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Feasibility and acceptability of wrist-worn actigraphy to measure frailty in homebound older adults

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Abstract

Background/Objectives: Frailty assessments in older adults are an important prognostic indicator for predicting health-related outcomes. The purpose of this study was to determine the feasibility and acceptability of using a wrist-worn actigraphy device to measure frailty in homebound older adults.

Methods: In this US single-site cohort study, older adult participants were asked to continuously wear an actigraphy device on their wrist for three weeks. Caregivers were asked to complete short descriptive surveys. Surveys collected demographic and subjective frailty measures; sleep and activity data were collected via Actiwatch. Descriptive statistics were performed for quantitative data; qualitative analyses were conducted for open-ended survey questions.

Results: Twelve of the thirteen dyads completed all study activities, participants demonstrated feasibility and acceptability of device use, and dyads reported overall positive experiences.

Conclusion: Findings suggest that wearing a wrist-worn actigraphy device is feasible and acceptable in homebound older adults and can potentially measure objective frailty over time.

Keywords

Frailty, passive sensing, physical activity, caregiver, homebound older adults

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Frailty is defined as a clinically recognizable state of decreased reserve and resistance to stressors resulting from cumulative declines across multiple physiologic systems that increase vulnerability to adverse outcomes.[1,2] The risk of frailty is heightened in older adults, with prevalence rising alongside age. A 2021 review found a frailty prevalence of 11% in adults aged 50–59, increasing consistently within 10-year age groups to 31% in adults aged 80–89 and 51% among adults aged 90 and older.[3] Moreover, frailty serves as a significant prognostic indicator for older adults. Those who are frail experience significantly higher rates of cardiovascular and pulmonary diseases, arthritis, and diabetes; according to Fried et al.,[1] mortality rates are threefold higher for 7-year survival in those who are frail compared to robust counterparts. In addition, frailty is highly prevalent in homebound patients, with estimates suggesting that over 50% are frail and another 40% are considered pre-frail.[4] As a result of the manifestations of physical and cognitive frailty, homebound patients have wide-ranging clinical consequences, including the progression of inactivity and physical, psychosocial, and/or spiritual problems.[5]

Historically, consistently defining and measuring frailty has been challenging due to many contributing factors.[6,7] Various rules-based definitions exist; for instance, Fried et al.'s[1] operational definition of frailty requires the presence of three out of five specific phenotypes: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed, and low physical activity. Aggregating cumulative functional impairments is another way to define frailty[8]; however, this approach can be time-consuming and often relies on self-reporting, making assessment in brief clinical visits difficult.[6,9] A third classification approach relies on clinical judgment to interpret the results of history-taking and clinical examination.[10] While frailty

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assessments are conducted to evaluate predictive value for adverse health outcomes, these objective tools are generally used only during physical exams and thus only assessed periodically at a single point in time. Prior studies have emphasized the significance of real-time data collection and unsupervised monitoring for accurately measuring frailty.[11] However, conducting frailty assessments to guide clinical decision-making and care are limited.[6,7]

Physical activity is an important component of frailty and is incorporated into almost all of the current validated frailty measures.[6] A study by da Silva et al.[12] measured physical activity in adults aged 60–96 and found that higher levels of sedentary behavior and less physical activity correlated with a higher level of frailty. In addition to self-report, wearable passive sensing devices such as pedometers or actigraphy devices are useful in monitoring older adults' physical activity and potentially indicate small changes in physiological function.[11,13] Monitoring older adults' step counts and movement is likely to be effective in predicting frailty, as decreased step counts have indeed been correlated to a higher level of frailty.[14] Furthermore, research suggests a weak correlation between self-reported and direct measures of physical activity, underscoring the immense utility of directly collecting this data.[15]

Many homebound older adults rely wholly on the physical, financial, and psychological support provided by caregivers, making the caregivers ideal reporters of these patients' day-to-day routines and activities.[16] For example, caregivers can provide crucial information to determine a patient's frailty status. Of the current validated frailty measurement tools, both the Rockwood Clinical Frailty Scale and the Gérontopôle Frailty Screening Tool include factors such as living alone, mobility difficulties, and help with activities of daily living (ADLs)—factors often reliant on caregiver input for assessment. In addition, depending on the mental status of the patient, they may not be able to provide accurate answers to questions posed in tools like the "FRAIL" Questionnaire Screening Tool, necessitating observant caregivers to assist.[17] While technological interventions have been shown to support caregivers psychologically and physically in general, no data exist on caregivers' impressions of the use of wearable devices for activity monitoring in at-risk homebound adults.[18,19] However, a recent study of caregivers showed that monitoring their care recipients' overall activity level was among the top five most beneficial information for caregiving.[20]

Wearable sensors have been found feasible for adults and older adults.[11] However, their use among homebound older adults, a population known to have unique care needs compared to their non-homebound counterparts, has not been explored.[4,5] As most homebound older adults rely upon a caregiver, the caregiver perspective is critical to inform indications for sensor use and for assessment and care for the patient population. The purpose of this study was to determine the feasibility and acceptability of using wrist-worn actigraphy to objectively measure frailty over time in older, homebound adults living with multiple co-morbidities. Caregiver perspectives on the participant's use of passive sensors and the potential of data to inform care were also collected. The long-term goal is to quantify changes in frailty using passive devices to inform clinical decision-making and interventions to improve healthcare outcomes.

Methods

We conducted a single-site observational cohort feasibility study from June 2022 to October 2022. The study was conducted in Charlottesville, VA, and surrounding counties. Participants were recruited from a home-based primary care program for older adults that serves homebound older adults across multiple counties through house calls with a team of nurse practitioners, nurse care coordinators, a population health specialist, a clinical pharmacist, and two geriatricians. The program aims to provide in-home primary care medical services, nursing care for the patient, caregiver support, and advance care planning to avoid acute care utilization and improve patients' quality of life. The program targeted dyads living in rural counties located in a central region of an Eastern US state.

Participants

Participants were recruited from the home-based primary care program. They were approached by an employed nurse practitioner for permission to allow a study team member to contact them about the research study. Participants consisted of a dyad of an older adult patient and their primary caregiver. To qualify for the study, patient participants had to be already enrolled in the home-based primary care program, greater than 50 years of age, and be able to understand and speak English. Participants also needed to be able to identify at least one regular daily caregiver. Exclusion criteria were current enrollment in dialysis or hospice care. The caregiver participant had to be greater than 18 years of age, able to understand and speak English, and self-identify as the patient's primary caregiver, defined as either a family member or friend or hired caregiver, who, by patient or proxy report, is most involved in assisting the patient with care. The sample size was dependent on the number of dyads and the size of the home-based primary care program.

Procedures

The study was approved by the University of Virginia Institutional Review Board for Health Sciences Research under approval number HSR220152. The program's nurse practitioner approached potential participant dyads (patient-caregiver) about interest in the study and, if interested, a

Table 1. Sample sleep statistics chart from actiwatch summary sheet

	Bed time	Get up time	Time in bed (hours)	Total sleep time (hours)	Onset latency (minutes)	Sleep efficiency (%)	Wakefulness after sleep onset (WASO—minutes)	Awak.* (#)
Min	6:01:30PM	3:00:30AM	10:27:30	7:25:00	0.00	59.82	7.50	12
Max	2:51:00AM	12:41:00PM	17:17:00	12:51:30	93.50	89.04	191.50	95
Avg	10:08:06PM	9:14:53AM	13:14:10	10:05:47	39.07	76.90	88.64	43.64

*Awak. = Awakening.

study team member called potential participants to describe the study and, if still interested, schedule a home visit. At the first home visit, the patient and caregiver provided written informed consent, or when too cognitively impaired to consent, surrogate consent was obtained. The study team member then administered a Qualtrics-administered survey[21] that included demographic questions and assessed the standard physical activity levels of the patient. The frailty and ADL scores were obtained using the Rockwood and Katz measurement scales.[10,22] The Rockwood Clinical Frailty scale score was assigned by the team member based on their assessment of the patient's functional and physical status. The patient participant then wore the Actiwatch Spectrum Plus (©Koninklijke Philips N.V., 2004–2020) device on their wrist of choice for three weeks. After one week, a study team member called the participants to evaluate the preliminary feasibility and acceptability of the Actiwatch wear and to schedule a second visit. This phone call included a single question for the patient or the caregiver to assess the patient's attitude toward the watch, specifically asking about discomfort, irritation, or any problems or questions regarding study participation. At the three-week follow-up visit, another survey was administered in which the patient and caregiver participants were asked about the experience of wearing a wrist-worn study device, if they had any difficulty with the device, and if receiving physical activity information would be helpful to them. The same frailty and ADL measurements were assessed at this visit as well. Throughout survey administration, the caregiver was allowed to answer for the patient participant if applicable, and this was documented when it occurred. At the end of this visit, participants were given a summary of their average physical activity levels and sleep over the previous three weeks as well as a $25 gift card for their participation in the study.

Equipment

The actigraphy device used in this study was the Actiwatch Spectrum Plus (©Koninklijke Philips N.V., 2004–2020). It is a wrist-worn device that uses accelerometers and light sensors to measure sleep and movement in 30-s-long epochs. Sleep-wake determination and sleep variables were computed by the Actiware software algorithm.[23] Most default settings were used in extracting the Actiwatch data with changes made only in the "Auto-intervals" section of the software. The software was allowed to automatically set major and minor rest intervals and detect more than one rest interval daily. We also adjusted the minimum length of a rest interval to 30 min instead of the default 40 min, due to the known decreased level of physical activity in our target population (5). The software automatically generates a "Clinicians Report" (see Table 1) with descriptive statistics of multiple sleep parameters, including bedtime, get-up time, time in bed (hours), total sleep time (hours), sleep onset latency (minutes), sleep efficiency (percent), wakefulness after sleep onset (WASO, minutes), and awakenings (number).

Measures

Feasibility was measured by enrollment rate, study completion rate, and actigraphy wear time over three weeks. Acceptability was assessed at three weeks post-assessment using four Likert-scaled questions where 1 = Not at all, 2 = Slightly, 3 = Somewhat, 4 = Mostly, and 5= Very: (1) "How easy was it for you to remember to wear the Actiwatch?" (2) "How difficult was it to remember to put the Actiwatch back on?" (3) "How uncomfortable was wearing the Actiwatch every day?" and (4) "How unattractive was the appearance of the watch for you?" Using the same scale, caregivers were also asked how helpful they thought having quantitative physical activity information generated by a passive sensing device would be.

Wear time. The Actiware software[23] automatically converted "off-wrist" time to an "excluded interval," meaning this time was not included in the software's numerical calculations, thus appearing unavailable. However, actigraphy data was retrievable through import by study staff following study completion.

Qualitative surveys. Demographic and subjective physical activity data were collected using a Qualtrics-supported questionnaire at baseline. The post-assessment questionnaire also asked caregivers about how helpful it would be for them to receive sleep and physical activity data, as well as what specific information they were interested in regarding the care recipient's sleep and physical activity. Participant dyads were also asked two open-ended questions in the three-week questionnaire: (1) "What was difficult about wearing the Actiwatch?" and (2) "Is there anything you would like the study team to know about you or your loved one's experience in this study?" The questions were generated by the study team and have not been validated.

Katz ADL. The Katz ADL is a validated instrument for use in older adults[22,24,25] that ranks performance across six functions of bathing, dressing, toileting, transferring, continence, and feeding. It is freely accessible for educational and clinical use.[26] It offers a numerical measure of a patient's ability to complete their ADLs. Independence in any of these functions counts as 1 point, while dependence in that function counts as 0 points, allowing for a maximum score of 6 and a minimum score of 0. Participant dyads were asked about independence vs. dependence for each function, with the Qualtrics survey programed to total these values and calculate the patient participant's score at both the initial and final visits.

Rockwood clinical frailty scale. The Rockwood Clinical Frailty Scale is a validated frailty instrument that relies on an observer or provider assessing a patient's functional and physical status.[10] It is free for research, education, or not-for-profit care.[27] The study team member recorded each patient participant's level on this scale at the initial and final visits through a clinical evaluation of their functionality and clinical status. Clinical and functional participant observations were made during the visit by study staff and were considered when completing the scoring for the Frailty Scale.

Actigraphy data. Physical activity and sleep were measured using the Actiwatch Spectrum Plus (©Koninklijke Philips N.V., 2004–2020). Actigraphy data were extracted using Actiwatch software.[23] Physical activity level was estimated using the activity count data from the Actiwatch, which logged "activity counts" in intervals of 30 s. Based on similar actigraphy studies,[28,29] we established a cutoff activity count value of 100 to indicate non-sedentary activity. The average number of minutes of physical activity per day was estimated by counting the number of epochs exceeding 100. Sleep data was automatically calculated using the Actiwatch software and extracted from each participant's "Clinician's Report"[23] (see Table 1). From this data, the total sleep time, sleep efficiency, and number of awakenings were parameters of interest.

Table 2. Sociodemographic characteristics of older adult study participants.

Baseline characteristic	*n*	%
Age, median, (range)	85 (range 71–98)	
Gender		
Male	3	23.1
Female	10	76.9
Living situation		
Alone	4	30.8
With others	9	69.2
Marital status		
Married	3	23.1
Widowed	9	69.2
Single, never married	1	7.7
Highest level of education		
High school degree	6	46.2
Anything beyond high school	4	30.7
Race		
White or Caucasian	10	76.9
Black	2	15.4
Asian	1	7.7

Analysis

Descriptive statistics were calculated using SPSS Version 29.0.2.0 for participant demographic and actigraphy data. Two-tailed Spearman's correlations were examined between physical activity and frailty, with significance set at $p < 0.05$. Answers to the two open-ended qualitative questions were independently categorized by LF and MM until convergence was met.

Results

Thirteen patient-caregiver dyads were enrolled in the study. Sociodemographic data for patient participants are

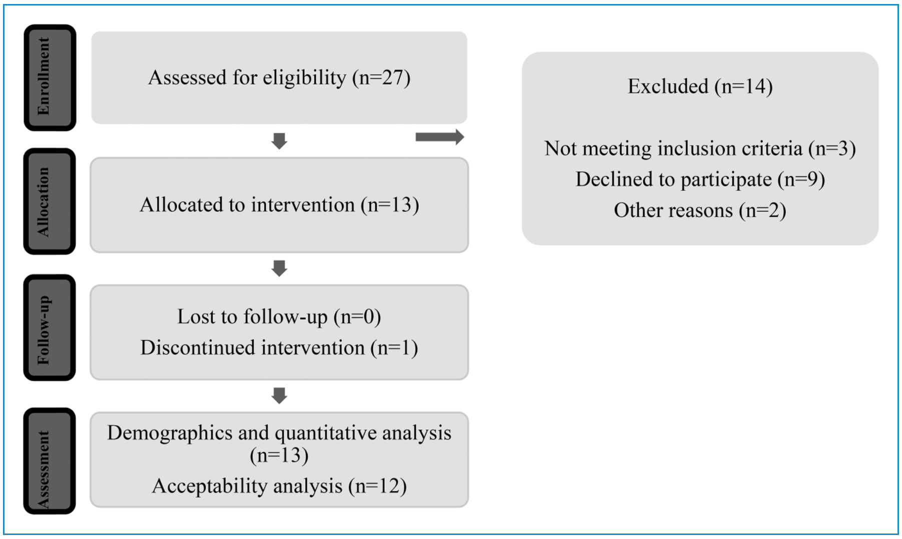

Figure 1. CONSORT flow diagram.

displayed in Table 2. The median age was 85 years (range: 71–98). Ten patient participants identified as white/Caucasian (76.92%), two as Black/African American, and one as Asian. Ten patient participants were female (76.92%), and three were male. The majority of patient participants lived in a household with other people ($n = 9$). There was a median of 11 comorbid diagnoses (range 7–14) and 16 medications (range 6–24) among the patient participants. The most common comorbidities were hypertension ($n = 10$), hyperlipidemia ($n = 8$), dementia ($n = 5$), and congestive heart failure ($n = 5$). Of the caregivers, 11 were female (84.5%), and two were male. Most caregivers were adult children of the participant (61.5%); the rest were married spouses (15.5%), niece/nephew (7.7%), or a hired caregiver (15.4%). Ten caregiver participants identified as White/Caucasian (76.92%), two as Black/African American, and one as Asian.

Out of 27 referred patients, only three were ineligible due to lack of a primary caregiver, nine declined participation, and two were lost to follow-up. Out of 24 eligible dyads, 13 enrolled, with 12 completing study activities. One dropped out of the study after six days of wearing the watch due to loss of interest but allowed inclusion of the limited actigraphy data in analyses. See Figure 1 for an overview of the enrollment process.

Actigraph data show that 11 patient participants wore the Actiwatch 100% of the time without removing it. One participant, who remained enrolled in the study through completion, was hospitalized 6 days into the study. She removed it during her hospital stay and stated she “didn’t feel like putting it back on.” The median total sleep time per night was 598 min (range: 132–752), and the median physical activity per day was 110.5 min (7–477). Median sleep efficiency was 73% (39%–88%), and the median number of awakenings per night was 44.5 (6–80).

Responses to the acceptability questions are presented in Figures 2 and 3. All patient participants who wore the wrist-worn device found it “very easy” to use ($n = 12$). Caregivers reported that knowing physical activity data was very, mostly, or somewhat helpful (58.3%, $n = 7$), while 41.7% ($n = 5$) said that it would be slightly or not at all helpful. Figure 3 presents feedback on participant-reported potential negative aspects of the watch. Only one participant found it difficult to remember to put the Actiwatch back on following a hospital visit; otherwise, all participants kept it on the whole time. Three-quarters of patient participants said the watch was “not at all” uncomfortable, and 91.2% ($n = 11$) of participants said the watch was “not at all” unattractive.

The two open-ended qualitative questions yielded 17 responses among 11 dyads, where six participants (either the patient or the caregiver) answered the difficulty of wear question, and 11 participants (either the patient or the caregiver) answered the question about overall experience. Of the 11 participants who answered the qualitative questions, five provided unsolicited negative feedback, while nine gave unsolicited positive feedback. In addition, three of the participants who provided negative feedback had at least one additional positive thing to say about their experience. Among the negative feedback, one participant complained that the watch was uncomfortable and unattractive and said that “it was too bulky and very annoying on the wrist.” Another participant thought it was a “nuisance,” and another said it “got in the way.”

In terms of positive feedback, seven participants voluntarily endorsed ease of actigraphy use. These included statements such as “it was very effortless” and had a “very simple and low profile—not a hindrance.” Although Actiwatch feedback was overall positive, there were some negative comments regarding the wrist strap. Comments focused on the strap size (“too thick” and “too short”) and

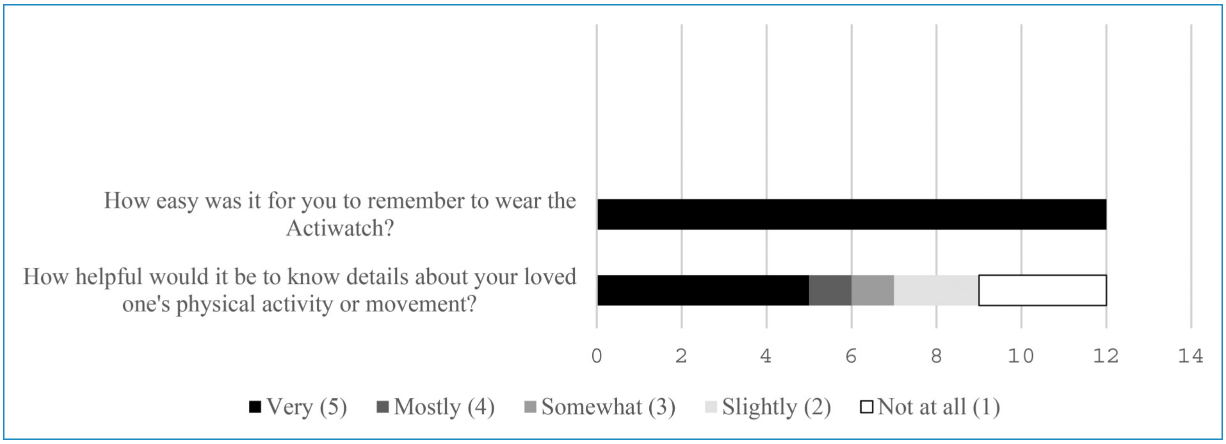

Figure 2. Positive acceptability question responses.

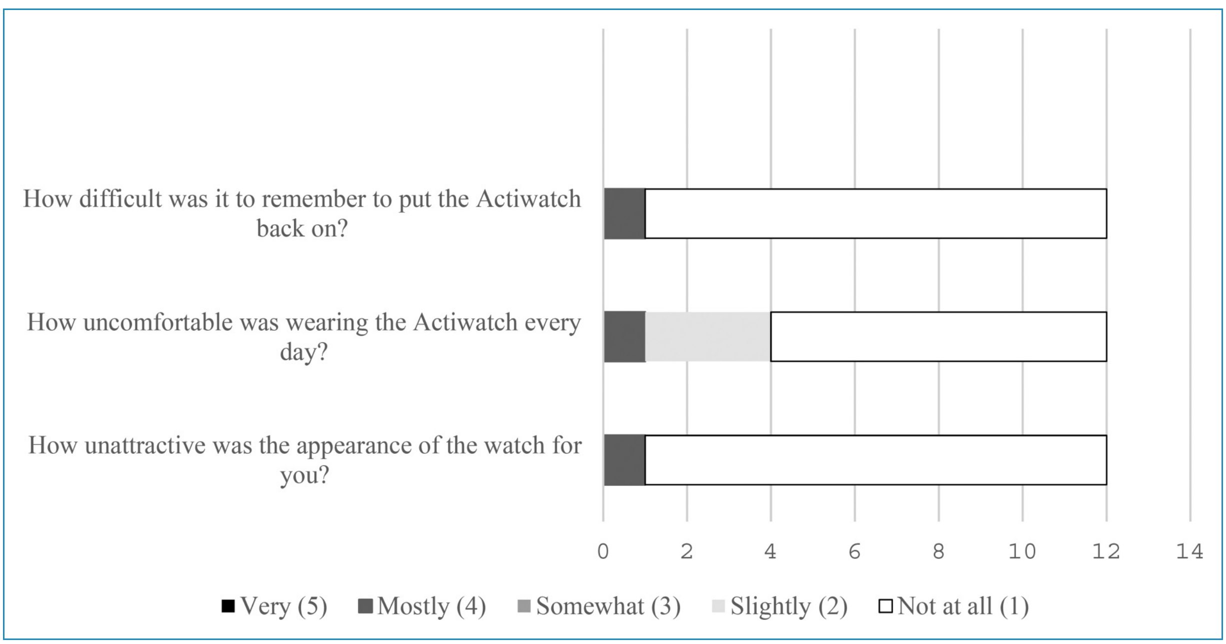

Figure 3. Negative acceptability question responses.

concerns about the strap "stick[ing] out" and getting caught on things. Conversely, three participants noted positive things about the watch strap including it being low profile, not too tight, and "wide enough to not irritate the skin." Although unprompted, there were also comments ($n = 5$) on the use of the Actiwatch that included things participants liked about its function and additional features they wanted to see in the device. Participants appreciated that it provided information on sleep and physical activity ($n = 3$) and expressed a desire for the watch to offer more visible and audible feedback/reminders ($n = 2$).

Increased physical activity was found to be positively associated with the Katz ADL score, $r(x) = 0.68$, $p = 0.016$, and negatively associated with the Rockwood Clinical Frailty score, $r(x) = -0.76$, $p = 0.004$ This implies that increased physical activity is associated with a higher level of ADL (measured by the Katz ADL score). In addition, similar to what would be expected, the negative association of physical activity and the Rockwood Clinical Frailty score indicates that a higher frailty score (i.e., more frail) is associated with a decreased level of physical activity.

Discussion

Findings provide evidence that homebound older adults found wearing a wrist-worn actigraph over three weeks to be feasible and acceptable. The high completion rate and extended wear time are promising indicators that this watch could serve as a viable intervention in older adults. All participants found the watch easy to remember to wear and very few found the watch uncomfortable or unattractive. In addition, the overwhelming majority of participant feedback regarding their experience was positive, with only five out of eleven participants endorsing any difficulty or nuisance they found with the device. In contrast, nine out of eleven participants voluntarily provided positive feedback including things they enjoyed or found useful about the device. This unsolicited feedback is significant, especially since it was provided in response to an open-ended question.

The unsolicited comments on the use of the Actiwatch were noteworthy. Feedback from both patient and caregiver participants recommended device use for gathering information about strength, physical activity, and sleep. Both members of the dyad also provided suggestions on desired additional features for future devices, such as providing reminders, having lights or sounds as alerts, or providing informative feedback. Finally, there was also a focus on strap-related concerns (both positive and negative), suggesting that allowing patients to choose the band for their device may enhance adherence rates. Overall, the wear time, suggested application of the device's use, and additional recommended features indicated a sustained interest in continued use within this patient population.

Caregivers are a crucial part of the care of many frail older adults, making their input essential for the success of any kind of intervention in this population. We included caregivers in this study to assess their perception of this kind of device monitoring as well as gain insight into how it could affect caregiver burden. Our data suggest that caregivers favor the informational gathering aspect of the device. The majority of caregivers indicated that physical activity data could be beneficial for monitoring their loved ones' movements consistently. Additionally, one caregiver was interested in physical activity data to better understand whether the patient could maintain their physical ability and strength after being enrolled in physical therapy. Many caregivers also suggested additional features or recommendations for the device. These results corroborate findings from prior studies that have found caregivers of older adults interested in gaining and understanding health information about their care recipients.[30,31]

Our study also showed a preliminary association between physical activity levels and frailty markers. The statistically significant correlation supports previous findings indicating that physical activity is a significant factor in measuring frailty and that measuring physical activity could be an accurate and reliable quantitative element in the frailty assessment.[6,12] This statistical significance also allows us to draw preliminary associations between physical activity and frailty and ADL scores. It appears that patients with higher ADL scores may have a higher level of baseline functionality and get more physical activity, as shown in earlier research.[32] It also appears that those who have lower frailty scores may also have a higher level of physical activity, confirming prior trends.[11,12]

There are several limitations to this study. Due to the small sample size, it is difficult to generalize these results to the broader homebound older adult and caregiver populations. Furthermore, we only required actigraph wear over three weeks, so there may be differences in wear time or altered objective responses from participants if they were to wear it for an extended duration. Future studies should explore its use and utility in a larger population for a longer period of time. Other commercially available wrist-worn passive sensing devices may be better suited to collect these data in real-time, specifically when considering individual patient needs, duration of wear, and charging time. The Rockwood Clinical Frailty Scale was also subjectively assigned by the team member visiting each participant; however, only one and the same person assessed each participant in this study. The questionnaires used to gather feasibility and acceptability data from the participants were created by the study team and have not been validated; thus, the measures of acceptability may not be comprehensive. Lastly, we enrolled participants under 65, which could be considered below the typical threshold for older adults. There was also a lack of racial and ethnic diversity that needs to be addressed in future studies.

Although there are validated clinical tools and markers of frailty in older adults, few track a patient's clinical status longitudinally or measure variables over time.[6,11] Moreover, these tools rarely aid in diagnosis, treatment, or interventions aimed at improving a patient's quality of life or health.[6] Because frailty is a dynamic condition[17] with a complex mechanism of progressive decline in multiple physiological systems,[33] it has the potential to be modified and improved upon. Focusing on the modifiable components of frailty will help lead to an increased understanding of the real-world implications of a person's frailty experience and open pathways to work to improve on it. Recognizing physical activity as an important marker of frailty[12] offers a possible approach to measuring frailty over time and tapping into the dynamic nature of this complex clinical syndrome. Wearable monitoring devices, such as accelerometers, are an objective and continuous measure of movement patterns, assessing an individual's activity level and functional capacity, and offering insights into frailty levels or risk.[34] Research has shown that physical activity and sleep data measured with wearable devices can be mapped to differentiate between pre-frail, non-frail, and frail individuals.[11] Future studies should further explore how passively collected data such as physical activity and sleep can be used to measure frailty based on our current definition of frailty and participant-specific needs. This data-driven frailty score, or risk score, has the potential to inform clinical decision-making and resource allocation, as well as guide recommendations for lifestyle and behavior changes to improve the health and prognosis of many older adults living with comorbidities.

Conclusion

This study demonstrated the feasibility and acceptability of using a wrist-worn passive sensing device to measure physical activity levels in homebound older adults with multiple co-morbidities. The results suggest that older adults can tolerate a wrist-worn device to measure their activity and even find it enjoyable. Caregivers also showed interest in patient participants using the watches and the informative data generated. There is potential for the use of passive sensing to objectively measure frailty over time, reducing patient and caregiver report burden while providing real-time data on sleep and activity. Future studies should attempt to quantify frailty using passive sensing alongside established subjective measures to explore how caregivers and clinicians can use these data to promote independence and mitigate frailty in homebound older adults.

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Statements and declarations

Ethical considerations

This study was approved by the University of Virginia Institutional Review Board for Health Sciences Research (HSR220152).

Consent to participate

All participants gave written consent for study participation, which was obtained in person.

Consent for publication

Not applicable.

Author contributions/CRediT

LFL, JM, and MM conceived the idea and designed the project. KD and LFL recruited and enrolled the participants. LFL carried out the surveys and data collection. LFL and MM performed the data analysis and wrote the manuscript. All authors reviewed and approved the final manuscript.

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Conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Supplemental material

Supplemental materials, including the surveys used within this study, are available online alongside this article on the journal's website at https://journals.sagepub.com/home/DHJ. Readers can access them by following the supplementary links provided.

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