 | .363 |
| FOF11 -walking on a slippery surface | 1.00 | 1.195 | .42258 | .00076 | 1.99924 | .028* |
| FOF12 – visiting a friend or relative | .50 | .926 | .32733 | -.27400 | 1.27400 | .169 |
| FOF13 - walking in a crowded place | .43 | .787 | .29738 | -.29909 | 1.15624 | .104 |
| FOF14 - walking on an uneven surface | 1.00 | 1.195 | .42258 | .00076 | 1.99924 | .021* |
| FOF15 – walking up or down a slope | .00 | 1.195 | .42258 | -.99924 | .99924 | .782 |
| FOF16 – going out to a social event | .25 | .886 | .31339 | -.49105 | .99105 | .282 |

*statistically significant at ≤.05**RESULTS:**

As presented in Table 3 below, the mean perceived stigma while using the AFARI device was 13. The most stigma was related to being left out.

Table 3

| Question | Minimum Score | Maximum Score | Mean | SD |
|---|---|---|---|---|
| People Uncomfortable | 1.00 | 3.00 | 2.20 | 1.03 |
| People Avoid Being | 1.00 | 2.00 | 1.20 | .63 |
| I feel left out | 1.00 | 3.00 | 2.20 | 1.03 |
| I feel embarrassed | 1.00 | 3.00 | 2.20 | 1.03 |
| People avoid looking | 1.00 | 3.00 | 1.80 | 1.03 |
| Overal Stigma Score | 7.00 | 13.00 | 9.20 | 2.20 |

Table 4 presents frequencies for the closed-ended usability survey.

| Table 4 - Usability items |
|---|
| 1. For what purposes would you use AFARI (Please circle all) |
| a. regular fitness program n=24 |
| b. outdoor walking with friends/family n=36 |
| c. walking by myself n=16 |
| d. other (please describe) (Walking the dog, n=1, Hiking, n=1) |
| e. Would not use n=2 |
| 2. If you are not likely to use |
| AFARI, why not? (circle all that apply): |
| a. I can walk/jog, run without assistance, n=2 |

*Forensic analysis*

Testers enthusiastically supported the contemporary design of AFARI and indicated that they would be proud to use it in a public space. Three features, upright posture, active steering and weight-bearing on forearms, were the attributes most highly rated by testers. Forensic analysis suggested the following unmet needs:

Ease of folding for transport, inclusion of add-ons such as a seat, drink holder, and even a small motor, ability to customize the device appearance with color choice and frame decals.

**Conclusions**

Before discussing conclusions, some limitations are noted. The population for this study was restricted to elder adults with osteoarthritis. While this decision was made for testing safety, the potential for the device to be of use to other groups such as those with neurological and cardiac conditions was not assessed. Research to examine the effect of a non-stigmatizing functional exercise device for outdoor use in a broad population of elders is therefore warranted. Second, cultural and gender differences were not tested in this study. Given the differences in aesthetic tastes among diverse groups, examining group differences could identify variations in design and feature preferences such that mobility equipment could be specifically tailored to individuals and groups to maximize usability and adherence to regular outdoor activity.

The findings were potent in confirming the usability, stigma reduction, and decrease in fear of falling realized from the design and functionality of AFARI. Consistent with the literature, the results from the Stigma Scale and the FES=I suggest that the sample perceived significant stigma related to typical device use and impairment condition, and had a heightened fear associated with a high risk of falling. It is therefore noteworthy that respondents articulated that use of AFARI decreased fear of falling, particularly during outdoor movement and activity on diverse and slippery terrain. This finding validates the designers' intent to develop a device to encourage outdoor fitness in populations who otherwise would avoid the activity due to fear.

Second, stigma related to typical device use in this sample was affirmed. The reduction in perceived stigma while using AFARI supports the importance of integrating aesthetic design into mobility support, particularly if such equipment is to be used in public. Consistent with the literature, eliminating stigmatizing appearance not only can reduce abandonment, but can motivate device users to go outdoors, thereby reaping the health and social benefits of environments outside of the house.

The usability items suggest that the intent and design of the AFARI device accomplished their aims. Only 2 testers indicated that they would not use AFARI, and provided multiple reasons including lack of need and adequate satisfaction with their current mobility device. Those who affirmed use indicated that they would use the device for its intended outdoor purposes. It is promising to note that twenty-four (n=24) testers would engage in regular exercise with AFARI and 36 would use it for outdoor walking with others. This finding highlights that the stigma reducing aesthetic and functional attributes of mobility devices are important motivators for movement, exercise and social participation.

Six (n=6) testers indicated that they might purchase AFARI from a sporting goods store. Retail outlets would further destigmatize and make mobility devices such as AFARI available to the public along the lines of hiking sticks. However, it is not surprising that ten (n=10) testers indicated that health providers would be the access point to the device. This finding makes current sense given that AFARI initially was tested by individuals with mobility impairments. However, AFARI was developed to meet the needs of a broad and diverse population of elders including those without mobility impairments. Thus, awareness efforts about its uses should be developed for providers as well as for deconditioned elders, those who need or want extra weight bearing support in order to engage in fitness, those desiring stability, or even overweight users who may want to start a fitness program but need the assistance that weight bearing and pain reduction can provide.

Forensic analysis affirmed the value to testers of the aesthetic design, postural integrity, and weight bearing configuration. Additional design changes were recommended and will be evaluated.

Future research will test prolonged adherence and fitness outcomes of AFAFI use, pain reduction, and condition specific clinical benefits.

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