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Remote Teleassessment and Telerehabilitation of a Comprehensive Exercise Training Protocol for Older Adults: Design and Methodology of a Usability Protocol

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Abstract

ABSTRACT

Purpose: The design, usability, safety, and feasibility of a telehealth protocol comprising teleassessment and tele rehabilitation to evaluate and improve physical and cognitive function among older adults was assessed. Methods: Healthy older adults (n=23) participated in a pre-post tele-assessment of a 4-week (3 sessions/week) telerehabilitation session. Tele-assessment was performed to evaluate balance, gait function, and cognition. Tele-rehabilitation sessions comprised of balance games, dancing, dual-tasking, yoga, and tai-chi exercises. Results: There were no adverse events reported to indicate concerns with the safety of the current telehealth protocol. Conclusion: The proposed telehealth protocol to assess and improve physical and cognitive function may be feasible for enrolling older adults into a home exercise trial.

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ABSTRACT
Purpose: The design, usability, safety, and feasibility of a telehealth protocol comprising teleassessment and tele rehabilitation to evaluate and improve physical and cognitive function among older adults was assessed. **Methods:** Healthy older adults (n=23) participated in a pre-post tele-assessment of a 4-week (3 sessions/week) telerehabilitation session. Tele-assessment was performed to evaluate balance, gait function, and cognition. Tele-rehabilitation sessions comprised of balance games, dancing, dual-tasking, yoga, and tai-chi exercises. **Results:** There were no adverse events reported to indicate concerns with the safety of the current telehealth protocol. **Conclusion:** The proposed telehealth protocol to assess and improve physical and cognitive function may be feasible for enrolling older adults into a home exercise trial.

Keywords: older adults, tele-assessment, tele-rehabilitation, NIH cognitive toolbox, balance, gait, dual-tasking, physical function, cognitive function.

INTRODUCTION

Aging increases the prevalence of balance and gait deficits and is also associated with increased falls.[1,2] These falls are associated with significant morbidity and mortality.[3,4] The current rehabilitation literature supports using home-based balance exercise training with Tele-rehabilitation to improve balance and gait function.[5,6] Telerehabilitation is a branch of telehealth, defined as the application of information and telecommunication technologies for delivering rehabilitation services from a distance.[7] Further, Tele-rehabilitation encompasses a broader set of users and provides an equally effective alternative to outpatient and community-based health care practices.[8] Tele-rehabilitation also fulfills the purpose of increasing accessibility and improving continuity of care in vulnerable, geographically remote populations with the potential to save time and resources in health care and allow easier dissemination of rehabilitation services.[9]

Exercise rehabilitation is one of the major upcoming telehealth technology applications.[8,10] However, outpatient and community-based health care practices do not provide long-term exercise maintenance. Moreover, the COVID-19 pandemic and subsequent stay-at-home orders have caused a general reduction in physical mobility among older adults in the United States of America.[11] Thus, remote testing and training can improve accessibility for long-term exercise maintenance among older adults.

Our preliminary studies conducted in the laboratory have shown promising results on various alternative methods for rehabilitating older adults, among which exergaming, defined as an integration of gaming and exercise (e.g. balance, cognitive, and dance exercises), has shown to provide highly customizable, controllable, multimodal simulation, ensuring high levels of motivation and compliance towards rehabilitation.[12-14] Exergaming-based dance therapy has exhibited feasibility in improving balance, mobility, cardiovascular function, and decreased fall risk.[13,14] Older adults show balance control and gait deterioration in dual-task conditions (i.e., simultaneous performance of two tasks).[15,16] A preliminary study on older adults has demonstrated the effectiveness of exergaming-based balance exercises in improving balance, gait, and cognition in single tasks (balance/gait/cognition) and dual-task conditions (balance/gait and cognition).[13] Apart from our preliminary studies, few systematic reviews have also emphasized task-specific and mind-body exercises (e.g., Yoga and Tai-Chi) to improve balance control in older adults.[17,18]

Thus, it could be postulated that older adults could benefit from integrated programs that can be delivered at home via telerehabilitation technologies and incorporate various physical exercises, such as conventional balance exercises, exergaming-based balance exercises, cognitive games, and dance training. However, despite satisfactory efficacy trials on integrated programs in improving physical and cognitive functions, research evidence on administering and evaluating a telehealth protocol's design, usability, safety, and feasibility is yet limited among older adults. A novel balance assessment methodology, in combination with telerehabilitation technology, can overcome these limitations. However, there is no data on the design, usability, and safety methods of the remote Tele-assessment and Tele-rehabilitation for the proposed integrated exercise training among older adults. Therefore, the purpose of the current study is to evaluate the design, usability, safety, and feasibility of i) using a teleassessment to assess balance, and cognitive function, and ii) an interdisciplinary comprehensive telerehabilitation approach to address physical, and cognitive frailty among older adults.

METHODS

Study design:

The current study used a pre-post teleassessment and a home-based balance exercise training with tele-rehabilitation.

Participant Recruitment*:*

Participants were recruited using various forms of advertising, including flyers, emails, and print advertisements in different senior and community-based exercise centers and independent senior living facilities located in the area. The Institutional Review Board approved this study protocol of the University of Illinois. All participants initially underwent a phone screening, after which eligible participants were provided an online consent form. The study was conducted in a participant's home-based setting via an online interface wherein the researcher personnel would be performing the assessments and training remotely.

Subject Eligibility

Participants underwent a phone screening in which they were excluded if they had had any recent surgeries (< 6 months ago) and/or any neurological, musculoskeletal, cardiovascular, or other systemic disorders. They were also excluded if they had any history of drug usage or severe visual impairment.[19,20] In addition, participants did not proceed with testing if their resting HR was > 85% of the age-predicted maximal heart rate using Fitbit Charge 2 wearable activity tracking device. They were further excluded if they could not stand for at least five minutes without an assistive device (length of each exercise) or if they had a history of a spine or long bone fracture in the last six months. To be included, participants had to be ≥ 55 years of age, answer a general health questionnaire, complete a Physical Activity Scale for the Elderly (PASE), and achieve a minimum score of twenty-four on the Montreal Cognitive Assessment (MOCA), which would prove "normal" cognitive performance. The lower age of 55 years was chosen as alterations in common balance, gait, and cognitive parameters have been shown from 50 years of age.[21-23] All participants provided written informed consent, which the Institutional Review Board reviewed.

System Design and Setup

A remote physical assessment and training system was designed to support the connection between participants' homes and health coach rehabilitation providers at their offices. This system utilized the secure (password protected) videoconferencing platform "Zoom".[24] The remote assessment system allowed comprehensive physical assessment and training (see below - *A Brief Description of Assessment Measures and Protocols, and Training Protocol)*. A system design of the remote assessment system is provided schematically in Figure 1.

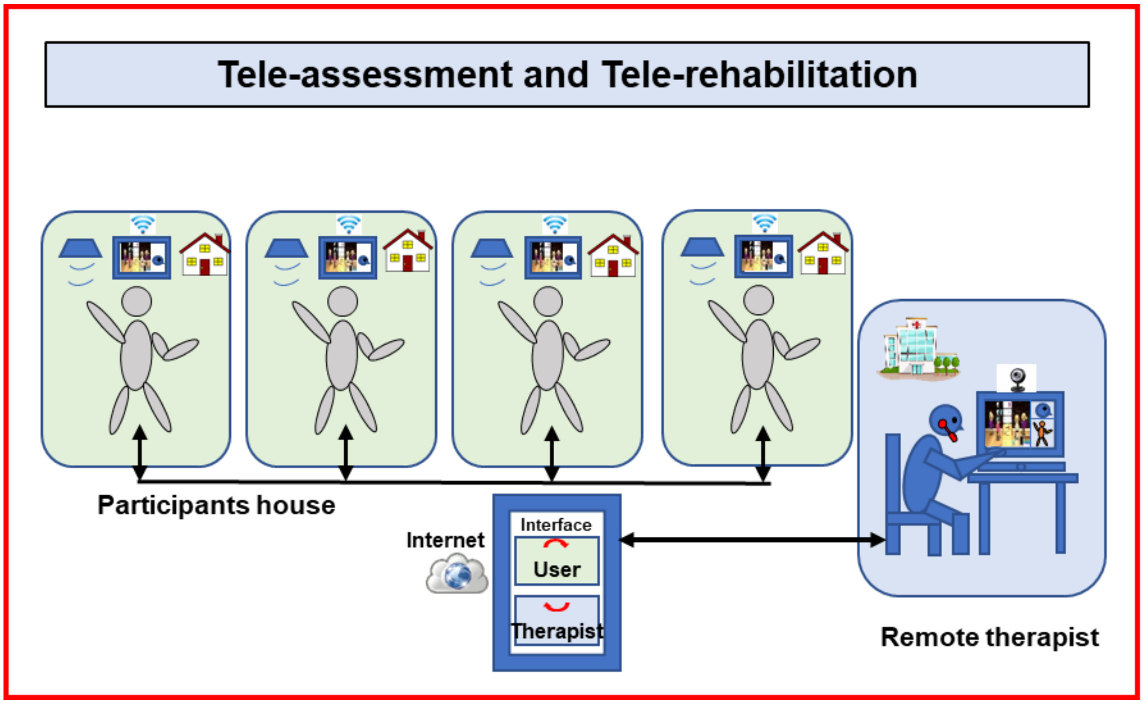

Figure 1. Schematic Representation of the Remote System of Telehealth

The system comprises 1) personal computer with Zoom for health coach; 2) personal computer/laptop/iPad/phone with Zoom for the participant; 3) Fitbit Charge 2 wearable activity tracking device and Fitbit app; and 4) Use of the iCardia research platform for remote collection and monitoring of heart rate and physical activity data from the Fitbit devices provided to all study participants for this study.[25] The system supported three roles: 1) health coaches who provided physical assessment and exercise training; 2) participants followed the health coach's instruction to be assessed/trained; 3) operation assistants supported the participant on both system setup (installing and setting up "Zoom"), and technical assistance during the assessment and training. The operational assistant also helped with a virtual home assessment, set up the vital monitoring system (iCardia) with the participant, and helped the health coaches and participants communicate via Zoom meeting. The health coach monitored heart rate data through the system in real-time. Thus, the health coach observed the participant's condition via the system during the remote assessment.

Safety Monitoring

Heart Rate and Physical Activity Monitoring system (Fitbit wearable tracker synced with mobile app and iCardia).

The Fitbit Charge 2 ™ (Fitbit Inc., San Francisco, CA) is a reliable and valid wrist-based wearable device that uses a three-dimensional accelerometer and an optical heart rate (HR) sensor to monitor intensity-specific minutes of physical activity and heart rate. [26-28] The research team created coded study email and Fitbit accounts for each participant to protect their anonymity from Fitbit and other third parties. Participants received the wearable tracker and were oriented to i) turn the Bluetooth on and off, ii) the need to sync the wearable PA tracker with the app, and iii) how to sync and navigate the Fitbit app. In addition, participants received their study email address, Fitbit accounts, passwords, and a short manual about Fitbit (how to wear, clean, charge, and sync the device with the app). The manual was developed using information from the official Fitbit Web site, and the content and adapted to meet the requirements of the sixth-grade reading level.

The Fitbit accounts were linked to the iCardia platform using the Auth 2.0 Authorization Framework to enable the research team to remotely collect and monitor all Fitbit data from study participants in near real-time.[29] iCardia comprises user-friendly visualization and data exporting tools allowing authorized study researchers to view and analyze objectively measured Fitbit data on PA (e.g., step count, intensity, type, and duration). Study participants did not have access to iCardia. Instead, they only interacted with their Fitbit mobile app and PA monitor. In this study, iCardia was used to facilitate remote monitoring of PA measures from Fitbit devices. Participants were asked to wear the Fitbit on their wrist for 3 wks during the intervention.

During the training, the research team was able to select a specific date using the calendar feature, and then view each participant's minute-level count and heart rate data, including number of steps, physical activity minutes classified by intensity (light, moderate, and vigorous), and calories burned (Figure 2).

In addition to intraday data, iCardia provided an excel output with the absolute values featured in the calendar profile. iCardia also supported analysis and visualization of physical activity/exercise data over training duration (Figure 3). The research team selected a date range to view each participant's activity trends and progress with respect to steps, light or moderate-to-vigorous physical activity minutes, and exercise. These measures were also supplemented with charts indicating actual Fitbit wear-time. The iCardia implemented a novel algorithm that leverages Fitbit's HR sensor to accurately calculate the total number of minutes each participant had worn his/her Fitbit activity tracker on any given day.

Tele-Assessment

Physical Function Assessment

Participants underwent assessments pre-and post-intervention in which they completed a physical examination that included: 1) 30-second chair stand test ii) 2 min step in place test iii) One-legged stand test iv) Four-step square test v) Tinetti Performance Oriented Mobility Assessment, and vi) functional clinical measures – a) Community integration questionnaire b) Activities Balance Confidence Scale c) RM-4 Motivation Questionnaire. The participant sits quietly for at least 5 minutes before initiation of the assessment

A Brief Description of Assessment Measures and Protocols

30-second chair stand test

Teleassessment equipment and setup: 1) A sturdy chair (a chair with arms was used to enhance safety), 2) Camera view: Frontal view of the participant's whole body. 3) Participants were provided with three options for where to place the chair: i) An open space, not supported by a mat or wall ii) An open space, support from a caregiver or family member if necessary iii) Supported against a wall (if chair movement was a safety hazard as evaluated by the health coach). Once the setup was completed, participants were instructed to sit in the middle of the chair, with their hands crossed across their chest, feet flat on the floor, and back straight to complete the test that was set for a 30-second duration with the timer. The health coach monitored the entire test and collected the required data (number of times the person sits and stands from the chair).

Teleassessment equipment and setup

1) Camera view: Frontal view of the participant's full body; and 2) Participants were required to stand up straight next to the wall while a mark is placed on the wall at the level corresponding to midway between the patella (knee cap) and iliac crest (top of the hip bone). The participant was asked to march in place for two minutes, lifting the knees to the height of the mark on the wall. Holding onto the wall or a stable chair was allowed. The health coach monitored the test and collected the number of steps taken by the participant in 2 minutes.

One-legged stand test

Teleassessment equipment and setup: 1) A sturdy chair on the side for support; and 2) Camera view: Frontal view of the participant's entire body. Post setup, the health coach recorded the time the participant could stand on one leg. The readings were recorded for both the dominant and nondominant lower extremities.

Four-step square test

Teleassessment equipment and setup: 1) Tape the floor as instructed by the health coach (Figure X); and 2) Camera view: Frontal view of the participant's whole body. Participants stood in square 1 facing square 2. When the instructor said 'start', the participant had to step in the following sequence: 12341 and then in the opposite direction, 14321. The participant had to step as fast as possible. Finally, the instructor checked how much time the participant took to complete the test.

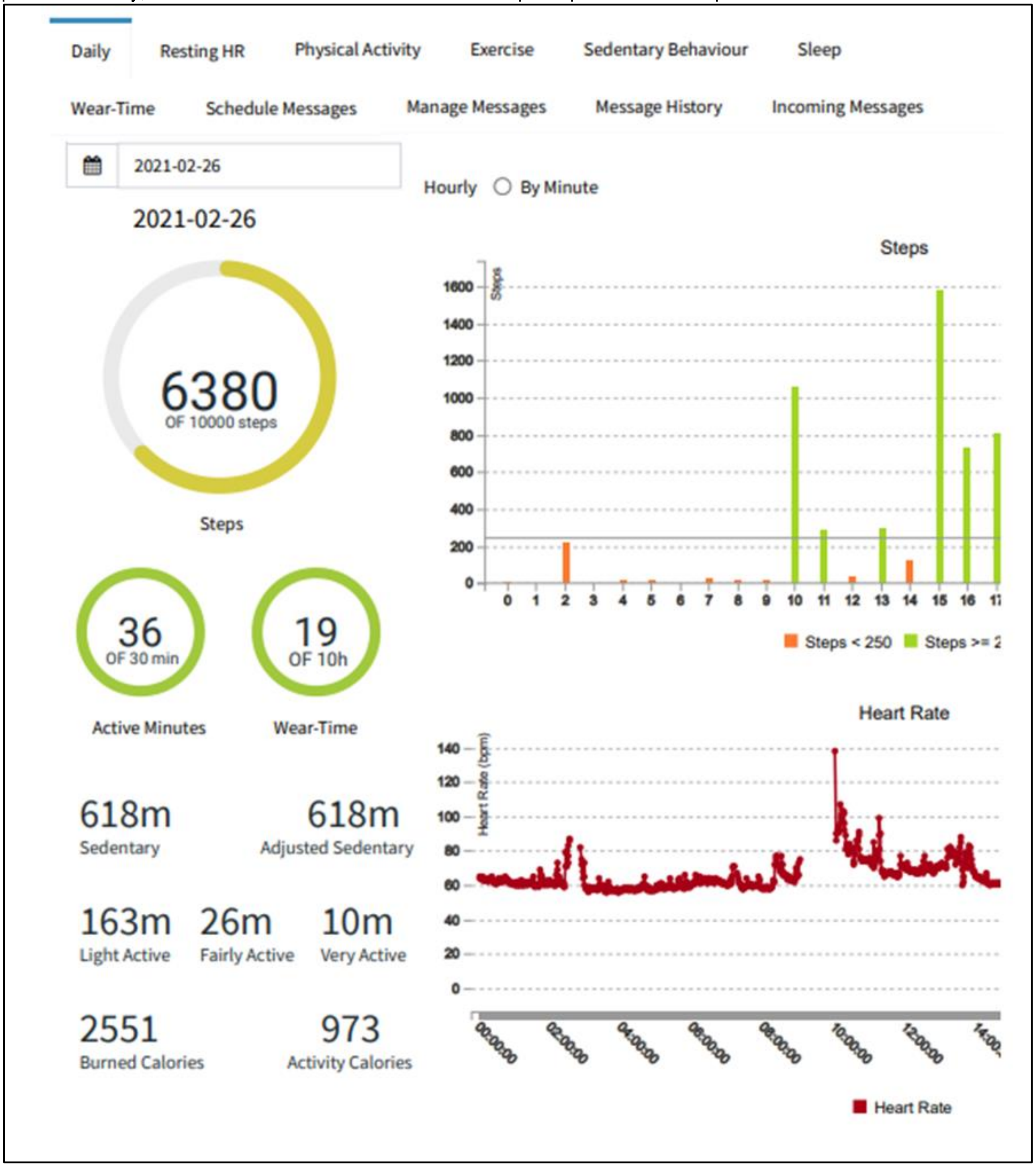

Figure 2. Intraday Physical Activity and Heart Rate

Tinetti performance-oriented mobility assessment

1) Study chair, 25 feet each way walking path) 2) Camera view: Frontal view of the participant's entire body. Participants were asked to do a series of tests, including sitting-to-stand, standing with eyes open/closed, turning 360 degrees, and walking to and from the camera. The health coach evaluated the performance based on the Tinetti scoring scale.

Cognitive function assessment
The cognitive tests include list sort memory test (working memory), which involves size order sequencing of familiar stimuli [30], dimensional change card sort test (executive function) that involves sorting of bivalent stimuli's, first according to one dimension (e.g., color), and then according to the other (e.g., shape), and finally pattern comparison processing speed test (processing speed) that requires participants to discern whether two side by side pictures are the same or now. The number of correct responses for all the tests was recorded [30-32].

Cognitive and physical demand
The cognitive and physical demand was assessed after each game via NASA TLX [33]. The NASA TLX is a numerical 20 point-scale, and participants will respond to the cognitive and physical demand questions accordingly. In addition, participants were asked to rate their level of exertion on the Borg scale to determine the fatigue level of the training [34]. If any fatigue was noticed or the participant demanded a break, they were asked to sit back in a chair, monitor their vitals, and report to the remote health coach to ensure safety. All participants' compliance was calculated across the training sessions.

Tele-Rehabilitation
Physical function training
Intervention protocol: Participants were provided with an additional session, beginning with Fitbit instructional sessions delivered by an operation assistant that helped the participants with orientation and troubleshooting the Fitbit device, app, and cell phone usage. Post the Fitbit orientation, participants were provided a survey form to fill in their availability for the training, and they were divided into four groups.

Each group received a total of 12 sessions for four weeks, which comprised three sessions/weeks. In addition, participants were provided with 10 minutes each of warm-up and cool-down exercises (e.g., half squats, lunges, arm Circles, shoulder squeeze, trunk rotations, heel raise, knee flexion, hip flexion-abduction-extension, hip circles), and pre-and post-training to help lessen the risk of exercise-related detrimental consequences.

The Tele-rehabilitation intervention delivered exercises via exergaming-based animation videos combined with or without explicit cognitive exercises delivered by a health coach monitoring the intervention. The intervention consisted of participants mimicking the exercises shown in the form of games and dances on their screen (similar to exergaming but being passive rather than interactive). The participants did not receive knowledge of performance or knowledge of results like in traditional exergaming; however, after each session, they received brief feedback by the health coach, 1) qualitative based on the movements, 2) quantitative based on their heart rate max (intensity achieved) and the number of steps per session (measured via wearable sensors/smartphone). The wearable device measured the heart rate and physical activity during training. Participants were asked to read out the heart rate and the number of steps before the training began (displayed on the wearable device).

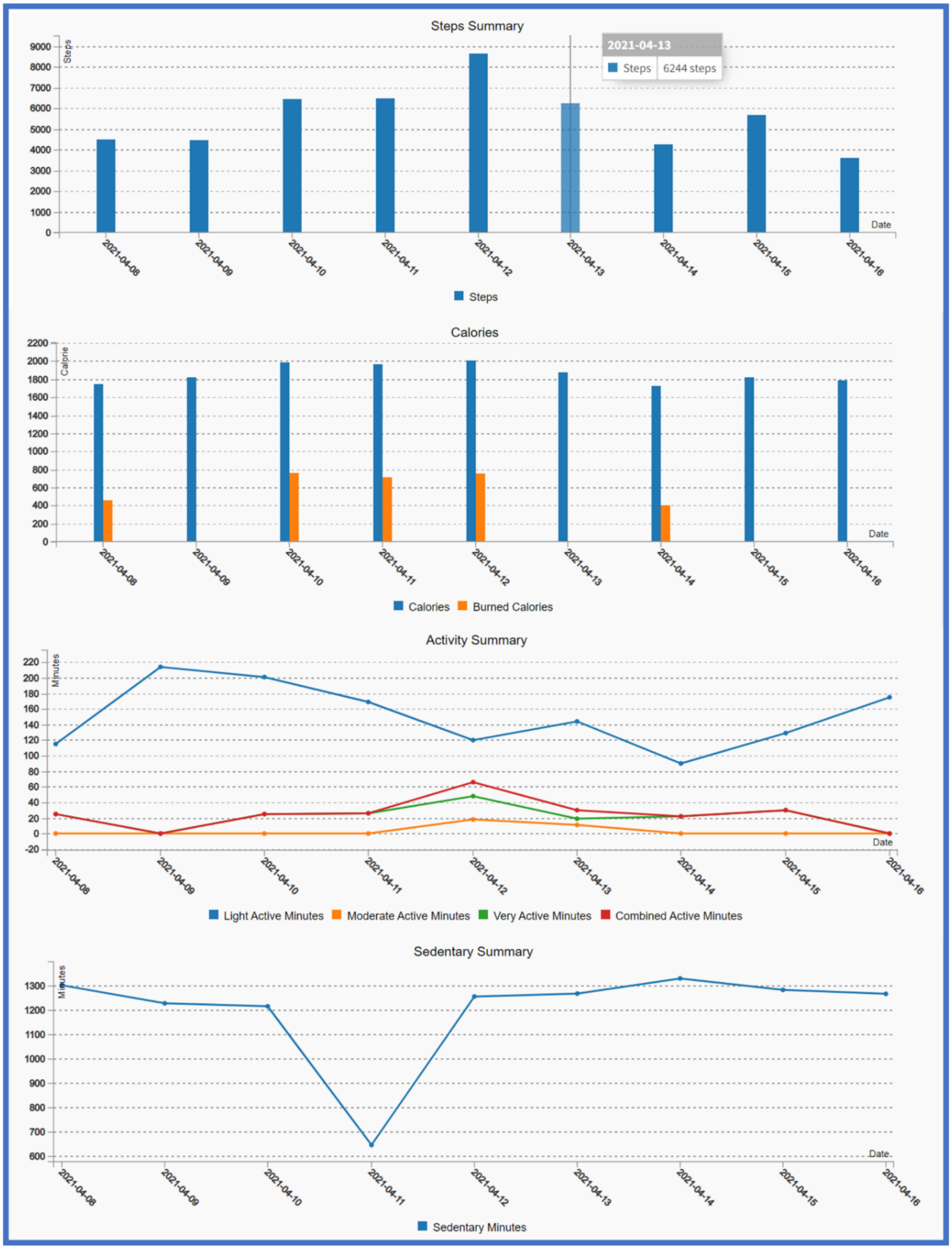

Figure 3. Physical Activity Trends Analysis Over Time

Furthermore, after each set of exercises, they were asked to note their heart rate and the number of steps displayed on their watch and to report it to the health coach. Participants had to show below 85% of the age-predicted maximum heart rate to continue testing and training. All participants were provided with a feasibility and experience questionnaire, and their compliance was recorded at the end of the four-week training. Participants were provided with balance exercises, which are demonstrated via animated avatars. The balance exercises were divided into four categories and included non-interactive

Balance games
Hula hoop – Participants were asked to observe the video and mimic twirling the hula hoop around the waist. Boxing – Participants were required to mimic the video and use their left and right arms to punch and block at head and body height. Stepping – Participants were instructed to step on and off the balance board coordinating with the same step (right or left) projected on the screen. Soccer head - Participants were asked to tilt their bodies and shift their weight from side to side to hit a soccer ball while avoiding hitting flying cleats and Pandas. All the above games provided training for hip rotation and stepping forward, backward, and sideways

Dance
Participants were provided with four dance song videos, "Party rock anthem", "Dynamite", "Price tag", I was made for loving you". The songs from the "hip-hop" genre were chosen due to the genre's wide availability, popularity, and enjoyment in both the United States and worldwide. In general, all the songs' dance movements included forward, backward, and lateral stepping, and the typical dance movements which comprised of rhythmic forward and lateral single- and double step touches, sidekicks and steps in-place, hip-hop bounces to front and back, along with in-place and forward marching, encouraging the use of upper and lower body movements in the anteroposterior and mediolateral directions. In addition, these dance movements incorporated flexion and extension of the hip, knee, and ankle joints and flexion and abduction of the shoulder joints.

Cognitive Motor Training
Mental math – Participants were required to do a mental math task (e.g., sum the digits) and step onto the target position where they see the answer. Stepping on candy – They were asked to step in the target position where they saw a candy on the screen. Visual stroop – In this task, color words that are printed in a different color had to be read aloud; the color of the written words has to be inhibited (e.g., the word 'red' printed in green) and vice versa. Sink shape to exercise – For this game, participants were shown a shape and asked to sink it to an exercise (for example, stepping to different target positions, lunge, single-leg stance, aerobic (stepping in place). Followed by which only the shape was shown, and they were required to perform the exercise.

Tai-Chi and Yoga
Participants were provided with some basic Yoga, and Tai-Chi poses. For the Yoga, participants were asked to practice the Warrior pose (Virabhadrasana), chair pose (Utkatasana), mountain pose (Tadasana), and standing spinal twist (Katichakrasana).[35] Tai-Chi included Sun, Chen, Wu/Hao, Yang, and Wu.[36]

RESULTS

Twenty-three older adults participated in this study. Two of them were excluded as they failed to qualify (cognitive impairment). One participant dropped out due to time constraints due to family commitments to withdraw from the study. Twenty participants completed the training and pre/post-assessments.

Recruitment commenced on August 28, 2020, using a multipronged recruitment strategy. Participants were recruited via various forms of advertising, including flyers, emails, and print advertisements in different senior and community-based exercise centers and independent senior living facilities located in the area. The Institutional Review Board of the University of Illinois approved this study protocol. All participants initially underwent a phone screening, after which eligible participants were provided an online consent form. Assessments were performed via an online interface remotely. Twenty healthy older adults completed the training and pre/post-assessments. The mean age of the sample was 72 years (SD±6.31). The health coach set up the remote physical assessment software and successfully monitored all the participant's real-time physical activity (e.g., step count, PA intensity, type, and duration) and heart rate. All participants completed physical function assessments, along with pre-and post-intervention. Only two participants were absent for one training session in the first two weeks, exhibiting 98% compliance. Seventeen participants had high adherence (92%), while three demonstrated medium adherence (76%) in wearing the tracker during the 12 training sessions with at least two h/session.

DISCUSSION

The current manuscript describes the protocol and methods of an in-home quantitative assessment and balance control training via tele-assessment. The study exhibited feasibility, safety, and usability in training older adults. The study findings will be relevant to clinicians who aim to conduct similar telehealth paradigms for this population group.

Telehealth offers several advantages, including bidirectional communication between participants and health coaches. The current pilot study attempted to bridge the gap in telehealth by exploring and successfully implementing a novel balance assessment and rehabilitation methodology. The study suggests that it is plausible to train physical and cognitive function among older adults using telehealth while monitoring the participants for safety (heart rate and physical activity monitoring system) and saving costs (e.g., travel expenses).

A few factors may limit the results of this study, and therefore the findings should be interpreted with caution. One notable limitation was the relatively small sample size of the study. However, the study exhibited feasibility, safety, and usability in training older adults. While the research team matched the standardized on-site assessment and training procedures as closely as possible, the psychometric properties (1.e., validity and reliability) of the specific teleassessment procedures and the efficacy of online versus in-person training have yet to be determined and tested. However, the current study has provided proof of in-home teleassessment and telerehabilitation feasibility.

Because telehealth is a relatively understudied area, there are many directions that future research may take; nonetheless, this pilot presents specific considerations for further study. First, it will be essential to identify if the above teleassessment methods identify change over short- and long-term rehabilitation; indeed, the methods that identified change over time showed high validity. Second, evaluating the feasibility and adherence of older adults to long-term telerehabilitation is essential. Lastly, health coaches and participants should undertake adequate training in the relevant technologies and work collaboratively to ensure the best possible transition to these technologies.

CONCLUSION

In conclusion, despite potential financial and functional implication in older adults, health-care personnel are limited in their ability to develop and validate comprehensive teleassessment and tele rehabilitation to evaluate and improve physical and cognitive function among older adults and show long-term compliance to rehabilitation. The proposed telehealth protocol to assess and improve physical and cognitive function if validated, older adults can be provided with a cost-effective, alternative home-based rehabilitation paradigm, thereby elucidating one of the most promising methods to rehabilitate.

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