

# **The Benefits of a Digital Exercise Intervention for Older Adults: Findings from the Fittle Trial**

Sara J Czaja, Joseph Sharit, Peter Pirolli, Mario Hernandez, Jerad H Moxley

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# The Benefits of a Digital Exercise Intervention for Older Adults: Findings from the Fittle Trial

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## Abstract

**Background:** It is well established that physical activity (PA) is important to health, quality of life, and well-being. Yet, most older adults do not engage in physical activity on a regular basis or meet the recommended physical activity guidelines.

**Objective:** This study evaluated the feasibility, acceptability, and efficacy of a digital exercise program, the Fittle Senior System (FSS). The FSS intervention was designed to provide customized behavior-change programs to increase engagement in physical activity and foster online social interaction and support from small teams pursuing similar goals.

**Methods:** One hundred and eighty-one adults aged 60 to 95, including males and females, participated in the study. Participants were randomized into the FSS intervention condition or a Tablet Education (TE) control condition using cluster randomization. Participants in the FSS condition were provided a tablet with the Fittle app, a Misfit Flare activity tracker, and a resistance band. The trial duration was six months. The initial three months of the trial was the active intervention phase, followed by the three month maintenance phase. Participants in the TE condition were also provided with a tablet, the Misfit Flare, a resistance band, and introduced to websites containing exercise programs for aging adults. Measures include measures of usability, acceptability, health outcomes, and psychosocial outcomes. Assessments occurred at baseline and 3- and 6- months post randomization.

**Results:** Fittle was usable and acceptable to the participants assigned to the FSS condition. Participants in both conditions experienced increased physical activity, exercise self-efficacy, health-related quality of life, social support, and decreased social isolation and loneliness. Participants who used the Fittle app to a greater extent reported higher self-ratings of health, better health compared to a year ago, higher exercise self-efficacy, and lower social isolation. Participants in the FSS condition also reported that the Fittle app was easy to use and motivating with respect to engaging in exercise.

**Conclusions:** Our findings indicate that digital exercise programs are feasible for and usable for older adults. These programs can result in improvements in health and psychosocial outcomes. Further, despite the disruptions of the COVID-19 pandemic, attrition in the trial was low, indicating that these types of interventions are valuable to aging adults, including those with multiple chronic conditions. Clinical Trial: NCT03538158

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## Original Manuscript

## The Benefits of a Digital Exercise Intervention for Older Adults: Findings from the Fittle Trial

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**Conclusions:** Our findings indicate that digital exercise programs are feasible for and usable for older adults. These programs can result in improvements in health and psychosocial outcomes. Further, despite the disruptions of the COVID-19 pandemic, attrition in the trial was low, indicating that these types of interventions are valuable to aging adults, including those with multiple chronic conditions.

*Keywords:* Physical Activity; Digital Exercise Programs; Aging, Health; Social Support; Isolation.



## Introduction

The aging of the U.S. population has given rise to concerns about strategies to maintain independence and quality of life in older age. In this regard, it is well documented that engaging in physical activity (PA) is a driver of health, quality of life, and well-being. Physical exercise, a form of PA, is a protector against diseases such as cardiovascular disease, stroke, diabetes as well as some forms of cancer. Additionally, physical exercise is associated with improved emotional health, quality of life, and physical and cognitive functioning<sup>1</sup>. Recently, Xu and colleagues<sup>2</sup>, for example, conducted a systematic review and meta-analysis of randomized controlled trials (RCTs) to compare the effects of aerobic and resistance training on the cognitive ability of older adults. The findings indicated that physical exercise, both aerobic and resistance training, improved the cognitive function of older adults across cognitive abilities. Fishleder and colleagues<sup>3</sup> examined changes in physical functioning among older adults from participation in the Enhance<sup>a</sup> Fitness (EF), a nationally disseminated, evidenced-based group exercise program. They found that participating in the program improved cardiovascular strength, flexibility, and balance. As expected, more consistent program attendance predicted more significant improvements. A recent meta-analysis (Chiung-ju et al.)<sup>4</sup> examined the benefits of multimodal exercise (e.g., combining strength and balance training) among older adults with reduced physical capacity. The findings indicated that multimodal exercise appears to have a broad effect on improving muscle strength, balance, and functioning of the lower extremities and reducing fall risk among older adults with reduced physical capacity.

Existing data also support the benefits of physical exercise on the emotional health of older adults. Agbangla and colleagues<sup>5</sup> conducted a systematic review of the meta-analyses examining the benefits of exercise for older adults in care settings. The findings indicated that overall, physical exercise reduces the rate of falls and improves mobility issues, functional dependence, health status, and depression. The authors underscore that new strategies are needed to increase the participation of older adults in exercise programs in care settings. Kell and Rula<sup>6</sup> examined the benefits of

participating in the evidenced-based Silver Sneakers program on the quality of life of aging adults. The findings showed that participation in the program was associated with improvements in ratings of quality of life and that these benefits increased with time engaged in the program.

Despite the extensive physical and mental health benefits of physical exercise, most older adults do not regularly engage in physical activity. In 2023, the US Department of Health and Human Services reported that only 14 percent of adults aged 65 and older meet recommended physical activity guidelines for aerobic and strength training<sup>7</sup>. A recent meta-analysis by Kilgour and colleagues<sup>8</sup> identified common barriers to exercise among older adults. The barriers fell into three categories: intrapersonal factors, such as fear of falling, physical limitations, and lack of interest; interpersonal factors, such as lack of support or company or lack of time due to a caregiving role; and environmental barriers, such as safety concerns, weather, cost, lack of equipment or opportunities. Also, sustained participation is challenging even when older adults begin engaging in an exercise program. Numerous intervention strategies have been developed to overcome these barriers and increase participation in physical activities among aging adults. These programs often involve formal exercise programs, motivational approaches<sup>9</sup>, or strategies to help integrate physical activity into daily life routines (e.g., Aging Go4 Life Program<sup>10</sup>). Other behavioral-type approaches include self-monitoring, goal setting, and prompting, and interventions with cognitive components include strategies such as education, problem-solving, or counseling. A meta-analysis by Chase<sup>11</sup> to determine the overall effectiveness of interventions designed to increase physical activity behaviors among community-dwelling aging adults found that interventions that combined behavioral and cognitive strategies were effective and that theory-based interventions were more effective than those without a theoretical basis.

The use of technology to deliver home-based physical exercise interventions has been increasing with the development of advancing technology tools. These approaches offer advantages such as convenience, flexibility with respect to tailoring, and removal of environmental barriers such

as safety concerns and weather. A recent systematic review and meta-analysis<sup>12</sup> that evaluated digital home-based exercise programs for older adults found that overall, the programs resulted in improvements in functional capacity, lower extremity functioning, and health-related quality of life. In another recent review, Costa-Brito and colleagues<sup>13</sup> also found that technology-based exercise interventions are associated with positive health outcomes in older adults and that older adults are willing and able to engage with these interventions if adequate support is available.

The current study examined the usability and efficacy of a tablet-based intervention, the Fittle Senior System (FSS), that provided (1) customized behavior-change programs for increased physical activity and (2) online social interaction and support from small teams pursuing similar goals. The FSS intervention was based on the Fittle platform<sup>14</sup> and designed to support positive health behavior change through integrated online social support and artificial intelligence (AI) based personalized coaching. The Fittle program was based on Self-Efficacy and Social Cognitive Theory<sup>15-16</sup>, Goal Setting<sup>17</sup>, and the Theory of Planned Behavior<sup>18</sup>. Fittle was designed to help individuals master healthy habits such as engaging in physical activity, accomplishing goals, and to increase self-efficacy and motivation. The team feature was designed to provide encouragement and increase social support. For this study, the Fittle program was modified for older adults (e.g., the exercises and graphics were designed for older adults) and placed on a computer tablet (Fittle was originally on a smartphone). The FSS intervention was designed using a user-centered design approach and was evaluated with a diverse sample of older adults drawn from two cities in the United States. The FSS intervention condition was compared to a tablet education (TE) control condition, where participants were provided with a tablet, given instruction on exercise safety, and provided with links to online exercise programs for older adults. We hypothesized that the use of FSS would be feasible and acceptable to the study participants. We also hypothesized that participants receiving the FSS intervention would demonstrate an increase in physical activity, greater exercise self-efficacy and social support, and decreased social isolation.

## Methods

### *Participants and Recruitment*

The trial was a multisite randomized controlled trial conducted in Miami, Florida, and New York City. The participant sample was a convenience sample and included males and females aged 60 and older who were English speaking, did not have a visual or hearing impairment that could not be corrected (e.g., with glasses or a hearing aid) or a severe illness that would interfere with participation, were able to walk without assistance, and were not currently engaged in a structured exercise program  $\geq 60$  minutes per week or have a gym membership and regular gym attendance in the past three months. Recruitment strategies included media advertisement, interactions with agencies serving older adults (e.g., Meals on Wheels), mailing lists, posting flyers, meeting with staff (senior housing), and working with ALC Directors and Activity Directors. During lockdown, recruitment occurred via neighborhood e-newsletters, virtual community lectures, and word of mouth. Enrollment began in January 2019 and ended in December 2021. Interested participants completed a telephone eligibility screening, during which potential participants were asked about their engagement in exercise. Participants were also administered the Telephone Interview for Cognitive Status (TICS)<sup>19</sup> and were excluded if they scored  $< 31$ . Those eligible and interested provided written informed consent or e-consent, completed a baseline assessment (by phone and mail due to COVID) and were assigned to study conditions.

### *General Protocol*

The Institutional Review Boards at the two sites approved the study protocol. The trial had a three-month active intervention phase and a three-month maintenance phase. Using a cluster randomization process, participants were randomized by group to the FSS or TE control condition by the team feature of Fittle. Each group contained 4-8 participants. Before COVID-19, the groups included 8 participants. However, this was changed to 4-5 participants as it was difficult to train eight people via Zoom. Participants in both conditions received two individual interactive training

sessions: one group via Zoom and one individual follow-up training via telephone. They also received check-in calls as described above. Participants completed follow-up assessments at baseline and 3- and 6-months post-randomization. An assessor blinded to treatment condition administered the primary and secondary outcome measures over the telephone at 3 and 6 months during the COVID-19 pandemic. The same assessor mailed self-administered instruments (e.g., Life Space Questionnaire<sup>20</sup>). Participants were compensated \$30 per assessment. They could keep the tablet post-intervention; however, FSS and free internet service were no longer available. They were offered help to procure and install a commercial internet service if desired. The study was disrupted due to the mandatory "shutdowns" associated with the COVID-19 pandemic.

### ***COVID-19 Protocol Changes***

Before the COVID-19 pandemic, the assessment battery included physiological measures including the Timed Get-up and Go Test (TUG)<sup>21</sup>, a measure of Grip Strength (using a hand dynamometer), the Berg Balance Scale<sup>22</sup>, Sit to Stand Test<sup>23</sup>, the 2 Minute Walk Test<sup>24</sup>, and assessments of VO2 Max<sup>25</sup> and Body Mass Index (BMI). Trained research assistants administered these measures at the labs of the respective study sites. In addition, the participants' initial level of physical functioning was determined based on their cardiovascular endurance and balance using the TUG and 2-Minute Walk tests. Participants were categorized as low functioning (low balance, low endurance; moderate balance, low endurance), moderate functioning (high balance, low endurance; moderate balance, high endurance), and high functioning (high balance, high endurance). This was used to tailor the exercise program for those in the FSS condition. An exercise physiologist developed the algorithm to determine functional level. Due to the lockdown associated with the COVID-19 pandemic we could no longer take the physiological measures or tailor the FSS program to the individual's initial level of functioning. Thus, further discussion of these measures is not included in this paper. Also, all study participants recruited during COVID-19, were assigned the moderate level of the FSS program, which had three levels of exercises (easy, moderate, and harder)

as described below.

Finally, prior to COVID participants had one day of in-person training with their group, which was changed to virtual Zoom training. The initial day of training was followed by a day of individual training.

### ***Fittle Senior System (FSS)***

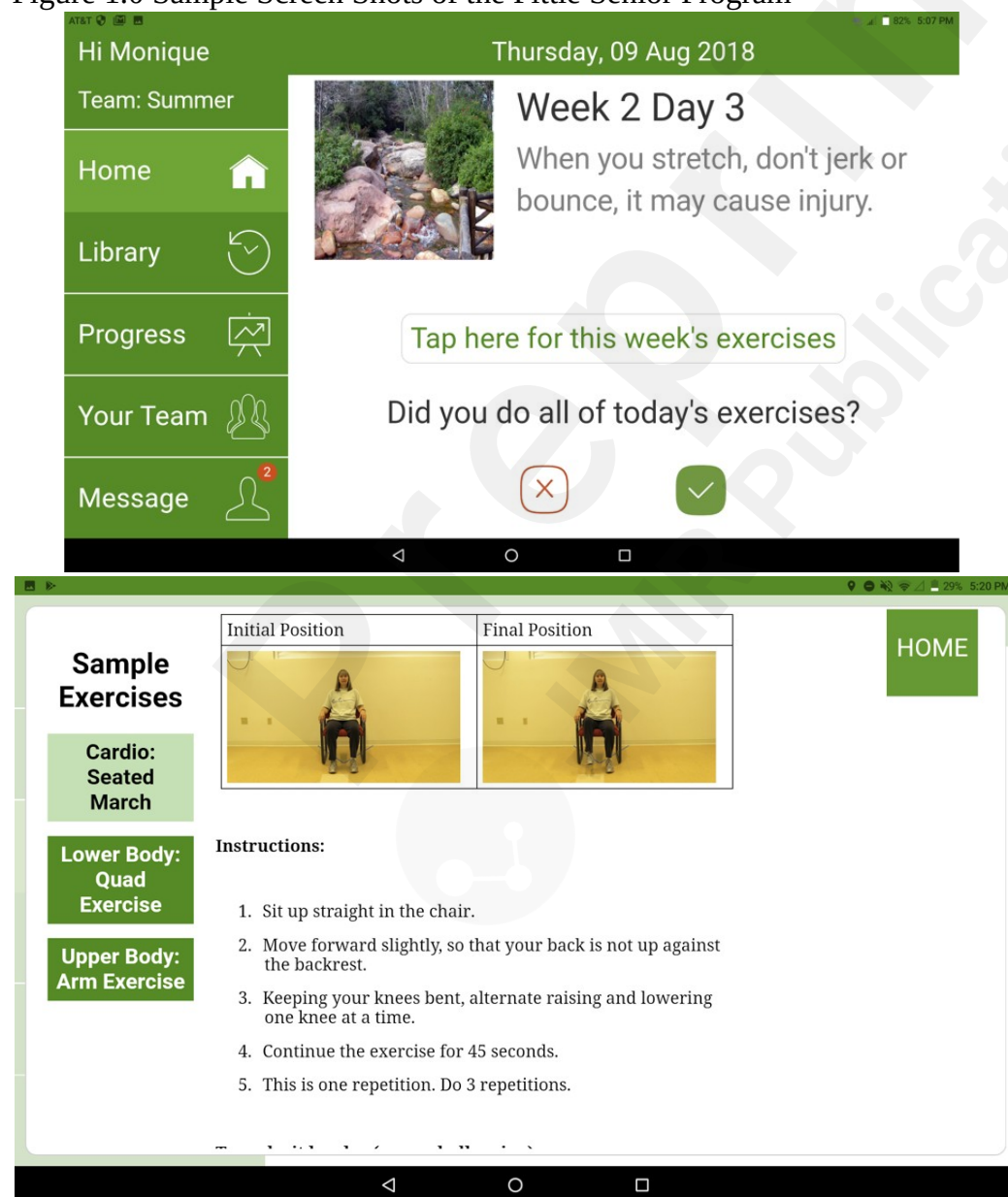
The Fittle Senior System was an app on a tablet that provided (1) personalized behavior-change programs for enhancing physical activity and (2) online social interaction and support from small teams. The exercises were placed in pictorial content on the Tablet. Other features of the FSS include a library feature, a progress feature, and message features that can be used to message the whole team or an individual (Figure 1). The exercises selected targeted balance, cardiovascular fitness, flexibility, and strength. The exercises were selected by exercise physiologists. Participants could choose to perform the exercises at an easy, moderate, or more difficult level. New exercise goals were provided each week, and participants were asked to report daily on their progress and, if they did not exercise, the reason for not exercising from a choice on a drop-down menu (e.g., too tired, did not have time). Participants also received weekly motivation messages. The FSS app included a library feature that provided tips on exercise safety and the weekly exercises, a progress feature that charted the participants' progress, and message features to message the whole team or an individual. FSS was developed using an iterative user-centered design approach that included two rounds of usability testing with older adults. The investigators also conducted a heuristic analysis of FSS using current usability guidelines<sup>26</sup>.

The active intervention period was three months. During this time, participants received new weekly exercise goals and weekly motivational messages. This was followed by a 3-month maintenance period in which participants were encouraged to complete the exercises in their Fittle library.

Participants assigned to the FSS condition were placed into teams to encourage online social

interaction with individuals pursuing similar goals. The teams were able to select a team name. Participants received an AT&T Primetime tablet equipped with a 10-inch display, Bluetooth, WIFI, and a Camera via mail. The tablets were also equipped with 'Quick Support' to enable the participant to screen share with a research assistant if needed. The FSS app was preloaded on the Tablet. Participants also received an exercise resistance band and a Misfit Flare activity tracker that was linked to the Tablet

Figure 1.0 Sample Screen Shots of the Fittle Senior Program



Training occurred over two days. The first training day took place virtually via Zoom in a

team format. Participants were introduced to their team, provided with training on basic exercise safety, and trained on the FSS app and the Misfit. The second training session was conducted individually over the telephone. Participants were contacted 3-5 days after the virtual training session to review the use of the Tablet and the FSS app and have questions answered. Participants also received weekly check-in calls during month one, bi-weekly check-in calls during months two and three, and monthly calls during months four–six.

### ***Tablet Education Condition (TE)***

Participants assigned to the TE condition received a tablet, Misfit Flare, and resistance band. They were directed to three websites that contained exercise programs for older adults: Go4Life<sup>27</sup>, NHS Exercises for older people<sup>28</sup>, and Exercise for Older Adults<sup>29</sup>. Participants in this condition also received two days of training on basic exercise safety, Tablet, and Misfit use, and were introduced to the three recommended websites. The initial training was in a group format via Zoom. The second training session was conducted individually over the telephone. Participants were contacted 3-5 days after the virtual training session to review tablet use, the websites and to have questions answered. Participants also received weekly check-in calls during month 1, bi-weekly check-in calls during months 2-3 and monthly calls during months 4-6.

### ***Treatment Fidelity***

Both sites used a detailed manual of operation procedures (MOP) and applied equivalent procedures and standardized protocols. We also developed manuals for the administration of the assessment battery. Assessor and interventionist training included training on the assessment battery and protocols for both study conditions. In addition, research assistants were provided scripts for participant interactions (e.g., screening, assessments, training, check-in calls, etc.). There were cross-site monthly project coordinator and bi-weekly investigator conference calls.

### ***Primary and Secondary Outcome Measures***

Primary outcome measures included changes over time in loneliness (UCLA Loneliness



Scale<sup>30</sup>), social isolation (Friendship Scale<sup>31</sup>), perceived social support (MOS Social Support Survey<sup>32</sup>), a measure of mobility (Life Space Questionnaire<sup>20</sup>), health-related quality of life (SF-36 Health Survey (modified)<sup>33</sup>), and engagement in physical activity (calculated in MET minutes from the Global Physical Activity Questionnaire, World Health Organization<sup>34</sup>). Secondary outcome measures included changes over time in Perceptions of Aging<sup>35</sup>, Exercise Self-Efficacy<sup>36</sup>, the Perceived Barriers to Exercise Scale<sup>37</sup> and Overall Self-Reported Health (Demographics Questionnaire).

### ***Additional Measures***

Feasibility was assessed by the achievement of recruitment goals and retention. The acceptability of the FSS intervention was assessed by the usability and evaluation ratings. Usability was measured using the System Usability Scale<sup>38</sup>. An evaluation questionnaire was developed for the project. We also measured the use of the Fittle app, and step counts from the Misfit activity tracker.

### ***Analyses***

A mixed-model design with person treated as having a random intercept was used for all analyses. We entered time as a factorial variable (allowing 3 and 6 months to have unique means) and a fixed effect. When comparing patterns of change, we found that the factorial model with time as a fixed effect showed a better model fit as measured by the Bayesian Information Criterion than entering time as a linear effect or allowing time to be a random effect.

For each model, we entered two main effects: time (baseline, three months, or six months), condition (TE Control or Fittle), and the interaction of time and condition. The analyses were conducted with SPSS, which uses the Satterthwaite approximation method<sup>39</sup> to estimate degrees of freedom for mixed methods.

Given that data collection was interrupted by the COVID-19 pandemic, we examined if the pandemic and the associated lockdown impacted our outcome variables. We found that participants whose data were collected during the lockdown reported significantly greater social isolation,

loneliness, and lower social support. They also reported significantly lower health-related quality of life, less physical activity, and greater perceptions of loss associated with aging (all  $p$  values  $> .01$ ). Surprisingly, the pandemic also had a significant impact on barriers to exercise such that participants reported fewer barriers to exercise during the pandemic ( $F(1, 482) = 9.47, P = .002$ ) (Table 1). This may be due to the fact that they had access to Fittle and the exercise programs on the Tablet. Given these associations, we created a dummy variable to reflect whether the data had been collected before or after the start of the lockdown. We included this variable as a control variable in the models.

Additionally, we explored, within the Fiddle condition, if the use of the Fittle app predicted changes in outcomes by adding usage and the interaction of usage and time to the model. Due to the sensitivity of testing for interactions, we used a log-transformed version of usage in the models.

Table 1. Demographic Characteristic of the two conditions.

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Variable		Condition		Test	Location		
		Control n (%)	FITTLE n (%)		NYC n (%)	UM n (%)	Test
<i>Gender</i>							
	Male	22 (24.7%)	15 (16.3%)	X(1)=2.0 P=.2	31 (23.8%)	6 (11.8%)	X(1)=3.3, P=.07
	Female	67 (75.3%)	77 (83.7%)		99 (76.2%)	45 (88.2%)	
<i>Race</i>							
	Hispanic	12 (13.5%)	11 (12.0%)	X(3)=1.0 P=.8	5 (3.8%)	18 (35.3%)	X(3)=39.7 , P<.001
	White Caucasian	62 (69.7%)	66 (71.7%)		102 (78.5%)	26 (51.0%)	
	Black/African American	11 (12.4%)	13 (14.1%)		21 (16.2%)	3 (5.9%)	
	other	4 (4.5%)	2 (2.2%)		2 (1.5%)	4 (7.8%)	
<i>Income</i>							
	Less Than \$ 20000	7 (7.8%)	4 (4.4%)	X(5)=5.6 P=.3	7 (3.8%)	6 (11.8%)	X(5)=5.7, P=.3
	\$20000-\$39999	14 (15.7%)	12 (13.0%)		21 (16.2%)	5 (9.8%)	
	\$40000-\$59999	18 (20.2%)	11 (11.9%)		20 (15.4%)	9 (17.6%)	
	\$60000-\$99999	16 (18.0%)	22 (23.9%)		29 (22.3%)	9 (17.6%)	
	over \$100000	12 (13.5%)	20 (21.7%)		24 (18.5%)	8 (15.7%)	
	don't know/refused	22 (24.7%)	23 (25.0%)		31 (23.8%)	14 (27.5%)	
<i>Meet Global Physical Health Standard</i>				X(1)=1.0 P=.3			X(1)=3.9, P=.049

No	36 (41.4%)	45 (48.9%)		52 (40.6%)	29 (56.9%)	
Yes	51 (58.6%)	47 (51.1%)		76 (59.4%)	22 (43.1%)	
<i>Education</i>						
High school/GED	8 (9.0%)	3 (3.3%)		8 (9.0%)	5 (9.8%)	
Vocational training	2 (2.2%)	0 (0%)		0 (0%)	2 (3.9%)	
Some college/Associates degree	18 (20.2%)	20 (21.7%)	X(5)=10.6 P=.06	25 (19.2%)	13 (25.5%)	X(5)=12.3 , P=.03
Bachelors degree (BA, BS)	19 (21.3%)	32 (34.8%)		36 (27.7%)	15 (29.4%)	
Masters degree or equivalent	34 (38.2%)	24 (26.1%)		49 (37.7%)	9 (17.6%)	
Doctoral degree	8 (9.0%)	13 (14.1%)		14 (10.8%)	7 (13.7%)	

Missing data was not an issue in this study; we had over 99.5% complete data. As mixed models are robust to different amounts of participant data, we included all participants for all time points for which they participated in the study.

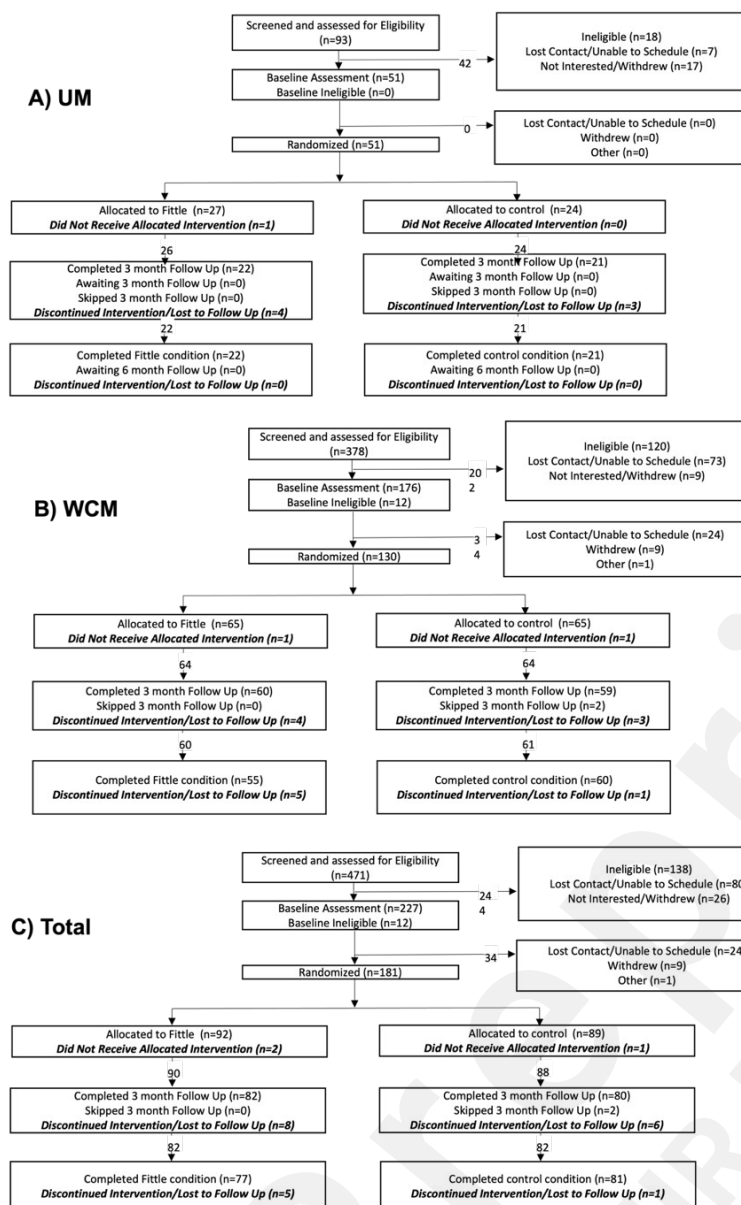
## Results

### *Enrollment and Sample*

Figures 2a, 2b, 2c present the site and overall consort diagrams. As shown, 19% of participants at the Miami site were ineligible at screening, an additional 18% were not interested in participating and 7% were lost to contact. The primary reasons for ineligibility included being too active (50%) or health reasons (28%). At the New York City site, of those screened, 32% were deemed ineligible, 28% were lost to contact, and 5% withdrew due to lack of interest. The primary reasons for ineligibility at the NYC site included being too active (33%), having an active gym membership (16%), or other reasons such as enrollment in a competing study, living too remote from the study area, or literacy problems (32%).

One hundred and eighty-one participants were randomized, including 51 participants at the Miami site and 130 participants at the NYC site. Our recruitment goal was 180 participants; thus, we were successful in our recruitment efforts. Across the sites, the sample ranged in age from 60 to 95 years ( $M = 70.12$ ,  $SD = 6.76$ ), was primarily female (80%), and ethnically diverse. Thirteen

Figure 2 (a-c). Consort Diagrams by Site and Combined.



percent of the sample self-identified as Hispanic, 13% as Black/African American, and 71% as White. Table 2 presents the baseline differences in the categorical demographic variables between the FSS and the TE control conditions and the study sites. Table 3 presents the group differences by condition for the outcome variables and age. Random assignment was highly successful; there were no differences between the conditions at baseline in any demographic or outcome variable. There were differences however, among the Miami and New York participants, with more Hispanic participants at the Miami site. The New York participants were more educated, on average, and also reported less social support, more loneliness, and lower health-related quality of life than the Miami participants.

Table 2. Baseline characteristics of the two Conditions.

Variables	Condition		t-test	Site		t-test
	Control Mean (SD)	Fittle Mean (SD)		NYC Mean (SD)	Miami Mean (SD)	
Age	70.5 (6.6)	69.8 (6.9)	t(179)=.7, $P=.3$	70.2 (6.5)	70.0 (7.5)	t(179)=.1, $P=.9$
Barriers to Exercise	28.8 (8.2)	28.4 (8.7)	t(177)=.3, $P=.8$	27.9 (8.2)	30.2 (8.7)	t(177)=-.1.6, $P=.1$
Environmental Support	20.4 (3.3)	20.3 (3.7)	t(178)=-.06, $P=.9$	20.2 (3.4)	20.8 (3.7)	t(178)=-1.0, $P=.3$
Exercise Efficacy	52.7 (19.2)	53.6 (18.7)	t(177)=-.3, $P=.7$	52.3 (18.4)	55.4 (20.1)	t(177)=-1.0, $P=.3$
Friendships	19.7 (4.1)	20.4 (3.8)	t(179)=1.1, $P=.3$	20.0 (3.5)	20.2 (5.0)	t(179)=-.3, $P=.8$
Health Related Quality of Life	783.2 (147.6)	796.7 (159.3)	t(179)=.6, $P=.6$	<b>770.7 (147.6)</b>	<b>839.4 (158.4)</b>	<b>t(179)=-2.8, <math>P=.006</math></b>
ISEL	25.4 (6.6)	25.9 (7.0)	t(178)=-.5, $P=.6$	<b>24.7 (6.7)</b>	<b>28.0 (6.5)</b>	<b>t(178)=-2.9, <math>P=.004</math></b>
Life Space	5.5 (1.5)	5.7 (1.4)	t(178)=-1.0, $P=.3$	5.6 (1.5)	5.6 (1.3)	t(178)=-.1, $P=.9$
Loneliness	38.9 (8.7)	37.3 (10.1)	t(179)=1.1, $P=.3$	<b>39.1 (9.2)</b>	<b>35.6 (9.8)</b>	<b>t(179)=2.3, <math>P=.02</math></b>
Met Minutes	1805.4 (2897.1)	2178.5 (5682.7)	t(177)=-.5, $P=.6$	2248.0 (5089.3)	1323.6 (2546.0)	t(177)=1.2, $P=.2$
Perceptions of Aging: Loss	2.3 (0.7)	2.2 (0.8)	t(179)=.8, $P=.4$	2.2 (0.8)	2.2 (0.7)	t(179)=.2, $P=.8$
Perceptions of Aging: Gains	4.2 (0.6)	4.3 (0.6)	t(179)=-.8, $P=.5$	4.2 (0.7)	4.3 (0.6)	t(179)=-.8, $P=.4$
Self Reported Health	2.4 (0.8)	2.3 (0.7)	t(179)=.8, $P=.4$	2.4 (0.8)	2.4 (0.8)	t(179)=.1, $P=.9$
Self-Rated Relative Health	2.9 (0.7)	2.9 (0.7)	t(177)=-.2, $P=.8$	3.0 (0.7)	2.8 (0.8)	t(177)=1.3, $P=.2$

## Attrition

Attrition at the 6-month follow-up at the UM site was 26%. At the NYC site, attrition was 12% at the 6-month follow-up. Across the sample, attrition was only 13% at six months. To examine if there were biases associated with attrition, we ran a logistic regression predicting dropouts with the following variables: age, affected by COVID-19 (yes=1), gender (male=1), self-reported general health, and number of chronic conditions. As a whole, this set of variables did not predict dropout  $X^2(6) = 2.9, P=.8$ . The individual parameters were OR=1.0,  $P=.5$ , for age, OR=.7,  $P=.5$  for being affected by covid (yes=1), OR=1.1,  $P=.9$  for being male, OR=.8,  $P=.5$  for self-reported general health, and OR=2.2,  $P=.8$  for number of chronic conditions.

### Primary Outcomes

There was a significant effect of time ( $F(2, 344) = 6.2, p = .002$ ) for loneliness, with participants in both conditions reporting being less lonely at six months compared to baseline. There was no effect of condition ( $F(1, 179) = 2.1, P = .1$ ), and the interaction of time and condition was not statistically significant ( $F(2, 324) = 1.5, P = .2$ ) for loneliness.

Table 3. Estimated Marginal Mean differences for the effect of the Covid-19 pandemic on outcome variables in the study.

Variables	Mean Difference Covid vs non-covid
Useability	MD=-.3, $P = .1$
Barriers to Exercise	<b>MD=-3.1, <math>P = .002</math></b>
Environmental Support	MD=.6, $P = .12$
Exercise Self-Efficacy	MD=-3.8, $P = .09$
Friendship	<b>MD=-3.0, <math>P &lt; .001</math></b>
Health Related Quality of Life	<b>MD=-84.6, <math>P &lt; .001</math></b>
ISEL	<b>MD=-.26, <math>P &lt; .001</math></b>
Life Space	<b>MD=-1.4, <math>P &lt; .001</math></b>
Loneliness	<b>MD=3.8, <math>P &lt; .001</math></b>
Met Minutes	<b>MD=2697.5, <math>P &lt; .001</math></b>
Perceptions of Aging: Loss	<b>MD=.5, <math>P &lt; .001</math></b>
Perceptions of Aging: Gains	MD=.9, $P = .3$
Self-Reported Health	MD=.06, $P = .4$
Self-Rated Relative Health	MD=-.03, $P = .8$

With respect to social isolation, there was an effect of time ( $F(2, 341) = 11.9, P < .001$ ), with participants at six months reporting significantly less isolation as compared to baseline. There was no effect of condition ( $F(1, 171) = 1.3, P = .2$ ), and the interaction of time and condition was not statistically significant ( $F(2, 318) = 1.1, P = .3$ ).

For social support, there was an effect of time ( $F(2, 344) = 7.1, P < .001$ ). At six months for participants in both conditions, there was statistically significant improvement in social support compared to baseline. There was no effect of condition ( $F(1, 175) = .8, P = .4$ ), and the interaction of

time and condition was not statistically significant ( $F(2, 321) = 1.7, P = .2$ ).

With respect to health-related quality of life, as measured by the SF36, there was an effect of time  $F(2, 358) = 7.1, P < .001$ , with participants in both conditions reporting significantly higher health-related quality of life at six months as compared to baseline. There was no effect of condition ( $F(1, 175) = .3, P = .6$ ), and the interaction of time and condition was not statistically significant ( $F(2, 327) = .6, P = .6$ ).

For physical activity, as measured by met minutes calculated from the global physical health survey, there was an effect of time ( $F(2, 358) = 9.2, P < .001$ ), with participants in both conditions at three and six months reporting greater physical activity than at baseline. There was no effect of condition ( $F(1, 176) = .6, P = .5$ ), and the interaction of time and condition was not statistically significant ( $F(2, 327) = .05, P = .95$ ).

### **Secondary Outcomes**

With respect to perceptions of loss associated with aging, there was no difference across time points ( $F(2, 287) = 2.2, P = .1$ ) or condition ( $F(1, 188) = .8, P = .4$ ) and the interaction of time and condition was not statistically significant ( $F(2, 285) = .04, P = .97$ ).

For perceptions of gains related to aging, there was no difference across time points ( $F(2, 275) = 1.5, P = .2$ ), condition ( $F(1, 176) = 1.2, P = .3$ ), and the interaction of time and condition was not significant ( $F(2, 271) = 1.3, P = .3$ ).

There was a significant effect of time ( $F(2, 276) = 7.8, P < .001$ ) for exercise self-efficacy such that participants in both conditions reported greater exercise self-efficacy across time. There was no effect of condition ( $F(1, 176) = .6, p = .4$ ), and the interaction of time and condition was not statistically significant ( $F(2, 272) = .3, p = .8$ ).

For overall self-reported health, there was no significant difference across time points ( $F(2, 343) = 1.8, p = .2$ ) or condition ( $F(1, 177) = .4, p = .5$ ), and the interaction of time and condition was not statistically significant ( $F(2, 322) = .5, p = .6$ ).

However, for self-reported health relative to last year, the effect of time was statistically significant ( $F(2, 360) = 3.7, p = .02$ ). Participants reported better ratings of their health relative to the previous year at both three months and six months as compared to baseline. Study condition was not statistically significant ( $F(1, 179) = .003, p = .95$ ), nor was the interaction of time and condition ( $F(2, 330) = .1, P = .9$ ).

Perceived barriers to exercise decreased over time for participants in both conditions ( $F(2, 353) = 8.25, P < .001$ ). Participants at six months reported significantly fewer barriers to exercise at six months than at baseline ( $t(394) = 2.92, P = .004$ ). The effect of condition on perceived barriers to exercise was not significant ( $F(1, 172) = .23, P = .6$ ). The interaction of time and condition was marginally significant ( $F(2, 323) = 2.99, P = .052$ ). This finding is difficult to interpret as there was a non-significant advantage for the TE control condition at three months ( $t(326) = 1.43, P = .15$ ) and a non-significant advantage for the FSS condition at six months ( $t(326) = -1.06, P = .29$ ).

Participants in both conditions also reported greater mobility over time as measured by the Life Space Questionnaire ( $F(2, 278) = 18.06, P < .001$ ). At both three months ( $t(284) = 3.79, P < .001$ ) and six months ( $t(265) = 6.01, P < .00$ ), participants reported significantly more mobility. There was no effect of condition on mobility ( $F(1, 162) = 1.92, P = .17$ ), and the interaction of time and condition was not statistically significant ( $F(2, 276) = 1.04, P = .36$ ).

### **Step Count**

The Misfit recorded activity data (step count). However, there were several days when participants did not get an adequate Misfit reading (e.g., very low values or a reading of zero) due to the participant choosing not to wear the Misfit, a dead battery, or incorrect placement of the Misfit on the wrist. Several of the Misfits had faulty batteries, which were difficult to replace promptly due to the pandemic. To be included in the Misfit analysis, we established a cutoff that a participant must have had Misfit data with at least a minimum of 100 steps for at least 50% (92 days) of 180 days of the study. Eighty-eight participants, 44 in both conditions, met this requirement. Overall, among



these participants, the average step count for those in the TE control condition was 5550.3 (SD=3126.5), and for those in the FSS condition, the average step count was 5039.6 (SD=2458.2). This difference was not statistically significant ( $t(86) = .8, p = .2$ ).

### ***Use of the FSS App***

In terms of use of the FSS app, 74 participants logged in and used the app on average 74.73 days (SD=48.37) over the six-month time frame. Ratings of usability were higher among participants who used the app to a greater extent ( $F(1,64) = 9.2, p = .003$ ). Further, greater usage of the FSS app significantly increased exercise self-efficacy ( $F(2,73) = 4.0, P = .048$ ). There was also a significant interaction of usage with time ( $F(2,113) = 6.1, P = .003$ ) such that greater use of the FSS resulted in increases in exercise self-efficacy at six months ( $t(120) = 2.8, P = .006$ ) as compared to baseline.

Participants who used the FSS app more also reported higher self-ratings of health at six months as compared to baseline ( $t(134) = -1.8, p = .08$ ). In addition, for ratings of comparison of self-ratings of health as compared to last year, there was a positive relationship with usage ( $F(1,70) = 3.6, P = .06$ ). Overall, participants who used the app more reported that their health was better as compared to the previous year. For social isolation there was also a significant time by usage interaction ( $F(1,129) = 3.4, p = .04$ ). Participants who used the app to a greater extent reported less isolation at six months as compared to baseline ( $t(131) = 2.4, P = .02$ ). There were no other effects of usage on the outcome variables (all  $p$  values  $> .05$ ).

We also explored the difference between the FSS participants who used the app and participants in the control condition. Instead of adding a variable for the amount of usage of the FSS app we included a dummy variable representing active FSS users and control participants. We found a marginally significant main effect difference between the two groups on loneliness  $t(159) = -1.73, P = .09$  and life space  $t(149) = 1.81, P = .07$ , such that users of the FSS app reported less loneliness and more life space across all time points. Additionally we found a marginally significant interaction of time and being a user of FSS on perceived barriers to exercise,  $F(2, 299) = 2.64, P = .07$ . While the

control group participants reported increased barriers to exercise at six months  $t(326)=2.87, P=.004$ , this was not the case for Fittle participants  $t(326)=1.58, P=.12$ .

### ***Usability and Evaluation of Fittle***

With respect to usability, the average usability rating of the FSS app, based on the System Usability Scale, was 69 ( $M = 68.77, SD = 21.68$ ) at three months and 71 ( $M = 70.58, SD = 21.6$ ) at six months, indicating that participants found the Fittle app to be usable. A score of 68 is the cutoff for above-average usability (Brooke, 1989). Participants also reported that it was easy to learn how to use Fittle (85%), that it was easy to understand the exercises (76%), and that the use of Fittle motivated them to exercise (74%). Most participants (70%) reported being satisfied with Fittle.

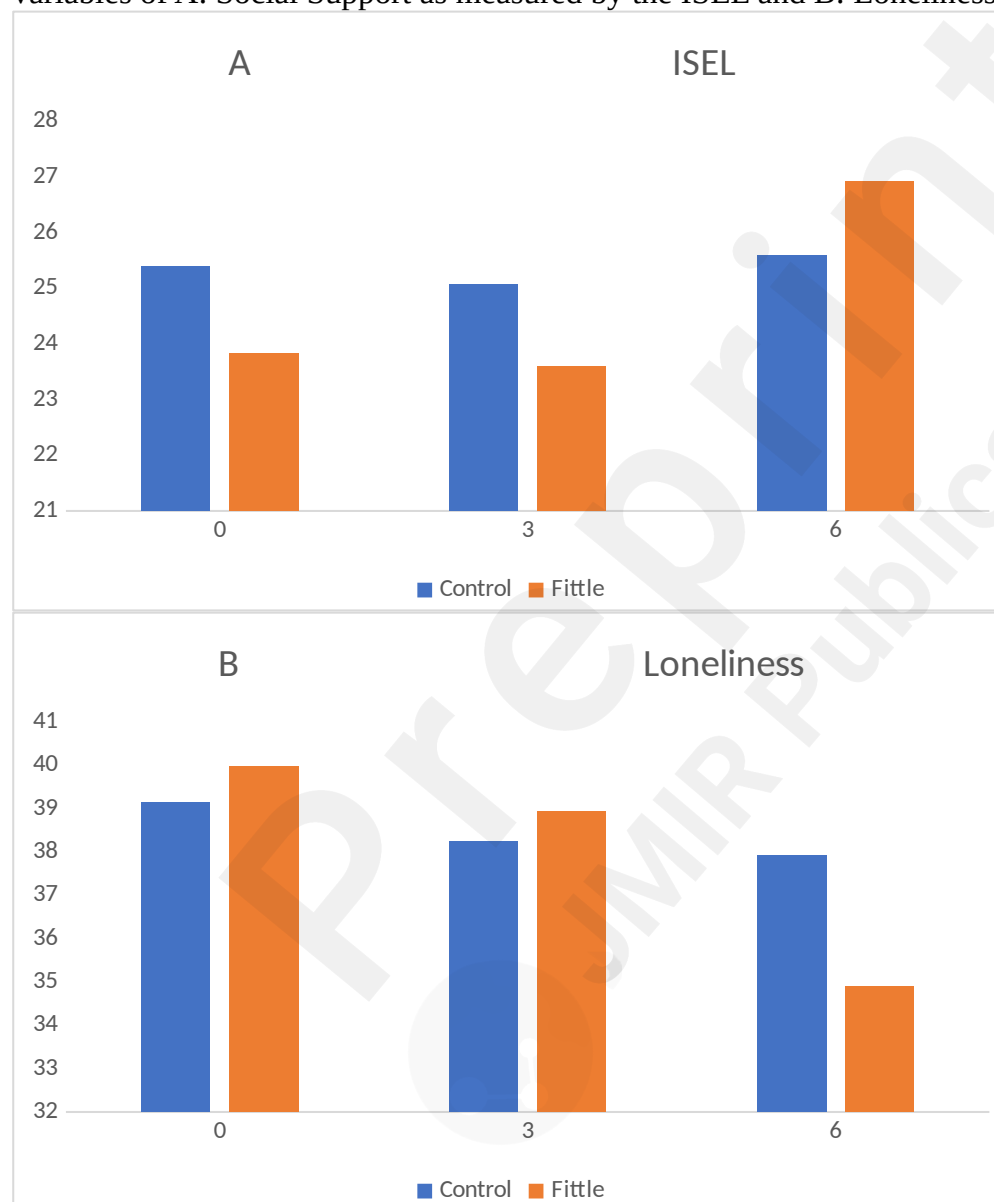
### ***Sub Analysis for People with Chronic Health Conditions***

The Fittle intervention was designed to motivate sedentary older adults or older adults with health limitations to engage in physical exercise. In general, our sample was fairly active for people of their age. The mean for MET minutes was over 1805 for the TE control participants and 2100 for the FSS participants at baseline (Table 2). Both values are higher than the 700 minutes typically used to classify someone as active. Therefore, we decided to explore the impact of the FSS intervention on individuals with multiple self-reported health problems or chronic conditions. Ninety-three participants in our sample met this criterion. We replicated the exact analysis we used for the primary outcomes for this subsample. Our central interest in these analyses was examining the potential impact of the FSS program in this population. Thus, we only report the interaction of time and condition.

The findings indicated that people with multiple chronic conditions assigned to the FSS condition reported significantly more social support at six months ( $B=2.9, t(166)=2.0, P=.048$ ). The positive parameter indicates that participants with multiple chronic conditions in the FSS condition improved more in social support relative to baseline than those with multiple chronic conditions in the TE control condition at six months.

The interaction of time and condition on loneliness was also marginally statistically significant ( $F(2, 166) = 2.5, P = .08$ ). Participants with multiple morbidities in the Fittle condition also reported less loneliness relative to baseline than those with multiple morbidities in the TE control condition at six months ( $B = -3.9, t(167) = -2.0, P = .047$ ) (Figure 3 a & b)

Figure 3. Interaction of time and condition among participants with Chronic Conditions on the variables of A: Social Support as measured by the ISEL and B: Loneliness



## Discussion

Despite the well-established benefits of exercise, most older adults do not meet current guidelines for engaging in physical activity. Common barriers to engaging in exercise include lack of social support and environmental obstacles, such as safety concerns, weather, cost, lack of

equipment, or availability of exercise programs geared for older adults<sup>8</sup>. Recently, there has been an increase in digital exercise programs as these programs can help remove some of the barriers to engaging in physical activity. Recent data indicate that these programs are feasible for and acceptable to older adults and result in health improvements<sup>12,13</sup>. This study evaluated the Fittle Senior System (FSS) a digital exercise program designed for older adults that included a social component. The FSS program was compared to a Tablet Education control condition. Our sample was ethnically diverse, varied across a wide age range, and more than half (51%) of our participants had multiple chronic conditions.

Overall, despite the disruptions due to the COVID-19 pandemic, participants in both conditions experienced benefits in health-related and psychosocial outcomes. Specifically, participants reported an increase in physical activity, mobility (as measured by the Life Space Questionnaire), and health-related quality of life. These findings support those of recent systematic reviews of digital exercise programs for older adults that indicate that digital exercise programs result in improved health outcomes. Access to these programs may remove some barriers to engagement in exercise such as concerns about safety, weather, and lack of available exercise programs geared for older adults. The exercises in FSS program and the exercise websites selected for the educational control condition were explicitly designed for older adults. Participants in both groups reported significantly fewer barriers to exercise throughout the program.

Participants in both groups also reported an increase in exercise self-efficacy over time. This is an important finding as higher self-efficacy is generally associated with greater engagement in physical exercise<sup>40,41</sup>. According to Social Cognitive Theory<sup>42</sup>, higher self-efficacy is associated with higher intrinsic motivation and commitment to engage in health-related behaviors. Similar to our findings, a systematic review and meta-analysis by Baghbani and colleagues<sup>43</sup> examining the impact of exercise interventions on perceived self-efficacy in older adults found that engaging in physical exercise was associated with an improvement in self-efficacy and improvements in motivation to

exercise.

There was also a significant improvement in the social outcomes over time, even after controlling for the lockdown associated with the COVID-19 pandemic. Participants reported a decrease in social isolation, loneliness and an increase in social support over the course of the trial. The FSS program had a social component, and participants in both groups received two days of training, one day in a group format and the second day individually. They also received regular check-in calls. These findings underscore that engagement in activities such as exercise results in benefits beyond health benefits and includes benefits in social outcomes. Eime and colleagues<sup>44</sup> conducted a systematic review of the benefits of sports participation for adults and found that sports participation resulted in improved psychosocial as well as physical health. Other investigators (e.g., Langhammer et al.<sup>1</sup>) have also discussed the social benefits of exercise for aging adults. Participants in the FSS program with multiple chronic conditions reported more social benefits than those in the TE control condition, suggesting that the social component of the FSS program was especially beneficial for this population. Poor health and disabilities are risk factors for social isolation and loneliness<sup>45</sup>. In our sample, number of chronic conditions was significantly associated with less social support and more loneliness. Perceptions that aging was associated with loss was also significantly associated with less social support, more social isolation and loneliness. These findings suggest that engaging in programs such as exercise programs with a social component should be encouraged for older adults with functional declines and disabilities. Of course, these programs must be tailored to the needs of these populations.

The findings regarding improved social outcomes are also in agreement with our findings<sup>46,47</sup> that access to technology can play an important role in decreasing loneliness and isolation among older adults. It is well documented that both social isolation and loneliness have detrimental consequences on cognitive, physical, and emotional health<sup>45</sup>.

There were no differential impacts on our primary and secondary outcomes according to

study condition. This may have been due to the design of the control condition. Participants in the TE control condition also received the Misfit Flare and a resistance band, which may have motivated them to exercise. They also received two days of training and regular check-in calls. However, examination of the usage data revealed that participants in the FSS condition who used the FSS app to a greater extent experienced more benefits than those in the TE control condition. Specifically, they reported greater increases in exercise self-efficacy, improvements in overall health, and less social isolation. An important next step is to identify factors that encourage the use of the FSS program. This might include changes such as adding an artificial intelligence coach or speech output and increasing the social component. The current system is restricted to text and pictures. Overall, participants found the FSS program to be usable and easy to learn. They also reported that the program encouraged them to engage in exercise. The FSS program is also feasible for older adults. Attrition was low among participants in both conditions.

Limitations of the study include that the sample was a convenience sample and only represented older adults in urban locations. Thus, the generalizability of the findings is limited. Further, our ability to obtain follow-up assessments on the physiological measures was limited due to the COVID-19 pandemic. Also, there were problems with the Misfit Flare, which limited measurement of step count. Despite these challenges, the findings are encouraging and indicate that digital exercise programs are feasible for and acceptable to aging adults and result in improved health and social outcomes. However, programs must be tailored to the fitness and functional level of the individual.

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## Abbreviations

PA: Physical Activity

RCTs: Randomized Controlled Trials

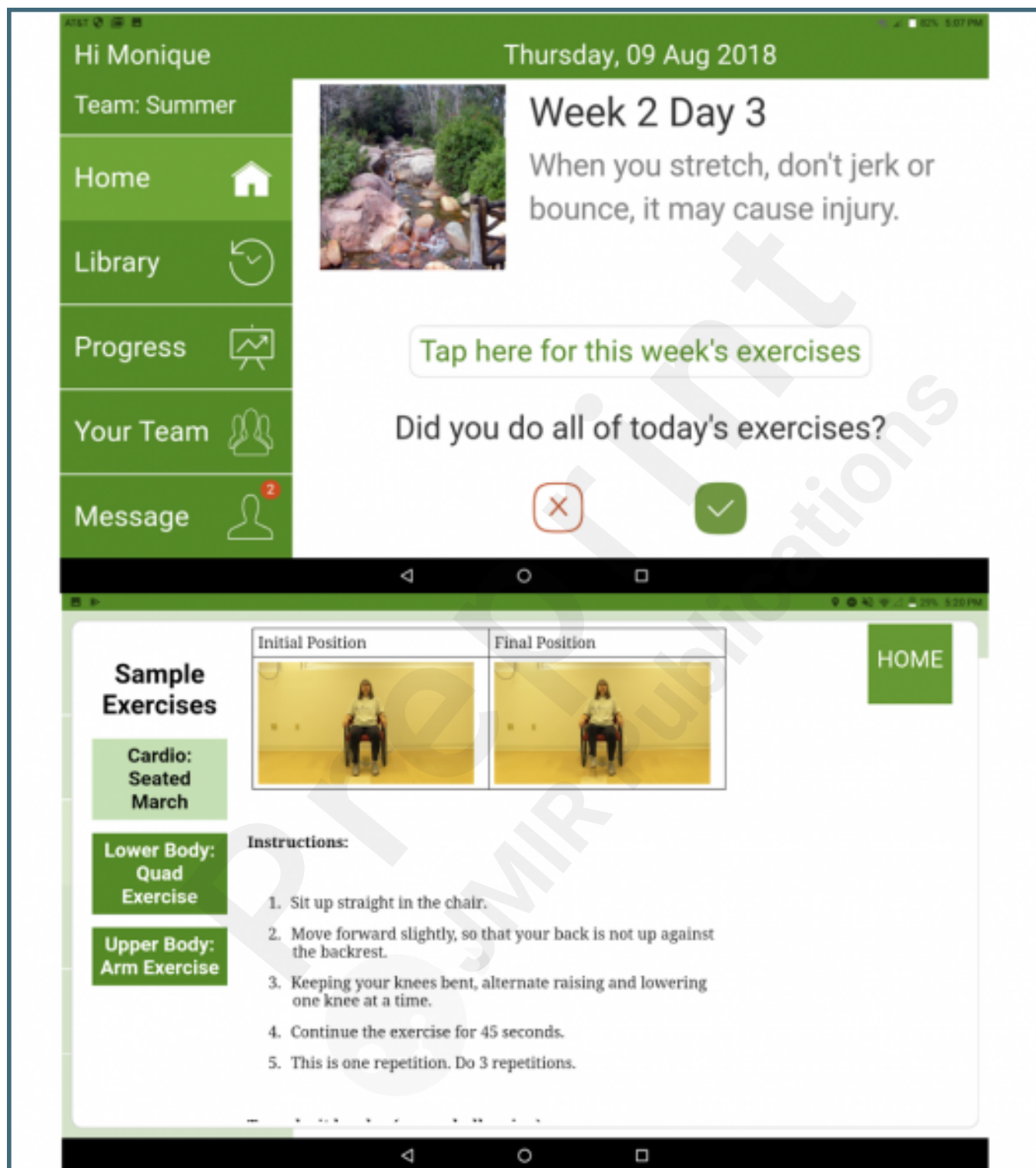
MOP: Manual of Operation Procedures



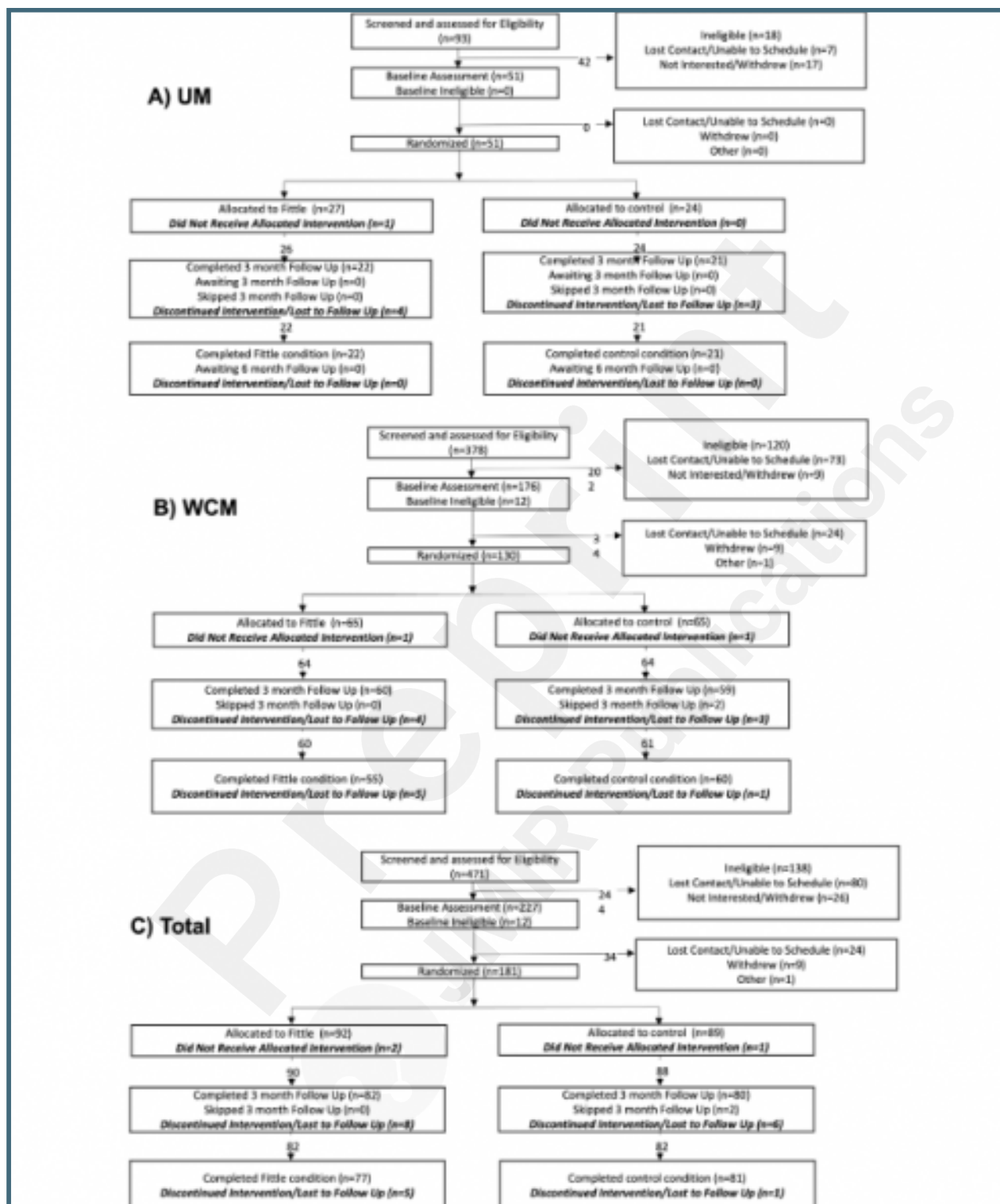
## Supplementary Files

## Figures

Sample screen shots of the Fittle Senior Program.



Consort diagrams by site and combined.





Interaction of time and condition among participants with chronic conditions on the variables of A: Social Support as measured by the ISEL and B: Loneliness.

