Original paper

Il-Young Jang¹,² MD; Hae Reong Kim³ MS; Eunju Lee¹ MD PhD; Hee-Won Jung⁴ MD MSc; Hyelim Park¹,² RN; Seon-hee Cheon² RN; Young Soo Lee¹ MD PhD; Yu Rang Park³ PhD

¹Division of Geriatric Medicine, Department of Internal Medicine, Asan Medical Center, Seoul, South Korea
²Pyeongchang Health Center & Country Hospital, Gangwon-do, South Korea
³Department of Biomedical Systems Informatics Yonsei University College of Medicine, Seoul 03722, Korea
⁴Graduate School of Medical Science and Engineering, Korea Advanced Institute Of Science And Technology (KAIST), Daejeon, Korea

Corresponding Authors:
Yu Rang Park, PhD
Department of Biomedical Systems Informatics Yonsei University College of Medicine,
Seoul 03722, South Korea
Email: yurang.park@gmail.com
Phone:

Authors’ contribution
Study concept and design: All authors
Data acquisition: IY Jang, H Park, S Cheon
Data preprocessing: IY Jang, HR Kim, H Park, HW Jung, YS Lee, E Lee
Statistical analysis and interpretation: IY Jang, HR Kim, YR Park
Discussion: IY Jang, HR Kim, YR Park
Drafting of the manuscript: IY Jang, YR Park
Study supervision: IY Jang, S Cheon, EJ Lee
Wearable device-based walking programs in rural older adults can improve physical activity and health outcome: A feasibility study

Abstract

**Background:** Community-dwelling older adults living in rural areas are in a very unfavorable environment for healthcare compared to urban older adults. We thought that intermittent coaching through wearable devices would help to optimize healthcare for older adults in medically limited environments.

**Objective:** We aimed to evaluate whether a wearable device and mobile-based intermittent coaching or self-management can increase physical activity and/or health outcome of small groups of older adults in rural areas.

**Methods:** To address the above evaluation goal, we carried out the "Smart walk" program, which is a healthcare model using a wearable device to promote self-exercise focused on community-dwelling older adults managed by a community health center. We randomly selected older adults who had enrolled in a population-based, prospective cohort study of aging, the Aging Study of Pyeongchang Rural Area. The "Smart Walk" program was a 13-month program from March 2017 to March 2018, consisting of six months of coaching, one month of rest, and six months of self-management. We evaluated (1) differences in physical activity and health outcome according to frailty status and (2) pre- and post-analyses of the Smart walk program. We also performed intergroup analysis according to adherence of wearable devices.

**Results:** We recruited 22 participants (11 robust and 11 pre-frail older adults). The two groups were similar in most variables, except age, frailty index, and SPPB score associated with frailty criteria. After a six-month coaching program, the pre-frail group showed significant improvement in usual gait speed (0.73±0.11 vs. 0.96±0.27, P=0.02), IPAQ Kcal
(2790.36±2224.62 vs. 7589.72±4452.52, P = 0.01), and Euroqol-5D score (0.84±0.07 vs. 0.90±0.07, P=0.02) variables, although there was no significant improvement in the robust group. The average total step count was significantly different, and that of the coaching period was approximately four times higher than that of the self-management period (5,584,295.83 vs. 1,289,084.66, P <0.001). We found that the ‘long-self’ group who used the wearable device for the longest time increased body weight and BMI by 0.65 ± 1.317 and 0.097 ± 0.513, respectively, compared to other groups.

**Conclusion:** Our Smart walking program improved physical fitness, anthropometric measurements, and geriatric assessment categories in a small group of older adults in rural areas with limited resources for monitoring. Further validation through various rural public health centers and a large number of rural older adults is required.

**Trial Registration:** This study was approved by the Asan Medical Center institution’s ethics committee (IRB File No: 2015-0673)

**Keywords:** wearable device, older adult, adherence, rural area, frailty
Introduction

Distinct from young adults, the elderly have different medical characteristics. Each older adult has a highly heterogeneous health status.[1, 2] Even with definite illness, symptoms are frequently ambiguous and non-specific in older adults.[1] Also, there are many frail older adults whose physiologic reservoirs are diminished and easily deteriorated regardless of comorbidities.[3] Therefore, early detection and appropriate preventive approach are crucial for older adults.

Many of the older adults living in the community show sedentary behavior. There are reports that more than 60% of community-dwelling older adults are sedentary.[4] Sedentary behavior is an important risk factor for cardiovascular disease,[5] falls,[6] and frailty[7] in older adults and is known to be associated with high mortality.[8] Therefore, preventing sedentary behavior and increasing physical activity for older adults are important in the public healthcare model.

However, community-dwelling older adults living in rural areas are in a very unfavorable environment for healthcare compared to those living in an urban environment. Healthcare facilities are usually poor or accessibility is limited in rural area.[9] In addition, rural dwellers have a relatively low socioeconomic status, lower education level, and a higher prevalence of living alone, multi-morbidity, frailty, and disability than urban older adults.[10] Thus, the role of a public health center is increasingly emphasized in rural areas with an optimized public health strategy. However, rural public health centers also should service relatively larger areas of dispersed older adults with insufficient resources, making it difficult to manage the cost-effective healthcare model. In addition, like several other Asian countries, the older population in rural Korea is increasing more rapidly than in urban areas.[11] Those greater burdens of aging-related health conditions and resource barriers for healthcare in rural area...
facilitate the paradigm shift from disease management to healthcare and prevention.

The health benefits of wearable devices are known in the older population.[12] Accurately assessing the physical activity in older adults through interviews and examination requires considerable time and effort.[13] Wearable devices have been applied to monitor physical activity, falls, or behavior of community-dwelling older adults and have been applied to change the lifestyle and reduce metabolic risk of older adults with chronic diseases.[14-16] From the perspective of public healthcare, mobile healthcare services are in the limelight. Specifically, it has been shown that such mobile services could induce behavioral change by adding coaching or incentive to wearable devices.[17] Some wearable device could be suitable upon adjusting for rural health resources. However, there are reports that adherence is reduced to less than 10% if the benefit to the participant disappears.[18] Further, those incentives can only be supported for a limited period. In rural areas, it is important to develop a wearable device-based healthcare program that can be operated with a small amount of resources and to encourage voluntary self-management after the end of the program.

Despite unfavorable conditions, public health centers in rural areas have several unique strengths for community studies.[9] Geographical isolation from private hospitals helps maximize the participation rate of the senior population within a short period, as well as the long-term retention rate.[19, 20] We thought that a mobile healthcare service centered on public-health center was the most affordable, easy to access, and a relatively costless method for healthcare of rural older adults. We aimed to evaluate whether a simple mobile healthcare device and mobile-based intermittent coaching or self-management can increase the physical activity and health outcome of older adults in rural areas.
Materials and method

Study design

In this study, we aimed to identify the following three questions. 1) Can a wearable device improve the physical activity and health outcomes of older adults in rural areas? 2) Are there differences in physical activity and health outcome improvement depending on frailty status? 3) Are there differences in wearable device adherence between coaching and self-management? To address the above questions, we carried out the "Smart walk" program as a healthcare model using a wearable device to promote self-exercise of community-dwelling older adults managed by a community health center. We selected older participants who had enrolled in the population-based, prospective cohort study of aging, the ASPRA (Aging Study of Pyeongchang Rural Area). The ASPRA cohort was established in October 2014 to determine the burden of frailty and geriatric syndromes in rural areas, understand the disparities between urban and rural older populations, and set the priority of public health interventions. The design and measurement protocol are described elsewhere [9, 10]. Briefly, participants living in rural Pyeongchang, located 180 kilometers east of Seoul, South Korea, were administered an annual comprehensive geriatric assessment including physical, mental, psychosocial, and frailty status, as well as medical conditions. The inclusion criteria were 1) age 65 years or older, 2) registered in the National Healthcare Service, 3) ambulatory with or without an assistive device, 4) living at home, and 5) able to provide informed consent. Those who were living in a nursing home, hospitalized, or bed-ridden and receiving nursing-home-level care at the time of enrollment were excluded. To conduct this project, an academic-public health collaborative team was organized, and about 95% of eligible older adults in the study area were enrolled. The characteristics of ASPRA participants were similar to those of the Korean rural population represented in the Korea National Health and Nutrition Examination Survey [9].
Frailty and comprehensive geriatric assessment

In recent decades, a frailty-based approach has been widely applied in communities having an older population.[21] Frailty is an age-related syndrome characterized by decreased physiologic reserve and increased vulnerability to the stressors that lead to adverse health outcomes such as disability, falls, institutionalization, and mortality.[3] Unlike the traditional comorbidity-based approach, a frailty-based strategy contains the concepts of an individualized approach, disability prevention, and enhancing quality of life regardless of age.[22] In this study, we screened the potential participants using Cardiovascular Health Study (CHS) frailty phenotype criteria, one of the most widely used assessment tools. For quantitative evaluation of frailty status, we used the frailty index suggested by Rockwood et al.[23], which encompasses physical, cognitive, psychosocial, geriatric syndrome, disability, and underlying disease. Scores vary from 0 to 1; a higher score indicates a more severe frailty burden [20].

Trained nurses administered the comprehensive geriatric assessment using the following instruments: the International Physical Activity Questionnaire (IPAQ) short form, the Korean version of the Mini-Mental State Examination (K-MMSE) for cognitive function, the Korean version of the Center for Epidemiological Studies Depression (CES-D) scale for depressive mood, usual gait speed, the Mini-Nutritional Assessment-Short Form (MNA-SF) score for malnutrition, multimorbidity, grip strength on dominant arm, the Short Physical Performance Battery (SPPB) score, and bio-impedance analysis using Inbody 620 (Inbody, Seoul, Korea). Detailed methods were described previously.[9]

Smart Walk Program

The "Smart Walk" program was a 13-month program conducted from March 2017 to March 2018, consisting of six months of coaching management, a one month rest, and six months of
self-management. There was an incentive (including two group picnics, $50 worth of nutritional supplements, and a wearable device worn by the participant) to encourage participants during the six-month coaching period only, followed by a seven-month follow-up with monthly questionnaires and data logs from the wearable device. Coaching was performed by eight health center staff through notification messages of the wearable device. If there was no record of device use, weekly follow-up was performed.

As there are no existing criteria for adherence of a wearable device, this study defined the criteria as continuous use if the device was used for at least one week per month. This criterion refers to the follow-up at weekly intervals during the coaching period.

This study was approved by the institutional review board of the hospital (IRB no. 2015-0673). We obtained a research study personal information agreement and exercise commitment letter from the study participants.

**Data description**

In this study, we collected three types of data: 1) data from the whole period of the wearable device, 2) Comprehensive Geriatric Assessment (CGA) before and after the coaching program, and 3) monthly questionnaire data during the follow-up period. The wearable device used in this study was a Xiao Mi Mi band 2. We chose this device because it is the model with the lowest battery consumption (up to three weeks on a single charge). We used only the step count for analysis. All participants underwent CGA that encompassed the assessment of cognitive and physical function, depression, nutrition, and body composition using bioimpedance analysis identical with the protocol of ASPRA cohort and an additional three-minute walk test before and after the coaching program [24]. The detailed measurements and definitions are described elsewhere [9]. Monthly assessment of geriatric
conditions was performed by an experienced nurse based on one-to-one interview by telephone or face-to-face meeting. The nurse also obtained information on demographic characteristics, living status, occupation, income, education level, chronic conditions, etc. (detailed variables are in Hee-Won Jung et al. [9]).

**Data analysis**

Among a total of 1,166 participants who participated in the ASPRA cohort, we excluded 177 participants who were graded within the frail state (based on CHS frail criteria [25]) in which participation in the “Smart Walk” program was difficult (Fig. 1). Of the 754 participants who were classified as robust or pre-frail, we randomly selected 22 older adults (Robust group = 11 and pre-frail group = 11) to participate in the “Smart walk” program. Those who could not walk 100 meters without an assistive device were excluded.

![Figure 1. Recruitment of the Smart Walk program in the Aging Study of Pyeongchang Rural Area Cohort.](image-url)
The initial data analysis compared the differences in physical activity and health outcome according to frailty status. Since the total number did not exceed 30, we performed a non-parametric test using Mann-Whitney-Wilcoxon and Fisher’s test for mean and ratio evaluation, respectively. To confirm the coaching effects before and after the "Smart walk" program, we also performed the non-parametric Wilcoxon signed-rank test on the pairs. The last analysis analyzed the health outcome according to adherence of the wearable device. According to adherence, the participants of the program were divided into the following three groups: 1) coaching only, 2) short-term self, and 3) long-term self. The Kruskal-Wallis test was performed to evaluate the differences among the three groups, and all pairwise analysis was performed with Mann-Whitney-Wilcoxon and Fisher’s tests for mean and ratio, respectively. All reported P-values were two-sided, and P-values less than .05 were considered significant. Data analyses were conducted with the R software, version 3.3.1 (R Foundation).

Result

Overall characteristics

In March 2017 to March 2018, 22 older adults participated in the Smart walk program (robust group: n = 11, 8/11 male; pre-frail group: n = 11, 6/11 male). The two groups were similar in most variables, except age, frailty index, and SPPB score associated with CHS frail criteria (Table 1). Although not statistically significant, the variables of living alone, including risk of malnutrition and fall in the past year, were higher in the pre-frail group. None of the participants were low income receiving national medical aid.

Table 1 Overall characteristics of participants of the Smart walk program by CHS frail index

<table>
<thead>
<tr>
<th>Variables</th>
<th>Robust (N=11)</th>
<th>Pre-frail (N=11)</th>
<th>P-value</th>
<th>Total (N=22)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th></th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (mean±SD)</strong></td>
<td>68.63±1.85</td>
<td>72.54±4.298</td>
<td>0.025</td>
<td>70.59±3.801</td>
</tr>
<tr>
<td><strong>Gender (M, %)</strong></td>
<td>72.70%</td>
<td>54.60%</td>
<td>0.659</td>
<td>63.60%</td>
</tr>
<tr>
<td><strong>Education level (mean±SD)</strong></td>
<td>11.54±4.22</td>
<td>10.45±5.3</td>
<td>0.658</td>
<td>11±4.711</td>
</tr>
<tr>
<td><strong>Medical aid (monthly income &lt; USD 500) (%)</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Living alone (%)</strong></td>
<td>0%</td>
<td>18.20%</td>
<td>0.476</td>
<td>9.09%</td>
</tr>
<tr>
<td><strong>Frailty index (mean, sd)</strong></td>
<td>0.07±0.04</td>
<td>0.17±0.085</td>
<td>0.005</td>
<td>0.12±0.083</td>
</tr>
<tr>
<td><strong>Multimorbidity (%)</strong></td>
<td>0.09±0.11</td>
<td>0.14±0.094</td>
<td>0.1637</td>
<td>0.12±0.106</td>
</tr>
<tr>
<td><strong>Cognition: MMSE score (mean±SD)</strong></td>
<td>28.81±0.60</td>
<td>27.90±1.814</td>
<td>0.252</td>
<td>28.36±1.399</td>
</tr>
<tr>
<td><strong>Mood: CES-D score (mean±SD)</strong></td>
<td>2.09±2.73</td>
<td>4.81±4.262</td>
<td>0.09</td>
<td>3.45±3.764</td>
</tr>
<tr>
<td><strong>Body Mass Index (mean±SD)</strong></td>
<td>24.26±2.74</td>
<td>25.41±3.478</td>
<td>0.949</td>
<td>24.84±3.115</td>
</tr>
<tr>
<td><strong>At risk of malnutrition: MNA-SF (%)</strong></td>
<td>9.1%</td>
<td>18.2%</td>
<td>1</td>
<td>13.6%</td>
</tr>
<tr>
<td><strong>SPPB score (mean±SD)</strong></td>
<td>11.81±0.40</td>
<td>10.54±0.934</td>
<td>0.0008</td>
<td>11.18±0.958</td>
</tr>
<tr>
<td><strong>Dominant grip strength (mean±SD)</strong></td>
<td>35.67±9.01</td>
<td>28.30±7.99</td>
<td>0.133</td>
<td>31.99±9.125</td>
</tr>
<tr>
<td><strong>Fall in the past year (%)</strong></td>
<td>0.0%</td>
<td>27.3%</td>
<td>0.214</td>
<td>13.6%</td>
</tr>
</tbody>
</table>

MMSE: Mini-Mental State Examination, CES-D: Center for Epidemiological Studies Depression, MNA-SF: Mini Nutritional Assessment Short-Form, SPPB: Short Physical Performance Battery
Comparison of health improvement during the coaching program

We analyzed health improvement by frail status through coaching by managers of public health center for the first six months of the Smart walk program. There was no statistically significant difference in the Robust group, but the Pre-frail group showed significant improvement in Usual gait speed (0.73±0.11 vs. 0.96±0.27, \( P = 0.02 \)), IPAQ Kcal (2790.36±2224.62 vs. 7589.72±4452.52, \( P = 0.01 \)) [26], and Euroqol-5D score (0.84±0.07 vs. 0.90±0.07, \( P = 0.02 \)) [27]. In the total group, physical fitness, anthropometric measurements, and geriatric assessment categories such as usual gait speed (0.85±0.21 vs. 1.02±0.27, \( P = 0.003 \)), IPAQ Kcal (3013.63±2387.08 vs. 7868.5±6250.56, \( P = 0.001 \)), BMI (24.84±3.11 vs. 24.52±3.36, \( P = 0.02 \)), and total fat mass (18.85±6.15 vs. 17.82±6.41, \( P = 0.01 \)) were significantly improved.

Table 2 Comparison of health improvement by Cardiovascular Health Study frail index with coaching program

<table>
<thead>
<tr>
<th>Physical performance (mean±SD)</th>
<th>Robust (N=11)</th>
<th>Pre</th>
<th>Post</th>
<th>P</th>
<th>Pre-frail (N=11)</th>
<th>Pre</th>
<th>Post</th>
<th>P</th>
<th>Total (N=22)</th>
<th>Pre</th>
<th>Post</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-minute walk test [meter]</td>
<td>249.18±76.59</td>
<td>266.00±50.40</td>
<td>0.2</td>
<td>4</td>
<td>236.81±110.37</td>
<td>252±80.06</td>
<td>0.39</td>
<td></td>
<td>243±92.92</td>
<td>259.00±65.67</td>
<td>0.14</td>
<td></td>
</tr>
<tr>
<td>Maximal grip strength in dominant arm [kg]</td>
<td>35.67±9.01</td>
<td>35.06±7.52</td>
<td>0.3</td>
<td>6</td>
<td>28.30±7.99</td>
<td>29.25±7.00</td>
<td>0.91</td>
<td></td>
<td>31.99±9.12</td>
<td>32.15±7.69</td>
<td>0.65</td>
<td></td>
</tr>
<tr>
<td>Usual gait speed [sec]</td>
<td>0.97±0.21</td>
<td>1.08±0.26</td>
<td>0.12</td>
<td></td>
<td>0.73±0.11</td>
<td>0.96±0.27</td>
<td>0.02</td>
<td></td>
<td>0.85±0.21</td>
<td>1.02±0.27</td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td>Chairstand [sec]</td>
<td>8.06±1.98</td>
<td>7.3±2.01</td>
<td>0.14</td>
<td></td>
<td>8.92±2.56</td>
<td>8.58±1.64</td>
<td>0.89</td>
<td></td>
<td>8.49±2.27</td>
<td>7.96±1.90</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>IPAQ Kcal [MET-min/wk]</td>
<td>3236.90±2628.2</td>
<td>2617.27±7877.19</td>
<td>0.0</td>
<td>5</td>
<td>2790.36±2224.6</td>
<td>7589.72±4452.52</td>
<td>0.01</td>
<td></td>
<td>3013.63±2387.08</td>
<td>7868.5±6250.56</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Anthropometric measurements (mean±SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body Mass Index [kg/m²]</td>
<td>24.26±2.74</td>
<td>23.83±2.90</td>
<td>0.0</td>
<td>8</td>
<td>25.41±3.47</td>
<td>25.21±3.77</td>
<td>0.24</td>
<td></td>
<td>24.84±3.11</td>
<td>24.52±3.36</td>
<td>0.02</td>
<td></td>
</tr>
<tr>
<td>Skeletal Muscle Index adjusted</td>
<td>7.38±0.76</td>
<td>7.47±0.74</td>
<td>0.17</td>
<td></td>
<td>6.84±0.78</td>
<td>6.89±0.83</td>
<td>0.41</td>
<td></td>
<td>7.11±0.80</td>
<td>7.18±0.82</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>by height[^2] [kg/m^2]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total fat mass [kg]</td>
<td>16.82±5.27</td>
<td>15.69±5.04</td>
<td>0.06</td>
<td>20.88±6.53</td>
<td>19.95±7.14</td>
<td>0.10</td>
<td>18.85±6.15</td>
<td>17.82±6.41</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geriatric assessment (mean±SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CES-D score</td>
<td>2.09±2.73</td>
<td>4.09±4.46</td>
<td>0.33</td>
<td>4.81±4.26</td>
<td>6.81±6.22</td>
<td>0.34</td>
<td>3.45±3.76</td>
<td>5.45±5.46</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Euroqol 5D-3L score</td>
<td>0.92±0.02</td>
<td>0.92±0.05</td>
<td>1</td>
<td>0.84±0.07</td>
<td>0.90±0.07</td>
<td>0.02</td>
<td>0.88±0.06</td>
<td>0.91±0.06</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE score</td>
<td>28.81±0.60</td>
<td>28.81±0.87</td>
<td>1</td>
<td>27.90±1.81</td>
<td>28.54±2.01</td>
<td>0.10</td>
<td>28.36±1.39</td>
<td>28.68±1.52</td>
<td>0.17</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IPAQ: International Physical Activity Questionnaire, CES-D: Center for Epidemiological Studies Depression, MMSE: Mini-Mental State Examination
Comparison of wearable device adherence during coaching and self-management

The proportion of wearable device continuous users showed a large difference between coaching and self-management periods (average: 21.83 vs. 8.16 persons, \( P < 0.001 \)) (Fig. 2). In particular, the total step average was significantly different between the two periods, with that of the coaching period being about four times higher than that of the self-management period (5,584,295.83 vs. 1,289,084.66, \( P < 0.001 \)). The average monthly steps of the robust group and the prefrail group also differed markedly during the coaching period, while both were lower during the self-management period.

Five of the 22 users (robust 1 and pre-frail 4) participated only in the coaching period (from March to September), and 11 people (robust: 8 and pre-frail: 3) participated through the short self-management period (from March to December). Long self-management (March 17 to March 18) included six people (robust: 2 and pre-frail: 4). An unusual finding was that The pre-frail person used the wearable device longer than the robust person, but the average step number per month of the pre-frail group was half that of the robust group.

Figure 2 Average step count and number of continuous users in robust and pre-frail groups by month. Histogram
plot is continuous users per month, and line plot is average total step count per month. The error bar of the line plot represents the standard deviation of average step count.

Figure 3 compares the monthly average number of steps and standard deviation between the three groups (coaching, short-term self, and long-term self-management). The long-term self-group and the coaching group differed significantly (average: 106309.15 vs. 222725.73 steps, $P = 0.02$). The short term self-group was similar to the coaching group at the beginning of the program, but it was more similar to the long self-group in the middle term.

![Figure 3 Monthly average step count by group of continuous use of the wearable device.](image)

**Health improvement comparison according to adherence of the wearable device**

Two participants were dropped during the research period. According to the CHS frailty criteria, both were in the robust group. The dropped participants refused the geriatric assessment 4 months after the coaching period. However, they showed more than 90% adherence for the six-month coaching period and were classified into the coaching group.
In the long-self group, there was not a single fall during the entire 13-month period, while an average of 0.25 and 0.4 falls occurred in the coaching and short-self groups, respectively. The number of outpatient days was an average of 10 or more in all three groups, with little difference between groups. There was no hospital admission in all three groups, and ER visits were reported only in the coaching group. Weight decreased by -1.325 ± 1.824 and -0.65 ± 1.317 in coaching and short-self groups, respectively, and increased by 0.65±1.317 in the long-self group. Similarly, BMI also increased in the long-self (0.097 ± 0.446) and decreased in the other two groups (coaching: -0.416±0.446 and short-self: -1.097±3.373). The MNA values decreased in short-self, but increased in the other two groups. There was no significant difference between all pairwise two-group comparisons (Supplementary Table 1.)

Table 3 Comparison of health improvement according to adherence type of the wearable device

<table>
<thead>
<tr>
<th></th>
<th>Coaching (N=4)</th>
<th>Short (N=10)</th>
<th>Long (N=6)</th>
<th>p-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of falls</td>
<td>0.25±0.5</td>
<td>0.4±1.265</td>
<td>0±0</td>
<td>0.489</td>
</tr>
<tr>
<td>Number of outpatient days</td>
<td>10.5±10.472</td>
<td>10±6.864</td>
<td>10.5±4.722</td>
<td>0.996</td>
</tr>
<tr>
<td>Number of admission days</td>
<td>0±0</td>
<td>0±0</td>
<td>0±0</td>
<td>NaN</td>
</tr>
<tr>
<td>Number of ER days</td>
<td>0.25±0.5</td>
<td>0±0</td>
<td>0±0</td>
<td>0.135</td>
</tr>
<tr>
<td>Weight [kg]</td>
<td>-1.325±1.162</td>
<td>-0.65±1.824</td>
<td>0.65±1.317</td>
<td>0.066</td>
</tr>
<tr>
<td>Body Mass Index [kg/m²]</td>
<td>-0.416±0.446</td>
<td>-1.097±3.373</td>
<td>0.097±0.513</td>
<td>0.295</td>
</tr>
<tr>
<td>MNA score</td>
<td>0.25±2.062</td>
<td>-0.2±1.687</td>
<td>0.333±0.516</td>
<td>0.655</td>
</tr>
<tr>
<td>K-frail score</td>
<td>0±1.414</td>
<td>0.3±1.059</td>
<td>0.167±0.408</td>
<td>0.602</td>
</tr>
</tbody>
</table>

* The Kruskal-Wallis test, a non-parametric test of three or more groups, was performed. ER: Emergency Room, NaN: Not a Number, MNA: Mini Nutritional Assessment

**Discussion**

This feasibility study showed that wearable device-based intervention had a significant effect on physical performance (usual gait speed and IPAQ Kcal) and anthropometric measurements (Body Mass Index and total fat mass) in rural older adults. In particular, usual gait speed \( (P=0.022) \), IPAQ Kcal \( (P=0.01) \), and Euroqol 5D-3L score \( (P=0.022) \) were
significantly improved in the pre-frail group compared to the robust group. In addition, compliance of wearable devices in this study confirmed a pattern of persistent use for 12 months or more by a total of 30% of users compared to the 10% one-year continuous use rate of other studies [18]. Four of six users of the long self-management group belonging to the pre-frail group support the rationale that health concerns are among the factors that increase adherence to wearable devices. Also, we found that the long-self group using the wearable device for the longest time showed an increased body weight and BMI by 0.65 ± 1.317 and 0.097 ± 0.513, respectively, compared to other groups. Decreased body weight in older adults is not a positive indicator for health outcome due to increasing loss of muscle mass [28]. In this respect, we improved the health outcome of the older population using wearable devices for a long time. Our findings match those of previous studies reporting that individualized programs and self-management techniques could enhance physical activity adherence among older adults [29-31].

Our positive results may be explained by two factors. First, in order to maintain high adherence, we collaborated with public health centers to reduce the cost of managing and encouraging older adults and chose a low management cost wearable device. Lewis et al. reported that wearable-only interventions tend to produce only a modest effect on improving physical activity behavior [32]. Therefore, we decided not only to select a wearable device, but add human intervention via collaboration with the public health center. The burden of checking the participants via smartphone every week and sending a message to the poor exerciser from a health center worker did not exceed 5% of the weekly working time, even in a manpower-restricted rural public health center. When selecting the appropriate device for rural order adults, the features of simple, easy to use, cheap, and long battery life > 3 weeks from a single charge helped achieve a higher adherence.
Second, by comparing coaching and self-management components, older people demonstrated that long-term use of wearable devices can be increased as needed. There are many studies on the strengths of the wearable device, but there are still many studies that have not maintained sustainable use and therefore have poor health outcomes [18, 33]. However, the higher long-term use in the less healthy pre-frail older adults in this study may lead to a new perspective on adherence to wearable devices. In other words, if long-term management is performed for users who need healthcare, not the general public, the low adherence of the wearable device can be improved. In this study, the long-self group using long-term wearable devices showed improved health outcomes in terms of nutrition (MNA score), physical activity (number of steps), and anthropometric measurements (weight and BMI).

**Limitations of this study**

The main limitation of this study is that it did not have many participants. The first goal of this study was to examine the possibility of older people to use wearable devices. Hence, a feasibility study utilizing a small number of individuals with different frailty levels rather than a large number of users was required. As a result, we verified the high level of adherence and health outcome of wearable devices in this study. Based on the results of this study, further studies are planned for many older adults with various frailty levels. The second limitation is that this study excluded frail older adults. The targeted daily step count of the wearable device was set by the researcher to increase by 1,000 steps every two months and finally reach 7,000 steps. Thus, frail older adults were not suitable for this study and were excluded, which could worsen the conditions of the frail adults. Further studies, however, are required to improve the health outcome of these frail older adults.

**Acknowledgement**
We thank our study participants and their family members in Haanmi-ri and Gaesu-ri, Pyeongchang-gun, Gangwon-do, Republic of Korea. We are also grateful to public health professionals at the Community Health Posts and County Hospital who provided administrative support.

References


