AIoT-Based Ergometer for Physical Training in Frail Elderly with Cognitive Decline: A Pilot Randomized Control Trial

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Abstract

Purpose Reduced physical activity is reported in the elderly, especially in institutional residents. Institutionalized older adults exhibit a high prevalence of frailty. In this work, we developed an artificial intelligence of things (AIoT)-based feedback assistive strengthening ergometer (AIFASE), for the physical strengthening of the elderly with intelligent assistance.

Methods We conducted a 12-week intervention in a long-term care facility. In total, 16 participants (84.38 ± 6.0 years; 4 males and 12 females) were recruited with 1:1 randomization of exercise to control groups. The muscle strength of the lower extremities, timed up and go test (TUG), and Short-form Physical Performance Battery (SPPB) of the participants were measured. The AIFASE system allows the clinical staff to record the personal physical performance of the elderly and generates personalized exercise prescriptions accordingly. AIFASE also displays the current usage status of all ergometers and the users’ physiological conditions. The algorithms were developed to generate warning alerts when the training workload was too large by personal physiological detection. AIFASE automatically customized the exercise prescription according to the user’s exercise performance.

Results After a 12-week AIFASE intervention, the intervention group exhibited significant improvements in the strength of the hip flexor, Semi-Tandem Stand, and Tandem Stand.

Conclusion In this study, we developed an AIoT ergometer that delivered customized physical training prescriptions to improve the physical performance of long-term care facility residents. We believe that the application of AIFASE will help improve the quality of institutional care.

Keywords Frailty · Artificial intelligence of things (AIoT) · Ergometer · Long-term care facility · Physical performance
1 Introduction

According to a report by the World Health Organization, the number of people aged 65 years or more was 703 million in 2019, and was expected to more than double by 2050 [1]. With the global aging, there is an emerging issue in frailty. The global prevalence of frailty among people aged 65 years and older was more than 10% [2]. In Taiwan, there was a frailty rate of 19% in elderly outpatients [3]. The prevalence of prefrailty in the elderly over 65 was 40.0% [4]. The muscle mass and strength gradually decline with age in the elderly. During bed rest, the muscle strength of the elderly decreased 2 to 3 times faster than that of young adults [5]. This shows the importance of maintaining adequate physical activity. Physical exercise such as aerobic training and resistance training is believed to counteract frailty in the elderly [6], and the main effect of physical exercise can be observed in the improvement of the muscle strength, gait speed, and physical performance[7, 8]. It was well demonstrated that muscle strength is associated with falling episodes among the elderly [9]. However, physical activity and overall exercise in long-term care facilities was rather low [10–12]. Previous studies indicated that the prevalence of frailty in long-term care facilities ranged from 19 to 85% [13–15]. Frailty has been shown to be one of the predictors of cognitive impairment [16]. Frail older adults are at high risk of disability and have an adverse impact on their quality of life [17]. Japan has the world’s oldest “super-aged” society, with 28.7% of the population aged 65 or older [18]. As the first country to enter a super-aged society, Japan has established many elderly care policies worth referring to. Their insurance policy support physicians with short-term or long-term rehabilitation programs in medical long-term care institutions and long-term care health facilities [19]. The Japanese government also provides preventive and welfare services in long-term care insurance to alleviate the financial burden of the growing disabled population [20]. With the second fastest aging population in Asia, Taiwan officially became an aged society in 2018 and is predicted to enter a super-aged society by 2025 [21]. With population aging, there is a serious shortage of manpower for rehabilitation and long-term care [22], especially the reablement and physical strengthening in long-term care facilities. The focus is whether the physical activity of the residents in the long-term care facilities is sufficient, and whether the manpower of the long-term care facilities is sufficient to support the physical strengthening of the residents, especially for the frail elderly with cognitive decline. Is there any innovative technology to support the caregivers and provide physical strengthening for the frail elderly with cognitive decline? Wearable devices were reported to provide remote health monitoring and health promotion [23, 24], but the applications and clinical trials in long-term care facilities is rare. Hence, in this study, we intergraded the wearable device with an artificial intelligence of things (AIoT)-based feedback assistive strengthening ergometer (AIFASE), to offer the physical strengthening of the frail elderly with intelligent assistance for caregivers, and we evaluated the effect of AIFASE with a pilot randomized control trial.

2 Methods

2.1 System Architecture of AIFASE

The architecture of AIFASE is developed based on the system environment of Linux, Apache, MySQL, PHP (LAMP). LAMP is a world-wide used system because it supports free and open-source software under the most Linux-based environments. In this study, the Apache/2.4.29 model is chosen as a HTTP/HTTPS web server. An SSL certificate, issued from TWCA (TAIWAN-CA INC.), enables the protection of the website and keeps the user data secure. The MySQL/5.7.37 model is chosen as relational database management system (RDBMS), and the programming language to build the web environment is using PHP/7.2.24. The host database and server are set up in the Computer and Network Center of the National Cheng Kung University, using the cloud web hosting service (NCKU Cloud) provided by NCKU. Moreover, the cloud web hosting service supports load balancers and firewalls (Citrix, NetScaler 9500, USA) to improve the processing performance (see Fig. 1).

The primary goal of AIFASE is to collect each piece of data during ergometer training via the system-embedded sensors and the Internet. The data are stored in a cloud database for several purposes, including reviewing progress, data manipulation, and data exchange. A cyber security check from the frontend of the webpage identifies the user authorized by the system manager. Authorization is then divided by the location of the care centers, which are all independent. This step protects data usage and helps to prevent mistaken log-in ins to other locations. The data were automatically manipulated, as there are algorithms aimed at fostering intelligent exercise programs and providing additional information. This function of data manipulation is only for post-processing and does not interfere with the physical interaction in real time, which considers the risks of any cyber-attacks. Using AIFASE, data exchange can only be performed in the system when users participate at different locations. The system can merge data by recognizing their identification. In addition, the database can be requested by other hospitals or care centers as an individual dataflow for storage, but it
cannot retrieve data from other hospital information systems (HIS). The reason for this is to avoid a breakthrough in cyber security.

AIFASE consists of one mobile application (App) and one web application (Webapp), specifically developed for the elders and clinical staff, respectively (see Fig. 2). The App is developed in Android Studio as a development platform with Android software development kit (SDK) as the primary language. The main function of this App is to connect several devices for the Internal of Things (IoT) data transfer, including an ergometer (RE-X4, Ventek Fitness Corporation, Taiwan) and a heart rate sensor (Scosche Rhythm24, Scosche Industries, Oxnard, California, USA) via Bluetooth transmission.

On the other hand, AIFASE Webapp is designed as a platform for management by the clinical staff with a wider range of applicability. The programming language of the Webapp is PHP with an approach of Responsive Web Design (RWD) to render the screen size of webpages on a variety of devices like mobile phones, tables, PC etc. It can display the physical performance of the elders and the relevant parameters of the physiological performance in the training process, such as physical evaluation data, training log, and the leaderboards.

### 2.2 Management Platform of AIFASE

As mentioned earlier, the management platform of AIFASE is implemented using the Webapp, providing a central
control interface to monitor the field status in real time. The default login users are clinical staff members and authorized to query and analyze the historical data. There are several essential functions, including the system user management, field management, machine management, case management, course management (see Fig. 3a), physical evaluation data, machine platform and health record (see Fig. 3b).

The logic of the system user management is the one-way privacy that only the clinical staff in the same field can monitor the information of the elders. The information

![Fig. 3 A variety of functions provided by the AIFASE management platform. There are several essential functions provided by the AIFASE management platform, such as case management, a course management, physical evaluation data, and b health record](image-url)
is secured by the identifications of different fields. The participating hospitals, care centers, and local health institutes are recognized as the fields. The management allows fields to be added at any time. The service of AIFASE integrates the ergometers as training machines. Each machine has its own identification number and can therefore be tracked and can record the elders’ health condition. AIFASE aims to provide a service of tele-care with the assistance of automation and Artificial Intelligence (AI). The function of the course management is the concept of simulating the scenario that clinical staffs instruct the elders with personalized exercise prescriptions. The exercise prescriptions in this study can be generated automatically following a decision tree altered by the record of the personal physical performance of the elders accordingly. The system also provides a browse page, which displays the current usage status of all ergometers and the user’s physiological conditions, such as the age, heart rate, resistance level, cadences, percentage maximal heart rate (%MHR), current laps, and training time (see Fig. 4). AIFASE automatically generates the next exercise prescription according to the user’s exercise performance and provides clinical staff to adjust the course according to the clinical situation.

2.3 User Interface of AIFASE

The frontend App is the user interface while implementing AIFASE by the elders. It provides the information of the physiological condition and course information. The left side of the user interface displays the name, the present heart rate, maximum percentage heart rate (%MHR), cycling cadence, and training duration. On the right side of the user interface, there is a black bar representing the total training time. A cyclist is at the bottom left of the black bar. When the user continues pedaling, the cyclist will ride from left to right. When the black bar turns to a blue bar, the class ends (see Fig. 5a).

2.4 The Intelligent Exercise Programs of AIFASE

The software program for the intelligent exercise machine in this study was proposed to be auto-adaptive to provide a program based on personal physical capacity and subjective feedback (Fig. 6). The core algorithm was the decision tree for sequential discriminants. The input variables included both objective and subjective items, such as personal physical capacity ($P_{ij}$), previous workload level ($W_{ij}$), and perceived exertion rating ($R$) obtained from frontend App queries at the end of each session. Initially, the root node was...
divided into three different class levels \((j \in \{1,2,3\})\) based on the participant’s physical evaluation. In this study, the results of the timed up and go test (TUG) were classified into two cut-off points, in which a TUG time of less than 10 s was considered as physical capacity better than the high standard \((S_{i \text{ high}})\), and a TUG time of more than 20 s was classified as physical capacity poorer than the low standard \((S_{i \text{ low}})\). There were five ratings for perceived exertion which acted as leaf nodes, generating workload levels for the next session. Iterations may update workload levels in the model, outputting to the AIFASE ergometer and management platform for the clinical staff. Such an intelligent exercise program can provide more systematic adjustments and combinations than usual. It is worth noting that, in line with the training guidelines for the frail elderly, we have designed intelligent exercise programs that prioritized increasing the training time over increasing the resistance level of the ergometer, allowing elderly users to gradually build up their physical capacity under a familiar resistance level. When the training time was gradually increased beyond 20 min, the intelligent exercise programs proceeded to the next iteration with a higher resistance level and a shorter training time. The extension of training time was determined by subsequent user feedback.

2.5 Remote Healthcare of AIFASE

In addition to the function of Artificial Intelligence, AIFASE provides a remote healthcare warning system to monitor any abnormal condition of the physical conditions as such overwhelming exercise or overloaded exercise intensity. This warning system is built by the decision trees, when the overwhelming exercise is above the instructed intensity during a gentle program for the elders. Exercise intensity is an important indicator of safety. The definition can be referred to as the maximum percentage heart rate, calculated by the Eq. (1) [25].

\[
\text{Maximum Heart Rate (%MHR)} = \left[ \frac{\text{current heart rate}}{208 - 0.7 \times \text{age}} \right] \times 100\%
\]  

The decision tree is set to emit a warning sound when the exercise intensity exceeds 85% MHR and displays an orange warning light on the frontend App as a warning (see Fig. 5b); when the exercise intensity exceeds 90% MHR, a red warning light is displayed (see Fig. 5c). When these abnormal conditions are detected, an alert is immediately shown on both the App and Webapp to warn the elders and clinical staff (see Fig. 4).  

2.6 Subjects

The clinical trial was conducted at a long-term care facility in Tainan city. In total, 16 participants (84.38 ± 6.0 years; 4 males and 12 females) were recruited for this study, all of them were aged ≥ 65 years and were mentally competent to understand the instructions. The inclusion criteria are potentially frail elders over the age of 65 living in long-term care facilities. The exclusion criteria included the current status of severe musculoskeletal/orthopedic disease and persons unable to follow instructions. The work was carried out in accordance with the principles embodied in the Declaration of Helsinki. All study participants signed an informed consent.
consent and ethical approval was granted by the National Cheng Kung University Hospital Institutional Review Board (approval number: A-ER-109-171).

2.7 Study Design

This was a gender-stratified randomized controlled trial with 1:1 randomization of the AIFASE intervention to control groups (see Fig. 7). All participants in this study received 1 h per week of regular physical training sessions provided by the long-term care facility prior to the intervention. After randomization, all participants continued to maintain regular physical training provided by the long-term care facility, while the intervention group received additional AIFASE training programs. The intervention group participated in the 12-weeks AIFASE system exercise intervention with 3–5 sessions per week, and the control group kept their regular activities. The demographic characteristics included the age, gender, height, weight, education, medical history, and the assistive devices used were recorded before intervention. The body height was measured using a measuring rod with an accuracy of 0.1 cm. The body weight was measured using a digital medical scale with an accuracy of 0.01 kg. The evaluation of the personal physical capacity including the body composition, muscle strength, and physical function tests was carried out before (week 0) and after (week 13)
of the AIFASE intervention. The health-related quality of life and questionnaires were also evaluated before and after intervention.

### 2.8 Physical Capacity Measurement

The participants received physical examinations before and after the intervention. The Body Mass Index (BMI) was calculated as personal weight (in kilograms) divided by the square of height (in meters). The appendicular skeletal muscle mass (ASM) of the left arm (LA), right arm (RA), left leg (LL), and right leg (RL) was determined using a bio-electrical impedance analyzer (BIA; Inbody S10, Seoul City, Korea). The skeletal muscle index (SMI) was calculated by the ASM divided by the height squared (kg/m²). The muscle strength of the grip, elbow extensor/flexor, knee extensor/flexor, and hip flexor was evaluated. The grip strength was measured using handgrip dynamometers (microFET® HandGRIP dynamometers, Hoggan Scientific, Salt Lake City, UT). The muscle strength of the elbow flexors/extensors, knee flexors/extensors, and hip flexors was measured using a hand-held dynamometer (microFET®2, Hoggan Scientific, Salt Lake City, UT), as previously described. The physical examination conducted in this study included timed up and go test (TUG), and short-form physical performance battery (SPPB) examination. TUG was measured by the time taken (in seconds) for a person to rise from a chair with armpits, walk 3 m, turn, return to the chair, and sit down. Durations of ≥ 13.5 s are used as the cut-point to identify those at increased risk of falls in the community setting. The participants were allowed to use walking aids (e.g., cane or walker) during TUG. The items in SPPB included balance test (side by side stand test, semi-tandem stand test, tandem stand test), gait speed test (4-m walk test), and chair-stand test (5 times sit to stand test). The total score of SPPB was calculated accordingly [26]. In the balance test, the participants were asked to maintain their balance in three different positions, i.e., a side-by-side position (SBS), a semi-tandem position (ST), and a full-tandem position. The gait speed was measured as the best performance achieved in two walks at the participant’s usual pace along a corridor 4 m long and was recorded in m/sec. Participants were allowed to use assistive devices. In 5 times sit to stand test, the participants were asked to stand up and sit down five times as quickly as possible, with their hands folded across their chest. All the three tests had a minimum score of 0 and a maximum score of 4. The SPPB scores were grouped into three classes: poor performers scoring 0–6 points, moderate performers scoring 7–9 points, and good performers scoring 10–12 points.

### 2.9 Health-Related Quality of Life and Questionnaire

All participants were asked to fill in a general questionnaire before and after the intervention. The physical function was screened with simple five-item questionnaire (SARC-F) based on the features or consequences of sarcopenia. The SARC-F questionnaire evaluated the Strength, Assistance with walking, Rise from a chair, Climbing stairs, and Falls. The SARC-F scores range from 0 to 10, with a score equal to or greater than 4 indicating sarcopenia. The frailty status of the subjects was evaluated by the Study of Osteoporotic Fractures (SOF) [27, 28]. The SOF queries weight loss, lower extremity function, and energy perception were determined via scores from 0 to 3, with a total score of 2 or 3 meaning frail, 1 indicating pre-frail, and 0 representing robust. The emotional status was determined by the Short-form Geriatric Depression Scale (GDS-5). GDS-5D, which was developed by Hoyl et al. [29] was composed of five-item queries that screen for depression in a frail community-dwelling older population. The score ranges from 0 to 5 points. The score of 0 or 1 indicates “not depressed,” hence the screening stops. If a patient scores 2 or more on the first 5 questions, there is a need for further checks. The cognitive status was measured by the Short Portable Mental Status Questionnaire (SPMSQ). SPMSQ consists of 10 items, including the orientation, personal history, recent memory, and calculation ability. The total number of errors is computed and the range of the total score is 0–10; where 0–2 errors imply normal mental function; 3–4 errors imply mild cognitive impairment; and 5–7 errors imply moderate cognitive impairment. The quality of life of the subjects was evaluated using the EQ-5D-3L questionnaire [30]. The EQ-5D-3L descriptive system comprises the following five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression. The patient is asked to indicate his/her health state by ticking the box next to the most appropriate statement in each of the five dimensions. The rating scale for each dimension can be rated as a number of 1, 2, or 3, where 1 means no problems, 2 means having some problems, and 3 means having extreme problems. According to this scale, we recorded the sum scores of EQ5D. The score ranges from 3 to 15 points. The functional status was assessed by modified Katz Activities of Daily Living (Katz ADL) scales [31, 32]. The scale contains seven items: bathing, dressing, going to toilet, transferring, walking, feeding, and continence. Each item had a three-point scale, with 0 representing dependence and 2 representing independence. The total score of the modified Katz Index ranges from 0 to 14 points, with a higher point indicating that a person functioned alone.
2.10 Statistical Analysis

Descriptive statistics describe the demographic variables between the intervention group and the control group, and the continuous variables are presented in averages and standard deviations. The Mann–Whitney U test was used to compare the variables between the control and intervention group before intervention. Linear Mixed Models analyses of Generalized Estimating Equations (GEE) were used to compare the variables between the groups and the changes over time were analyzed. The threshold of the statistical significance was defined as p-value > 0.05. All the statistical analyses were performed by SPSS version 17.0.

3 Results

In this study, AIFASE was applied in a long-term care facility of the frail elderly with cognitive decline. A total of 16 elderly people participated, of which 8 were in the control group and the other 8 were in the AIFASE group. Table 1 lists the baseline characteristics of the participants. There were no significant differences in the demographic characteristics between the groups before intervention. Table 2 lists the physical, cognitive, and functional status between the groups. The participants were in the pre-frail stage with moderate cognitive decline. There were no significant differences between the groups. After a 12-week intervention, under the time × group interaction analyses, the results showed that the muscle strength of the right hip flexor was significantly improved (p = 0.014). The muscle strength of the left hip flexor also increased although the difference was not significant. The Semi-Tandem Stand (p = 0.025) and Tandem Stand (p = 0.034) also showed significant improvement after the AIFASE intervention (see Table 3).

4 Discussion

In this study, we designed AIFASE to assist caregivers in maintaining or even strengthening the physical capacity of the residents of long-term care facilities. We used SOF to evaluate the frailty status of the subjects, with a total score of 2 or 3 indicating frailty, 1 indicating pre-frailty, and 0
representing robustness. As shown in Table 2, the average SOF scores in the control and AIFASE groups were 1.0 ± 1.5 and 1.4 ± 1.2, respectively, suggesting that most of the participants were in the pre-frail stage. The SPMSQ, which was used to assess the cognitive status of participants, consisted of ten items, with a score of 5–7 indicating moderate cognitive impairment. The initial SPMSQ scores were 7.6 ± 3.0 and 6.3 ± 3.2 in each group, suggesting that most of the participants had moderate cognitive impairment. This study investigated the effect of AIFASE in pre-frail older adults with moderate cognitive impairment.

In the 12-week intervention, the caregivers reminded the elders to practice AIFASE training for at least 3–5 sessions per week. AIFASE provides gradual build up of physical training for the users. The group-by-time analysis showed an increase in the muscle strength of the lower extremities, and the improvement in balance. This study showed that AIFASE intervention is effective for the physical strengthening of elders with cognitive decline. The improvement in SPPB was in the semi-tandem stance and tandem stance. This implies that AIFASE contributed to balance improvement. Balance and muscle strengthening are elements of fall prevention. Falls in the elderly cause a high incidence of morbidity, and mortality [33]. Falls related costs in long-term-care facilities were more than 6200 USD per resident per year, and caregivers are advised to reduce fall rates to meet cost-effectiveness [34]. The application of AIFASE in long-term care facilities is believed to reduce the risk of falls of the elderly and ease the burden of care.

As a result of the flourishing of the healthcare industry in recent years, a large amount of research and development in healthcare technology has been used to assist in rehabilitation, reablement, and health promotion, such as 3D printing for assistive devices [35], information and communications technology (ICT) for tele-rehabilitation [36], and mechanical design technology for sensorimotor control training [37, 38]. The adoption rate and usability of healthcare technology among older adults has been less satisfactory [39]. Thus, the visual interface design for seniors should consider the limitations and human factors related to aging such as vision problems, reduction in speed and cognitive capacity, and decline in dynamic visual attention [40].

### Table 3 Physical capacity between groups before and after intervention

| Variables | Control Group (n = 8) | AIFASE Group (n = 8) | GEE Group*Time |
|-----------|------------------------|----------------------|----------------|
|           | WK0 | WK13 | WK0 | WK13 | β | SE  | p* |
| **Body composition** | | | | | | | |
| BMI (kg/m²) | 24.9 ± 5.0 | 24.8 ± 5.2 | 25.0 ± 2.1 | 25.2 ± 2.2 | 0.247 | 0.2627 | 0.347 |
| SMI (kg/m²) | 6.7 ± 1.4 | 6.4 ± 1.6 | 6.0 ± 1.0 | 5.9 ± 1.0 | 0.200 | 0.2597 | 0.441 |
| **Muscle strength** | | | | | | | |
| Grip (ND) (kg) | 11.3 ± 3.5 | 11.1 ± 5.7 | 12.5 ± 3.0 | 11.6 ± 3.6 | −0.910 | 1.3202 | 0.491 |
| Grip (D) (kg) | 12.7 ± 2.8 | 12.0 ± 3.3 | 14.3 ± 4.6 | 14.2 ± 5.3 | 0.329 | 1.2094 | 0.785 |
| Elbow flexor (L) (kg) | 8.8 ± 2.6 | 9.5 ± 3.0 | 10.9 ± 2.8 | 10.0 ± 4.0 | −0.650 | 0.9674 | 0.502 |
| Elbow flexor (R) (kg) | 9.5 ± 2.7 | 10.0 ± 2.8 | 9.8 ± 2.6 | 10.8 ± 4.7 | 0.525 | 1.2742 | 0.680 |
| Elbow extensor (L) (kg) | 5.8 ± 1.7 | 5.6 ± 1.2 | 6.2 ± 1.7 | 6.0 ± 2.4 | 0.158 | 0.8133 | 0.846 |
| Elbow extensor (R) (kg) | 5.8 ± 2.1 | 5.2 ± 1.1 | 5.7 ± 1.7 | 5.7 ± 2.7 | 0.746 | 0.6993 | 0.286 |
| Knee flexor (L) (kg) | 8.5 ± 4.3 | 7.8 ± 3.9 | 7.7 ± 1.5 | 8.1 ± 3.1 | 1.000 | 0.9620 | 0.299 |
| Knee flexor (R) (kg) | 7.6 ± 3.3 | 7.3 ± 2.8 | 8.1 ± 1.8 | 7.9 ± 2.5 | 0.050 | 0.8432 | 0.952 |
| Knee extensor (L) (kg) | 10.5 ± 2.9 | 10.3 ± 3.0 | 12.3 ± 3.3 | 11.6 ± 4.0 | −0.767 | 1.1704 | 0.512 |
| Knee extensor (R) (kg) | 10.0 ± 3.2 | 9.7 ± 2.2 | 11.4 ± 2.8 | 12.2 ± 3.6 | 1.113 | 0.9542 | 0.244 |
| Hip flexor (L) (kg) | 10.5 ± 4.1 | 11.9 ± 4.9 | 9.4 ± 1.1 | #13.8 ± 4.8 | 2.933 | 1.5924 | 0.065 |
| Hip flexor (R) (kg) | 11.0 ± 5.9 | 11.1 ± 3.8 | 9.20 ± 1.09 | #13.7 ± 4.5 | 4.350 | 1.7665 | *0.014 |
| **Physical function tests** | | | | | | | |
| Time up and go test (s) | 16.2 ± 8.3 | 16.3 ± 14.6 | 20.0 ± 7.65 | 21.6 ± 9.6 | 1.486 | 4.5541 | 0.744 |
| Side by side stand test (s) | 10 ± 0 | 8.8 ± 3.5 | 8.75 ± 3.54 | 8.8 ± 3.5 | 1.250 | 1.1693 | 0.285 |
| Semi-tandem stand test (s) | 10 ± 0 | 7.6 ± 3.8 | 7.5 ± 4.63 | 8.4 ± 3.6 | 3.306 | 1.4775 | *0.025 |
| Tandem stand test (s) | 7.4 ± 4 | 4.9 ± 4.7 | 3.13 ± 4.39 | 3.4 ± 4.4 | 2.807 | 1.3238 | *0.034 |
| 4 m walk (s) | 6.1 ± 2.8 | 5.3 ± 4.4 | 7.05 ± 2.43 | 6.9 ± 3.3 | 0.741 | 1.2607 | 0.557 |
| 5 times sit to stand test (s) | 23.7 ± 12.4 | 17.7 ± 13.2 | 21.49 ± 12 | 16.8 ± 4.9 | 1.335 | 5.2387 | 0.799 |
| SPPB score | 7.8 ± 2.7 | 7.0 ± 4.4 | 6.25 ± 3.15 | 6.8 ± 3.3 | 1.250 | 0.8053 | 0.121 |

Values are mean ± SD. BMI body mass index; SMI skeletal muscle index; ND non-dominant; D dominant; L left; R right; #a significant difference within group (p < 0.05) *a significant difference between group (p < 0.05)
frontend App based on the guideline of digital interface design for elderly people. The user-friendly interface was shown to increase the usability of AIFASE for the elderly with cognitive decline, which can be found in the engagement and usage in the AIFASE group. Each session in the study was set to be 8–20 min long, with gradually increasing durations based on feedback. The backend data showed that users trained for 55.6 ± 19.8 min a week, an increase from the baseline of 32.4 to 89.75 min per week. This indicates that users are highly willing to participate in AIFASE programs. We believe that the user-friendly interface and intelligent exercise programs will contribute to the feasibility of AIFASE. In terms of muscle strength gains, AIFASE showed a 47–49% increase in user hip flexor strength. For participants who trained for more than 60 min per week, the muscle strength gains in knee flexors were as high as 24%, and that in hip flexors were as high as 62% (data not shown). We believe that large-scale enrollment would consolidate the impact of AIFASE on physical improvement. Additionally, when we asked formal caregivers how their cases improved after treatment, they stated that they believed that the main improvements following AIFASE intervention were in muscle strength and overall health (Table S1).

A limitation of this study is that the sample size of the participants was rather small, and significant differences were only observed in balance improvement and hip flexor muscle strength. Moreover, elders in long-term care facilities are often challenged by unexpected physical illness caused by aging. These magnify the differences between the individuals and cause long-term research difficulties. Studies with longer interventions and more subjects enrolled are needed. Furthermore, older adults with type II diabetes mellitus experience poor balance and muscle strength in the extremities [41]. Therefore, the effect of AIFASE on the improvement of muscle strength and balance in patients with diabetes warrants further study.

### 5 Conclusion

In conclusion, we demonstrated that a 12-week AIFASE intervention improved the muscle strength of the lower extremities, and physical fitness, especially in balance ability. A further and larger scale of investigation is warranted. We hope that the application of AIFASE can alleviate the needs of manpower in long-term care and release the burden on clinical staff.

#### Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1007/s40846-022-00759-8.

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Declarations

Conflict of interest None.

Ethical Approval Yes.

Consent to Participate Yes.

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