Original Paper

Managing Musculoskeletal Pain in Older Adults Through a Digital Care Solution: Secondary Analysis of a Prospective Clinical Study

Anabela C Areias[1], PhD; Dora Janela[1], PT; Maria Molinos[1], PhD; Robert G Moulder[1,2], PhD; Virgílio Bento[1], PhD; Vijay Yanamadala[1,3,4], MBA, MD; Steven P Cohen[5,6], MD, PhD; Fernando Dias Correia[1,7], MD, PhD; Fabíola Costa[1], PhD

[1]Sword Health, Inc, Draper, UT, United States

[2]Institute for Cognitive Science, University of Colorado Boulder, Boulder, CO, United States

[3]Department of Surgery, Frank H Netter School of Medicine, Quinnipiac University, Hamden, CT, United States

[4]Department of Neurosurgery, Hartford Healthcare Medical Group, Westport, CT, United States

[5]Departments of Anesthesiology & Critical Care Medicine, Physical Medicine and Rehabilitation, Neurology, and Psychiatry and Behavioral Sciences, Johns Hopkins School of Medicine, Baltimore, MD, United States

[6]Departments of Anesthesiology and Physical Medicine and Rehabilitation, Uniformed Services University of the Health Sciences, Bethesda, MD, United States

[7]Neurology Department, Centro Hospitalar e Universitário do Porto, Porto, Portugal

Corresponding Author:
Fabíola Costa, PhD
Sword Health, Inc
13937 Sprague Lane, Suite 100
Draper, UT, 84020
United States
Phone: 1 385 308 8034
Fax: 1 801 206 3433
Email: f.costa@swordhealth.com

Related Article:
This is a corrected version. See correction statement in: https://rehab.jmir.org/2026/1/e97495

Abstract

Background: Aging is closely associated with an increased prevalence of musculoskeletal conditions. Digital musculoskeletal care interventions emerged to deliver timely and proper rehabilitation; however, older adults frequently face specific barriers and concerns with digital care programs (DCPs).

Objective: This study aims to investigate whether known barriers and concerns of older adults impacted their participation in or engagement with a DCP or the observed clinical outcomes in comparison with younger individuals.

Methods: We conducted a secondary analysis of a single-arm investigation assessing the recovery of patients with musculoskeletal conditions following a DCP for up to 12 weeks. Patients were categorized according to age: ≤44 years old (young adults), 45-64 years old (middle-aged adults), and ≥65 years old (older adults). DCP access and engagement were evaluated by assessing starting proportions, completion rates, ability to perform exercises autonomously, assistance requests, communication with their physical therapist, and program satisfaction. Clinical outcomes included change between baseline and program end for pain (including response rate to a minimal clinically important difference of 30%), analgesic usage, mental health, work productivity, and non–work-related activity impairment.

Results: Of 16,229 patients, 12,082 started the program: 38.3% (n=4629) were young adults, 55.7% (n=6726) were middle-aged adults, and 6% (n=727) were older adults. Older patients were more likely to start the intervention and to complete the program compared to young adults (odds ratio [OR] 1.72, 95% CI 1.45-2.06; *P*<.001 and OR 2.40, 95% CI 1.97-2.92; *P*<.001, respectively) and middle-aged adults (OR 1.22, 95% CI 1.03-1.45; *P*=.03 and OR 1.38, 95% CI 1.14-1.68; *P*=.001, respectively). Whereas older patients requested more technical assistance and exhibited a slower learning curve in exercise performance, their engagement was higher, as reflected by higher adherence to both exercise and education pieces. Older patients interacted more with the physical therapist (mean 12.6, SD 18.4 vs mean 10.7, SD 14.7 of young adults) and showed higher satisfaction scores (mean 8.7, SD 1.9).

XSL•FO
RenderX

Significant improvements were observed in all clinical outcomes and were similar between groups, including pain response rates (young adults: 949/1516, 62.6%; middle-aged adults: 1848/2834, 65.2%; and older adults: 241/387, 62.3%; *P*=.17).

Conclusions: Older adults showed high adherence, engagement, and satisfaction with the DCP, which were greater than in their younger counterparts, together with significant clinical improvements in all studied outcomes. This suggests DCPs can successfully address and overcome some of the barriers surrounding the participation and adequacy of digital models in the older adult population.

(JMIR Rehabil Assist Technol 2023;10:e49673) doi: 10.2196/49673

KEYWORDS

aged; digital therapy; eHealth; musculoskeletal conditions; older adults; pain; physical therapy; telehealth; telerehabilitation

Introduction

The US population over 65 years of age is forecast to double in the coming decades, from 49.2 million in 2016 to 94.7 million people in 2060, depicting aging as a major driver of changes in US health care systems [1]. Aging is associated with an increased likelihood of developing musculoskeletal conditions [2-5], with around 40% to 60% of older adults reporting persistent musculoskeletal pain [6]. Older adults contribute to 35.2% of the US $381 billion annual spending in this domain [7]. Musculoskeletal disorders elevate the risk of developing comorbidities [8] and increase the odds of mortality [9] in older adults as a result of decreased physical activity, which increases falls and frailty, poor mental health, sleep disturbances, and overall impaired quality of life [2,3,10-13].

Current guidelines advocate for exercise-based physical therapy as the mainstay intervention in musculoskeletal care [14-16]. Telerehabilitation emerged to address barriers associated with conventional physical therapy, thereby improving access to care by mitigating provider shortages, travel and time constraints, and obviating concerns about infection during the COVID-19 pandemic [17]. Despite a general acceptance of telerehabilitation, older adults face specific barriers and concerns associated with digital programs [18,19]. These are related to accessing and being comfortable technology, internet accessibility, perception of a lack of personal connection in digital care, and perceived insufficient effectiveness of remote interventions. Thus, it is particularly important to frame the development of interventions acknowledging generational needs. Helping older adults become more tech-savvy has been shown to improve their health and overall quality of life, as it improves access to information and to community while promoting self-efficacy in daily life [20]. Moreover, the internet usage gap between those who are older than 65 years and younger individuals has narrowed in the past decade [1], providing an opportunity to leverage digital health as a scalable solution that will benefit older adults. Herein, we describe a patient-centered multimodal digital care program (DCP) combining exercise with education and cognitive behavioral therapy (CBT) that has been validated for several acute and chronic musculoskeletal conditions [21-25]. This program was designed to maximize adherence, acknowledging each participant's unique needs. This study aimed to investigate whether the known barriers and concerns of older patients impacted their participation in or engagement with a DCP, or the observed clinical outcomes, in comparison with younger individuals. This secondary analysis hypothesizes that regardless of age, all patients will experience comparable levels of engagement and significant improvements in all clinical outcomes.

Methods

Study Design

This is a secondary analysis of a single-arm investigation into clinical and engagement-related outcomes of patients with musculoskeletal conditions following a DCP delivered between June 18, 2020, and August 3, 2022.

Study Population

Inclusion criteria were US adult (≥18 years of age) beneficiaries of employer health plans with the presence of musculoskeletal pain either in the ankle, elbow, hip, knee, low back, neck, shoulder, wrist, or hand, and duration of pain of >12 weeks. Eligible individuals were invited to apply to Sword Health's DCP (Draper, Utah) through a dedicated enrollment website. Exclusion criteria include health conditions incompatible with at least 20 minutes of light to moderate exercise, ongoing cancer treatment, and the presence of signs or symptoms indicative of serious pathology (eg, rapid progressive motor weakness or sensory alterations, or bowel or bladder dysfunction). All participants provided informed consent. Participants who skipped exercise sessions for 28 consecutive days were considered dropouts.

Intervention

The intervention consisted of exercise, education, and CBT administered for up to 12 weeks, depending on each patient's condition. During onboarding, patients selected a certified doctor of physical therapy (DPT) according to their preferences, who was responsible for tailoring and monitoring the program according to the patient's goals. Each patient received a Food and Drug Administration–listed class II medical device that included a tablet with a mobile app (already installed and ready to use), which displayed exercises and provided real-time video and audio biofeedback on exercise execution through either the use of motion trackers or the tablet's camera. It was recommended that patients perform 3 sessions per week. Exercise data were stored in a cloud-based portal that enabled asynchronous and remote monitoring by the DPT. Condition-specific education and CBT were made available through written articles, audio content, and interactive modules focused on health literacy, pain self-management skills, and mental health [14-16].

XSL•FO
RenderX

The DCP was designed to minimize barriers for those less comfortable with technology and to build trust and commitment from the start. This included an on-call onboarding assistant who was available to help fill out the onboarding form and answer any questions regarding the program's journey. Onboarding assistance was also provided through the enrollment web chat room. Tablet app design followed best practices for acknowledging older adults' use [26] (eg, white spaces between content, allowing to adjust font size and audio volume). The time between exercises could be adjusted to age-appropriate rhythms. Continuous technical support was available to troubleshoot any issues across the intervention (either related to tablet, sensors, or connectivity). A set-up booklet was provided to guide tablet initiation and Wi-Fi connection. A Wi-Fi hotspot was provided to those lacking an internet connection. A personal connection with the DPT was fostered through the onboarding video call and a built-in secure chat on a smartphone app. This allowed for rapport development between DPTs (frequent outreach to provide motivation and feedback on evolution) and patients (who could share ongoing questions and concerns).

Outcomes

Assessment surveys collected at baseline, 4, 8, and 12 weeks were used to analyze mean changes in clinical outcomes between baseline and program end. Engagement data were collected from the cloud-based portal. Table 1 describes the studied outcomes.

Table 1. Description of the assessed outcomes.

Outcome measure	Outcome description
Engagement	
Assistance requests	Amount of support requests during enrollment, onboarding, app installment, member account set-up, and participation
Exercise performance	Corresponds to the sum of correct movements divided by the sum of total movements (independently if correct or incorrect) for each session
Sessions per week	Mean number of sessions performed per week
Total time on sessions	Total time spent exercising during the intervention
Total articles read	Number of articles read during the intervention
Total messages sent by the member	Number of text messages sent by the patient to the DPT[a]
Satisfaction	Evaluated through the question: "On a scale from 0 to 10, how likely is it that you would recommend this intervention to a friend or neighbor?"
Clinical	
Numerical Pain Rating Scale	"Please rate your average pain over the past 7 days from 0 (no pain at all) to 10 (worst pain imaginable)." A 30% or greater decrease was considered to represent a "Minimal clinically important difference (MCID)" [27]
Mental health	Anxiety was assessed by the GAD-7[b] (range 0-21) [28], and depression was assessed by the PHQ-9[c] (range 0-27) [29], in which higher scores denote worse outcomes
WPAI[d]	Collected within employed population to assess overall work impairment (WPAI overall), presenteeism (WPAI work), absenteeism (WPAI time), and activities impairment (WPAI activity) [30], with higher scores denoting poorer outcomes
Analgesics intake	Consumption of analgesics (either over-the-counter or prescribed) for the treated condition (binary response)

[a]DPT: doctor of physical therapy.

[b]GAD-7: Generalized Anxiety Disorder 7-item scale.

[c]PHQ-9: Patient Health Questionnaire 9-item scale.

[d]WPAI: Work Productivity and Activity Impairment Questionnaire.

Statistical Analysis

Participants were categorized into 3 age groups: ≤44 years old (young adults), 45-64 years old (middle-aged adults), and ≥65 years old (older adults). The threshold used to identify older adults is in accordance with age classifications established by the World Health Organization [31] and the US Census, while the threshold to differentiate young and middle-aged adults was based on previous reports from the Centers for Disease Control and Prevention [32,33]. Demographics and clinical outcomes at baseline and engagement metrics were compared between groups using a 1-way ANOVA with Bonferroni correction or chi-square test. Distance to health care facilities was calculated using each patient's geo-coordinates cross-referenced with the geographic location of health care resources (filtered for clinics, doctors, hospitals, and rehabilitation units) [34,35].

A multiple-group latent growth curve analysis (mLGCA) following an intention-to-treat approach was used to assess clinical outcome changes at the program end as well as exercise performance across the program. LGCA is a structural equation

XSL•FO
RenderX

model [36] that provides estimates of overall change based on individual trajectories using time as a continuous variable. Key advantages of LGCA include providing a measure of fitness and addressing missing data through full information maximum likelihood [37]. mLGCA allows the creation of separate models for different groups, accounting for unbalanced group size while simultaneously permitting intergroup comparisons. An analysis focused on patients with minimally significant baseline impairment in the various domains was performed: ≥5 points for Generalized Anxiety Disorder 7-item scale (GAD-7) and Patient Health Questionnaire 9-item scale (PHQ-9) [28,29], and >0 for Work Productivity and Activity Impairment Questionnaire (WPAI; overall, work, time, and activity). A robust sandwich estimator was used for standard errors. Gender, BMI, race or ethnicity (White, non-White, and prefer not to specify), rurality (rural vs urban [38]), and symptomatic anatomical areas (upper limb, lower limb, and spine) were used as covariates for all the above-mentioned models.

An adjusted ordinal regression analysis was performed to longitudinally assess the latent distribution of analgesic consumption until the program ended within and between age groups. An adjusted odds ratio (OR) for being a program starter, being a completer, and reaching the minimum clinically important difference for pain was calculated using binary logistic regression.

Since education levels were considered a robust and consistent predictor of eHealth literacy [39], the impact of education levels (lower education: less than high school diploma, high school diploma, and some college vs higher education: bachelor's or graduate degree) on engagement outcomes was evaluated among older adults through mLGCA. All statistical analyses were conducted using commercially available software (SPSS v22; IBM Corp) and R (version 4.2.2, R Foundation for Statistical Computing). The level of significance was set at $P<.05$ for all 2-sided hypothesis tests.

Ethics Approval

The trial was prospectively approved (New England IRB number 120190313) and registered on ClinicalTrials.gov (NCT04092946) on September 17, 2019.

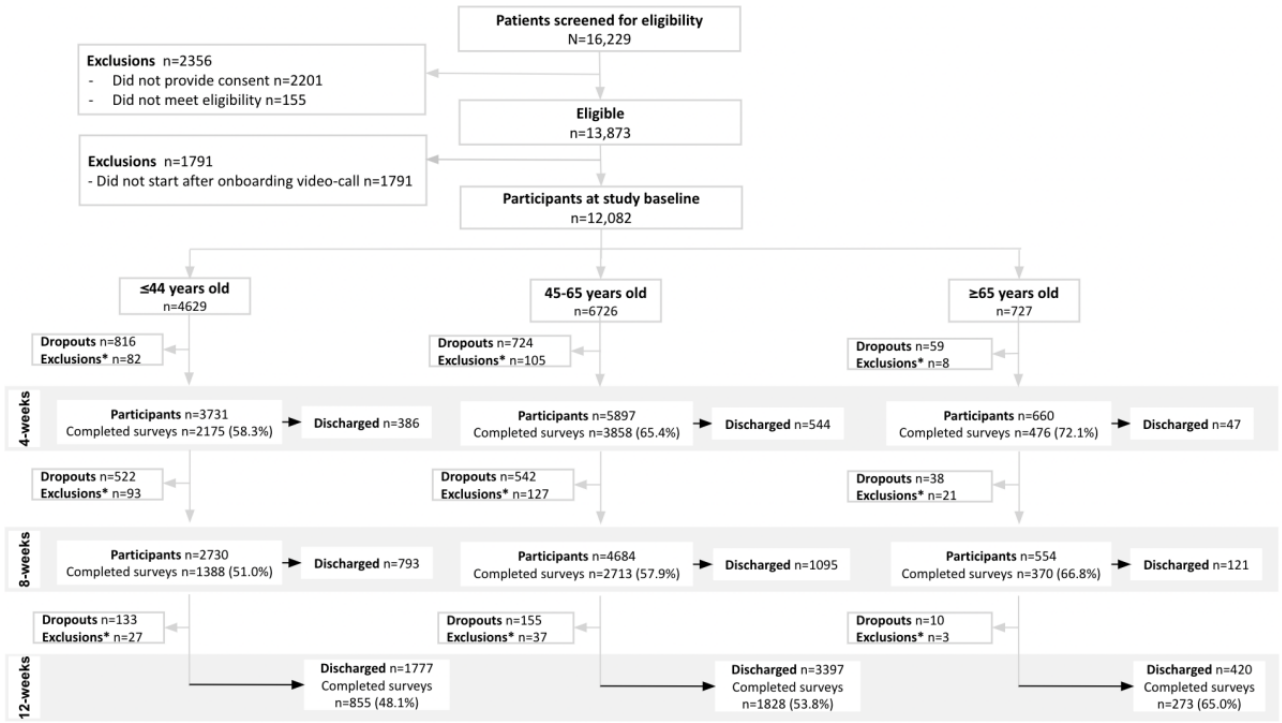
Results

Overview

From a total of 16,229 patients, 12,082 (74.4%) started the study, of which 4629 (38.3%) were young adults (≤44 years old), 6726 (55.7%) were middle-aged adults (45-64 years old), and 727 (6%) were older adults (≥65 years old; Figure 1 and Table 2).

The likelihood to start the intervention (ie, engaging with exercise sessions) was higher among older adults compared to young adults (OR 1.72, 95% CI 1.45-2.06; $P<.001$), and middle-aged adults (OR 1.22, 95% CI 1.03-1.45; $P=.03$). The proportion of those requesting assistance (in the scope of the enrollment, onboarding, app install, member account registration, and set-up questions) was higher for older adults (138/727, 19%) versus middle-aged adults (1031/6726, 15.3%) and young adults (481/4629, 10.4%; $P<.001$), with similar assistance requests per person between groups (mean 1.2, SD 0.5 requests per person in middle-aged adults vs mean 1.1, SD 0.4 requests per person in young adults and mean 1.1, SD 0.4 requests per person for older adults; $P<.001$). The older adults group was also more likely to complete the program than the young (OR 2.40, 95% CI 1.97-2.92; $P<.001$) and middle-aged adults (OR 1.38, 95% CI 1.14-1.68; $P=.001$) groups.

Figure 1. Flowchart of the study stratified by age following the CONSORT (Consolidated Standards of Reporting Trials) guidelines. *Exclusions unrelated to the clinical condition.



XSL•FO
RenderX

Table 2. Cohort demographic characteristics stratified by age groups. Missing values: BMI (n=23); geographic location (n=4); and distance to health facilities within 6 miles (n=25).

Characteristics	Age groups			*P* value
	Young adults (≤44 years old; n=4629)	Middle-aged adults (45-64 years old; n=6726)	Older adults (≥65 years old; n=727)	
Age (years), mean (SD)	35.9 (5.7)	54.5 (5.6)	67.3 (3.1)	<.001
Gender, n (%)				<.001
Woman	2587 (55.9)	4005 (59.5)	352 (48.4)	
Man	2011 (43.4)	2708 (40.3)	372 (51.2)	
Nonbinary	25 (0.5)	10 (0.1)	2 (0.3)	
Other	0 (0)	1 (0)	1 (0.1)	
Prefers not to answer	6 (0.1)	2 (0)	0 (0)	
BMI (kg/m^2), mean (SD)	28.4 (6.7)	29.7 (6.7)	29 (5.8)	<.001
BMI category (kg/m^2), n (%)				<.001
Underweight (<18.5)	51 (1.1)	39 (0.6)	6 (0.8)	
Normal (18.5-25)	1576 (34)	1663 (24.7)	165 (22.7)	
Overweight (25-30)	1524 (32.9)	2266 (33.7)	296 (40.7)	
Obese (30-40)	1169 (25.3)	2199 (32.7)	224 (30.8)	
Morbidly obese (>40)	305 (6.6)	542 (8.1)	34 (4.7)	
Race and ethnicity, n (%)				<.001
Asian	460 (9.9)	458 (6.8)	32 (4.4)	
Black	343 (7.4)	559 (8.3)	35 (4.8)	
Hispanic	444 (9.6)	462 (6.9)	29 (4)	
Non-Hispanic White	2078 (44.9)	3384 (50.3)	391 (53.8)	
Other	139 (3)	108 (1.6)	1 (0.1)	
Not available or prefers not to specify	1165 (25.2)	1755 (26.1)	239 (32.9)	
Employment status, n (%)				<.001
Employed	4278 (92.4)	6139 (91.3)	577 (79.4)	
Not employed	233 (5)	426 (6.3)	138 (19)	
Not available or prefers not to answer	118 (2.5)	161 (2.4)	12 (1.7)	
Education level, n (%)				<.001
Less than high school diploma	25 (0.5)	46 (0.7)	5 (0.7)	
High school diploma	266 (5.7)	501 (7.4)	68 (9.4)	
Some college	835 (18)	1518 (22.6)	155 (21.3)	
Bachelor's degree	1694 (36.6)	2184 (32.5)	208 (28.6)	
Graduate degree	1040 (22.5)	1353 (20.1)	183 (25.2)	
Prefers not to answer or is not available	769 (16.6)	1124 (16.7)	108 (14.9)	
Geographic location, n (%)				<.001
Urban	4182 (90.4)	5918 (88)	631 (86.8)	
Rural	446 (9.6)	805 (12)	96 (13.2)	
Minimum distance to nearest health care facilities in miles				<.001
Median (IQR)	2.1 (3.5)	2.5 (4.2)	2.6 (4.1)	
Mean (SD)	4.2 (6.1)	4.9 (6.6)	5.1 (7)	

XSL•FO
RenderX

Characteristics	Age groups			*P* value
	Young adults (≤44 years old; n=4629)	Middle-aged adults (45-64 years old; n=6726)	Older adults (≥65 years old; n=727)	
Number of health care facilities located within 6-mile radius of residence				<.001
Median (IQR)	5.00 (14)	4.00 (8)	3.00 (8)	
Symptomatic anatomical area, n (%)				<.001
Ankle	229 (4.9)	263 (3.9)	20 (2.8)	
Elbow	91 (2)	175 (2.6)	7 (1)	
Hip	399 (8.6)	683 (10.2)	97 (13.3)	
Knee	599 (12.9)	1097 (16.3)	153 (21)	
Low back	1937 (41.8)	2359 (35.1)	269 (37)	
Neck	538 (11.6)	661 (9.8)	57 (7.8)	
Shoulder	666 (14.4)	1229 (18.3)	109 (15)	
Wrist or hand	170 (3.7)	259 (3.9)	15 (2.1)	

Baseline Characteristics

The older adults group was more balanced gender-wise compared to other age groups, which contained a greater proportion of women (Table 2). Young and middle-aged cohorts had lower BMI levels and included significantly more people of color than older adults (Table 2). Although the majority of older adults were employed (79.4%), the group also had the highest percentage of nonemployed participants (19% vs 6.3% and 5%; *P*<.001), which was primarily due to the high percentage of retirees (106/138). Young adults reported significantly higher education levels than middle-aged and older adults (Table 2). Older adults mainly resided in urban areas but also had the highest percentage (13.2%) of patients situated in rural areas compared to young (9.6%) and middle-aged adults (12%; *P*<.001). Older adults lived farther away from health care facilities, with fewer providers within a 6-mile radius compared to other groups (Table 2).

The most reported symptomatic anatomical areas across groups were the low back, knee, and shoulder (Table 2). Pain scores were significantly higher in older (mean 4.83, SD 2.0) and middle-aged adults (mean 4.90, SD 2.0) compared to young adults (mean 4.48, SD 1.9; *P*<.001; Table 3). A commensurate trend was observed for analgesic consumption (34.3% of older adults vs 27.1% in middle-aged adults vs 16% in young adults; *P*<.001). Among those who reported at least mild anxiety or depression symptoms at baseline, older adults had lower levels of anxiety (mean 7.98, SD 3.6 vs mean 8.54, SD 3.9 in middle-aged adults and mean 9.2, SD 4.1 in young adults; *P*<.001), and depression (mean 8.12, SD 3.4 vs mean 9.07, SD 4.2 in middle-aged and mean 9.66, SD 4.5 in young adults; *P*<.001; Table 3). A significantly higher proportion of young adults (2429/4278, 56.8%) reported overall productivity impairment at baseline versus middle-aged (3217/6139, 52.4%) and older adults (281/577, 48.7%; *P*<.001; Table 3). However, similar average work productivity and activity impairment scores were observed between groups (Table 3). Presenteeism was particularly an issue for young adults (WPAI work: mean 29, SD 19; *P*=.02), while absenteeism was mainly reported by older adults still in the workforce compared to other age categories (WPAI time: mean 40, SD 40.6; *P*=.002; Table 3).

XSL•FO
RenderX

Table 3. Clinical characteristics at baseline stratified by age. For unfiltered cases, see Table S1 in Multimedia Appendix 1.

Outcomes	Age group						*P* value
	Young adults (≤44 years old)		Middle-aged adults (45-64 years old)		Older adults (≥65 years old)		
	Patients, n	Mean (SD)	Patients, n	Mean (SD)	Patients, n	Mean (SD)	
Pain	4629	4.48 (1.9)	6726	4.90 (2.0)	727	4.83 (2.0)	<.001
GAD-7[a] score of ≥5	1778	9.15 (4.1)	1815	8.54 (3.9)	133	7.98 (3.6)	<.001
PHQ-9[b] score of ≥5	1292	9.66 (4.5)	1410	9.07 (4.2)	136	8.12 (3.4)	<.001
WPAI[c]-Overall score of >0	2429	31.4 (21.8)	3217	30.9 (22.0)	281	29.7 (23.5)	.42
WPAI-Work score of >0	2363	29 (19.0)	3090	28.4 (18.8)	260	25.7 (17.6)	.02
WPAI-Time score of >0	477	23.8 (28.0)	595	26 (30.5)	46	40 (40.6)	.002
WPAI-Activity score of >0	3532	35 (21.5)	5109	35.7 (22.5)	536	35.2 (22.3)	.31
Analgesic intake (binary), n (%)	741 (16)	N/A[d]	1821 (27.1)	N/A	249 (34.3)	N/A	<.001

[a]GAD-7: Generalized Anxiety Disorder 7-item scale.

[b]PHQ-9: Patient Health Questionnaire 9-item scale.

[c]WPAI: Work Productivity and Activity Impairment Questionnaire.

[d]N/A: not applicable.

Engagement Outcomes

Overview

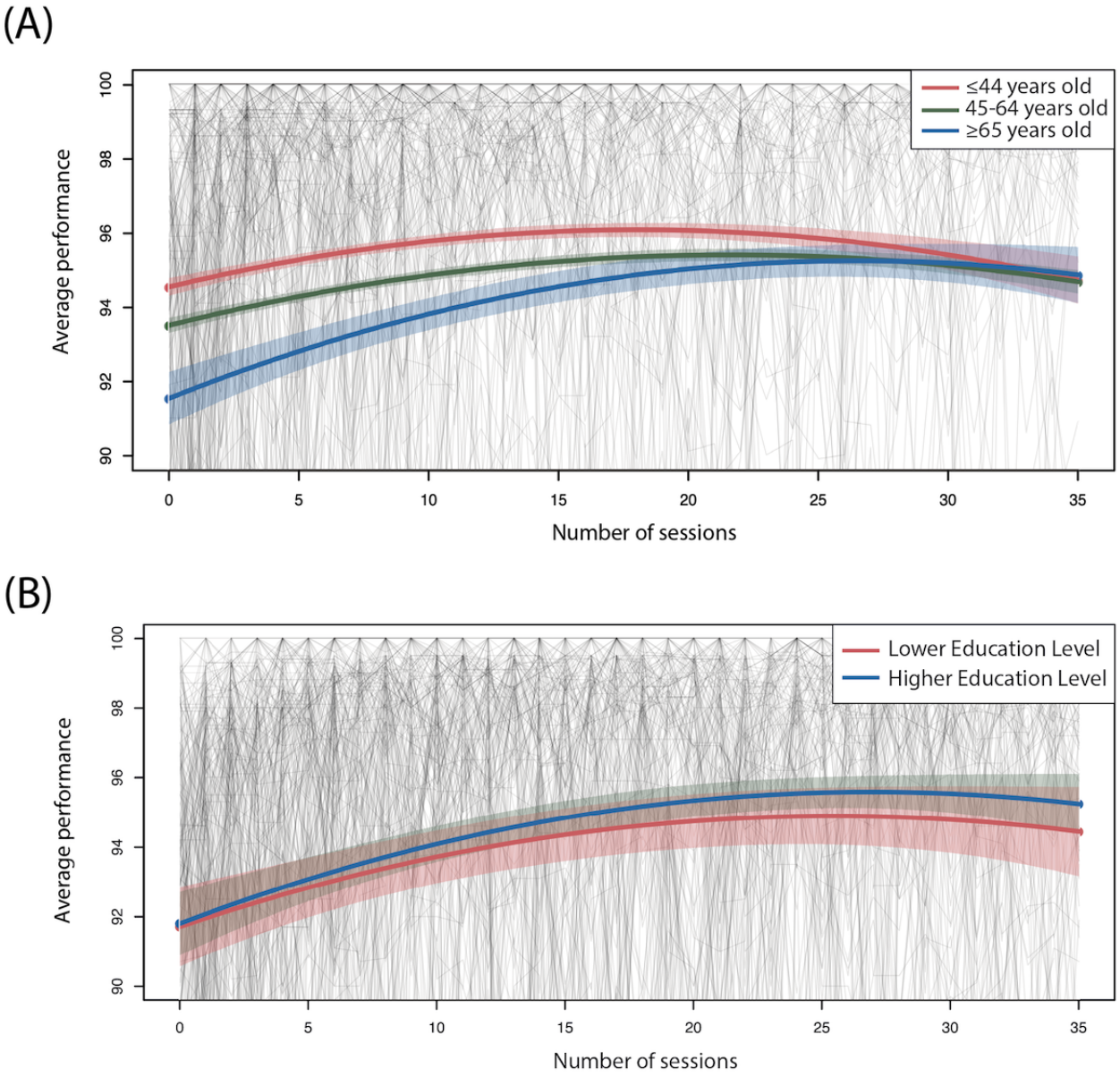
Older adults completed significantly more sessions than the other groups (sessions per week: mean 3.1, SD 1.2 for older adults vs mean 2.4, SD 0.9 for young adults, and mean 2.7, SD 1.1 for middle-aged adults; *P*<.001). Older adults also dedicated more overall time to sessions (mean 698.5, SD 740.4 minutes) than young (mean 320.6, SD 354.7 minutes; *P*<.001) and middle-aged adults (mean 473.9, SD 524.6 minutes; *P*<.001).

Regarding the learning curve for correctly performing the proposed exercises, all groups attained high exercise performance (>90%) at the intervention start, with older adults performing at significantly lower levels than the other cohorts (intercept: 91.5, 95% CI 90.8-92.2 vs 93.5, 95% CI 93.3-93.7 for middle-aged adults and 94.5, 95% CI 94.3-94.8 for young adults; *P*<.001 for all combinations; Figure 2A and Table S2 in Multimedia Appendix 1 [40,41]). However, the difference between older and middle-aged exercise performance disappeared by session 20 (Figure 2A and Tables S2 and S3 in Multimedia Appendix 1). The leveling effect observed toward the intervention's end was not statistically significant between groups. Older adults read on average more pieces of education than other groups (mean 3.9, SD 6.7 vs mean 2.2, SD 4.3 young adults; *P*<.001 vs mean 3.3, SD 6.0 middle-aged adults; *P*=.005).

Both older adults (mean 12.6, SD 18.4) and middle-aged adults (mean 11.8, SD 16.7) sent significantly more text messages with the DPT than young adults (mean 10.7, SD 14.7; *P*=.02 and *P*=.004, respectively). Total satisfaction with the program was high, with older adults (mean 8.7, SD 1.9) and middle-aged adults (mean 8.8, SD 1.7) being significantly more satisfied with the program than younger patients (mean 8.5, SD 1.8; *P*<.001).

XSL•FO
RenderX

Figure 2. Engagement outcomes. (A) Average exercise performance trajectories broken down by age group. (B) Average performance for older adults stratified by education attainment. Shadowing indicates each trajectory's confidence interval, while individual trajectories are depicted with lighter gray lines.



Subgroup Analysis: Impact of Education Level on Older Adults' Engagement

Among older adults, those with lower education levels spent a similar amount of time on sessions (mean 640.5, SD 599.3 vs mean 649.3, SD 705.5; *P*=.09) and participated in a similar number of sessions per week (mean 3.0, SD 1.2 vs mean 3.1, SD 1.2; *P*=.10) as those with higher education levels. Similar numbers of educational resources were viewed (mean 3.5, SD 6.1 vs mean 3.7, SD 6.6; *P*=.38) and messages were sent to the DPT (mean 13.5, SD 20.1 vs mean 11.8, SD 16.5; *P*=.32) in the older cohort regardless of education level. Exercise performance trajectories were not influenced by education level (Figure 2B and Table S4 in Multimedia Appendix 1). Overall satisfaction was similar between groups (mean 8.7, SD 1.8 for the lower education subgroup vs mean 8.9, SD 1.7 for the high education subgroup; *P*=.25).

Clinical Outcomes

Clinical outcomes are presented in Table 4. The mLGCA model's estimates and fitness are presented in Tables S5 and S6 in Multimedia Appendix 1, respectively, showing a good fit.

XSL•FO
RenderX

Table 4. Program end and estimated outcome mean change for each age category.

Outcome measure	Young adults (≤44 years old; n=4629), mean (95% CI)	Middle-aged adults (45-64 years old; n=6726), mean (95% CI)	Older adults (≥65 years old; n=727), mean (95% CI)
Pain			
Program end	1.90 (1.62 to 2.18)	2.09 (1.91 to 2.26)	2.53 (1.97 to 3.08)
Mean change	2.37 (2.08 to 2.66)	2.62 (2.43 to 2.80)	2.11 (1.53 to 2.69)
GAD-7[a] score of ≥5			
Program end	3.82 (2.73 to 4.90)	3.99 (3.03 to 4.95)	4.90 (3.06 to 6.74)
Mean change	5.21 (4.15 to 6.28)	4.26 (3.32 to 5.22)	3.10 (0.98 to 5.22)
PHQ-9[b] score of ≥5			
Program end	4.25 (2.74 to 5.76)	3.13 (2.16 to 4.10)	4.79 (2.47 to 7.11)
Mean change	4.97 (3.53 to 6.42)	4.94 (3.93 to 5.94)	2.10 (–0.70 to 4.90)
WPAI[c]-Overall score of >0			
Program end	13.71 (9.52 to 17.90)	10.73 (7.83 to 13.62)	17.98 (7.15 to 28.81)
Mean change	16.01 (11.87 to 20.15)	18.29 (15.26 to 21.32)	7.12 (0 to 17.65)
WPAI-Work score of >0			
Program end	12.12 (8.33 to 15.90)	8.59 (6.22 to 10.96)	12.58 (5.89 to 19.26)
Mean change	14.70 (10.85 to 18.54)	17.82 (15.30 to 20.34)	9.77 (3.21 to 16.33)
WPAI-Time score of >0[d]			
Program end	9.50 (5.7 to 13.28)	8.12 (5.24 to 11.00)	13.45 (2.93 to 24.00)
Mean change	14.13 (10.06 to 18.20)	17.84 (14.45 to 21.21)	23.88 (13.64 to 34.12)
WPAI-Activity score of >0			
Program end	11.25 (8.46 to 14.04)	12.27 (10.17 to 14.37)	12.20 (6.46 to 17.94)
Mean change	20.69 (17.66 to 23.73)	19.34 (17.11 to 21.57)	13.62 (7.03 to 20.20)

[a]GAD-7: Generalized Anxiety Disorder 7-item scale.

[b]PHQ-9: Patient Health Questionnaire 9-item scale.

[c]WPAI: Work Productivity and Activity Impairment Questionnaire.

[d]WPAI Time results were yielded from an unconditional model due to poor model fitness when adjusting for the covariates.

Pain

All age groups experienced significant reductions in pain by program end (Table 4), with no statistically significant differences between them (young adults: 2.37, 95% CI 2.08-2.66; middle-aged adults: 2.62, 95% CI 2.43-2.80; and older adults: 2.11, 95% CI 1.53-2.69; *P* values in Table S7 in Multimedia Appendix 1). Response rate did not differ across groups (young adults: 949/1516, 62.6%; middle-aged adults: 1848/2834, 65.2%; and older adults: 241/387, 62.3%; *P*=.17), when considering a 30% minimal clinically important difference for pain [27].

Analgesic Consumption

All groups reduced analgesic consumption by the program's end. Using intention-to-treat analysis, a lower probability of analgesic intake at the program's end was similar across groups (mean change in young adults group: –0.040; *P*<.001; middle-aged adults group: –0.056; *P*<.001; and older adults group: –0.091; *P*<.001; Table S8 and Figure S1 in Multimedia Appendix 1).

Mental Health

Despite different mental distress levels (GAD-7 and PHQ-9 scores of ≥5) at baseline (Table 3), all groups showed significant and similar improvements at the intervention's end (*P*<.001; Table 4, Table S7 in Multimedia Appendix 1). The observed end scores indicated the absence of relevant anxiety (young adults: 3.82, 95% CI 2.73-4.90; middle-aged adults: 3.99, 95% CI 3.03-4.95; and older adults: 4.90, 95% CI 3.06-6.74) [28], and depression symptoms at program end (young adults: OR 4.25, 95% CI 2.74-5.76; adults: OR 3.13, 95% CI 2.16-4.10; and older adults: OR 4.76, 95% CI 2.47-7.11) [29].

Productivity

Recovery in overall productivity was significant and similar between groups (mean changes for young adults 16.01, 95% CI 11.87-20.15; middle-aged adults 18.29, 95% CI 15.26-21.32; and older adults 7.12, 95% CI 0-17.65; Table 4 and *P* values in Table S7 in Multimedia Appendix 1). Older adults reported similar presenteeism recovery to young adults (9.77, 95% CI 3.21-16.33 vs 14.70, 95% CI 10.85-18.54, respectively; *P*=.20), but slightly lower than middle-aged adults (vs 17.81, 95% CI

XSL•FO
RenderX

15.30-20.34; *P*=.02; Table 4 and Table S7 in Multimedia Appendix 1). The older adults group reported a high improvement in absenteeism (23.88, 95% CI 13.64-34.12), which was not significantly different from the other groups (14.13, 95% CI 10.06-18.20, *P*=.08 in young adults and 17.84, 95% CI 14.45-21.21, *P*=.27 in middle-aged adults; Table S7 in Multimedia Appendix 1). All groups recovered from the impairment in non–work-related activities to the same extent (Table S7 in Multimedia Appendix 1).

Discussion

Main Findings

Older adults may face age-specific barriers and concerns when considering digital musculoskeletal care. This study aimed to investigate whether these barriers and concerns impacted their participation in or engagement with a DCP or the observed clinical outcomes in comparison with younger individuals. Here, among those who applied to the program, older adults were more likely to start the intervention. Although they requested more technical assistance and exhibited lower initial exercise performance, the performance gap shortened over time, disappearing after 20 sessions. Overall, engagement was higher among older adults. The adherence to exercise and education and the frequent communication with the DPT suggest older adults felt comfortable with the technology and were able to establish a therapeutic relationship. Engagement outcomes were not influenced by education level, which was used as a proxy for digital literacy. Significant and similar clinical improvements in pain (with similar response rate), mental health, analgesic consumption, and productivity were observed across age groups, reinforcing the relevance of the program regardless of age. Overall, this study supports the delivery of digital musculoskeletal care to older adults.

Comparison With Previous Research

Older adults account for 16% of the US population [42], whose distribution in terms of race and ethnicity [42], rurality [43], and employment [42] matches the older adult cohort herein described.

Comfort With Technology

Health equity considerations highlight the importance of developing interventions that specifically address the barriers and concerns felt by older patients. Evidence suggests that musculoskeletal digital programs are feasible in this population [44-47]. In this study, we observed higher adoption than previously reported for older adults [45,46], as well as a higher likelihood of starting the intervention than their younger counterparts, suggesting that the possible distrust phenomenon was overcome in this particular cohort.

Although a higher number of older adults asked for technical assistance, the mean requests per patient were similar across groups. At the intervention start, older adults had lower exercise performance than younger groups, despite starting at a high score. Importantly, older patients were able to learn and improve their performance, challenging the myth that older adults are less capable of using technology. This is further reinforced by the similar engagement metrics observed regardless of education levels, although the older adult cohort reported a slightly higher proportion of those with higher education (bachelor's degree or higher) than the US population [42].

The tailored exercise program with continuous feedback and monitoring may have empowered patients to exercise [48,49], positively impacting their self-efficacy and motivation to adhere to the intervention, as previously suggested [50]. Older adults were more adherent than other age groups, as shown by the higher number of executed sessions, time dedicated to sessions, and completion rates, in accordance with previous literature [44]. However, older adults were on average located farther away from health care facilities, which bolsters the rationale for using a DCP, especially for those with limited mobility capabilities who rely on caregivers to commute to in-person clinics.

Musculoskeletal pain management guidelines recommend education during interventions [14-16], and digital interventions may play a crucial role in dissemination, given their tailored nature, and wide and convenient accessibility. High engagement in educational content was observed, particularly in older adults.

Establishment of a Therapeutic Relationship in Remote Care

Establishing a collaborative relationship between the patient and DPT is key to building rapport, ensuring patient adherence, and driving positive clinical outcomes [51,52]. The DCP ensured collaborative goal setting, development of achievable tasks during onboarding, and ongoing bidirectional communication [51,52]. These factors have been previously shown to be key elements in establishing a strong therapeutic alliance [51-53]. The higher number of messages sent by older adults to the DPT, and the higher satisfaction with the program highlight the importance of the DCP design to change the perception of lack of personal connection in digital care. These results are in line with studies reporting that technologically advanced solutions can achieve the same level of trust as traditional methods [54].

Clinical Outcomes

Significant and similar improvements in pain (including comparable response rates) were observed across age groups. Older adults have lower pain thresholds and lower tolerance than their younger counterparts [55], and have been shown to have lower recovery rates on some outcome measures than their younger peers [56]. The higher number of completed sessions by older adults may have contributed to this finding, as higher adherence is associated with better outcomes [57,58]. Despite a larger proportion of older adults reporting analgesic consumption at baseline, they were able to significantly reduce analgesic intake to the same extent as other age groups. This is particularly important in an era where medications are overprescribed and older adults are prone to side effects and drug-drug interactions [59-61].

Musculoskeletal pain is a major driver of productivity impairment [62,63]. At baseline, 79.4% of older adults were in the workforce, but about half reported productivity issues mainly driven by absenteeism [64,65]. Older patients reported similarly significant productivity and non–work-related activity improvements as younger patients at the program end. This

XSL•FO
RenderX

suggests that despite the obstacles to returning to work for this age group [66], the DCP was effective in reducing absenteeism. Non–work-related activity improvement is particularly important for older adults as it contributes to the maintenance of autonomy.

Collectively, these findings supported wider dissemination of DCPs in the older adult population. Although not all patients may be eligible for a digital program (eg, due to cognitive decline) [67], a significant proportion of this population could benefit from timely and continuous care to manage their chronic musculoskeletal conditions. Future research should aim to identify and better characterize those who can benefit the most from digital programs, and design and study ways to improve implementation. Mobilizing older adults toward the use of digital technology may empower patients to play an active role in care management, thereby decreasing condition-related mental distress and improving their overall quality of life.

Strengths and Limitations

The major strength of this study is the novelty of analyzing specific engagement metrics to deep dive into the older adults' interface with a DCP, which were not explored before. An additional strength is the wide range of clinical outcomes based on validated scales, which can enhance generalizability. This study provides the groundwork to further develop and refine telerehabilitation programs that ensure equitable and continuous care regardless of age.

The major limitation is the lack of a control group, for which the most obvious comparator would be a "waiting list." This may not be ethical considering the high accessibility this technology affords in a real-world context. Another alternative would be a control group that receives "usual care," which could provide valuable insight into the acceptance of digital interventions versus conventional care. Since the program enrolled beneficiaries of employers' health benefits, the current cohort may not be representative of the older adult population in the United States, for whom Medicare is the major insurance payer. Despite education levels being considered a proxy of digital literacy, other objective metrics might provide a better understanding of the impact of digital literacy on telerehabilitation. Finally, the lack of long-term follow-up precludes the evaluation of long-term benefits.

Conclusions

This study reports high adherence, engagement, and satisfaction with a digital musculoskeletal care program in an older adult population, which were greater than in younger counterparts. Older adults achieved statistically significant and clinically meaningful improvements in all studied outcomes (in pain, mental health, analgesics consumption, and productivity), suggesting that DCPs can successfully overcome some of the barriers surrounding participation in this population. This study showcases the importance of acknowledging generational needs when designing digital interventions in order to ensure equitable and continuous care regardless of age.

Acknowledgments

The authors would like to thank the team of physical therapists responsible for managing the participants. The authors also acknowledge the contributions of João Tiago Silva, Margarida Morais, and Guilherme Freches in data validation and Evelyn Chojnacki for constructive criticism of the manuscript (all employees of Sword Health). The study sponsor, Sword Health, was involved in the study design, data collection, interpretation, and writing of the manuscript.

Data Availability

The data sets generated or analyzed during this study are available from the corresponding author upon reasonable request.

Authors' Contributions

All authors made a significant contribution to the work reported as follows: FDC and FC were responsible for the study concept and design; MM acquired the data; RGM performed the statistical analysis; FC, ACA, DJ, MM, and SPC interpreted the data; ACA and FC were responsible for drafting the work; and VB was responsible for funding. Critical revision of the manuscript for important intellectual content was done by all authors. All authors were involved in the final approval of the version.

Conflicts of Interest

ACA, FC, DJ, MM, RGM, FDC, and VY are employees of Sword Health, the sponsor of this study. FDC, VY, and VB also hold equity in Sword Health, and VB is the chief executive officer of the same company. SPC is an independent clinical consultant who received an adviser honorarium from Sword Health.

Multimedia Appendix 1

Information regarding (1) baseline clinical characteristics for unfiltered cases, (2) model estimates and fitness from latent growth curve analysis (LGCA) following intent-to-treat analysis, (3) statistical differences in exercise performance between groups, (4) model estimates and fitness from LGCA stratified by education levels following intent-to-treat analysis, (5) model estimates from the conditional model, (6) model fitness from conditional LGCA, (7) statistical differences between groups in mean changes for clinical outcomes, (8) probability of analgesics consumptions, and (9) medication reduction trajectories per age category.
[DOCX File , 1613 KB-Multimedia Appendix 1]

XSL•FO
RenderX

Multimedia Appendix 2

Overview of the exercise prescription framework, including exercise characteristics, dosage parameters, and progression principles. [DOCX File , 16 KB-Multimedia Appendix 2]

References

1. Faverio M. Share of those 65 and older who are tech users has grown in the past decade. Pew Research Center. Jan 13, 2022. URL: https://www.pewresearch.org/short-reads/2022/01/13/share-of-those-65-and-older-who-are-tech-users-has-grown-in-the-past-decade/ [accessed 2023-05-19]
2. Briggs AM, Cross MJ, Hoy DG, Sànchez-Riera L, Blyth FM, Woolf AD, et al. Musculoskeletal health conditions represent a global threat to healthy aging: a report for the 2015 World Health Organization world report on ageing and health. Gerontologist. 2016;56(Suppl 2):S243-S255. [FREE Full text] [doi: 10.1093/geront/gnw002] [Medline: 26994264]
3. Welsh TP, Yang AE, Makris UE. Musculoskeletal pain in older adults: a clinical review. Med Clin North Am. 2020;104(5):855-872. [FREE Full text] [doi: 10.1016/j.mcna.2020.05.002] [Medline: 32773050]
4. Roberts S, Colombier P, Sowman A, Mennan C, Rölfing JHD, Guicheux J, et al. Ageing in the musculoskeletal system. Acta Orthop. 2016;87(sup363):15-25. [FREE Full text] [doi: 10.1080/17453674.2016.1244750] [Medline: 27748151]
5. Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ. 2003;81(9):646-656. [FREE Full text] [Medline: 14710506]
6. Dahlhamer J, Lucas J, Zelaya C, Nahin R, Mackey S, DeBar L, et al. Prevalence of chronic pain and high-impact chronic pain among adults—United States, 2016. MMWR Morb Mortal Wkly Rep. 2018;67(36):1001-1006. [FREE Full text] [doi: 10.15585/mmwr.mm6736a2] [Medline: 30212442]
7. Dieleman JL, Cao J, Chapin A, Chen C, Li Z, Liu A, et al. US health care spending by payer and health condition, 1996–2016. JAMA. 2020;323(9):863-884. [FREE Full text] [doi: 10.1001/jama.2020.0734] [Medline: 32125402]
8. Williams A, Kamper SJ, Wiggers JH, O'Brien KM, Lee H, Wolfenden L, et al. Musculoskeletal conditions may increase the risk of chronic disease: a systematic review and meta-analysis of cohort studies. BMC Med. 2018;16(1):167. [FREE Full text] [doi: 10.1186/s12916-018-1151-2] [Medline: 30249247]
9. Cunningham C, O'Sullivan R, Caserotti P, Tully MA. Consequences of physical inactivity in older adults: a systematic review of reviews and meta-analyses. Scand J Med Sci Sports. 2020;30(5):816-827. [doi: 10.1111/sms.13616] [Medline: 32020713]
10. Scheer JK, Costa F, Janela D, Molinos M, Areias AC, Moulder RG, et al. Sleep disturbance in musculoskeletal conditions: impact of a digital care program. J Pain Res. 2023;16:33-46. [FREE Full text] [doi: 10.2147/JPR.S394421] [Medline: 36636267]
11. Lohman MC, Whiteman KL, Greenberg RL, Bruce ML. Incorporating persistent pain in phenotypic frailty measurement and prediction of adverse health outcomes. J Gerontol A Biol Sci Med Sci. 2017;72(2):216-222. [FREE Full text] [doi: 10.1093/gerona/glw212] [Medline: 28087677]
12. Niederstrasser NG, Attridge N. Associations between pain and physical activity among older adults. PLoS One. 2022;17(1):e0263356. [FREE Full text] [doi: 10.1371/journal.pone.0263356] [Medline: 35089966]
13. Cooper R, Kuh D, Hardy R, Mortality Review Group, FALCon and HALCyon Study Teams. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. BMJ. 2010;341:c4467. [FREE Full text] [doi: 10.1136/bmj.c4467] [Medline: 20829298]
14. Kolasinski SL, Neogi T, Hochberg MC, Oatis C, Guyatt G, Block J, et al. 2019 American College of Rheumatology/Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip, and knee. Arthritis Care Res (Hoboken). 2020;72(2):149-162. [FREE Full text] [doi: 10.1002/acr.24131] [Medline: 31908149]
15. National Guideline Centre (UK). Low Back Pain and Sciatica in Over 16s: Assessment and Management. London. National Institute for Health and Care Excellence (NICE); 2016.
16. Avin KG, Hanke TA, Kirk-Sanchez N, McDonough CM, Shubert TE, Hardage J, et al. Academy of Geriatric Physical Therapy of the American Physical Therapy Association. Management of falls in community-dwelling older adults: clinical guidance statement from the Academy of Geriatric Physical Therapy of the American Physical Therapy Association. Phys Ther. 2015;95(6):815-834. [FREE Full text] [doi: 10.2522/ptj.20140415] [Medline: 25573760]
17. Fiani B, Siddiqi I, Lee SC, Dhillon L. Telerehabilitation: development, application, and need for increased usage in the COVID-19 era for patients with spinal pathology. Cureus. 2020;12(9):e10563. [FREE Full text] [doi: 10.7759/cureus.10563] [Medline: 33101809]
18. Reed ME, Huang J, Graetz I, Lee C, Muelly E, Kennedy C, et al. Patient characteristics associated with choosing a telemedicine visit vs office visit with the same primary care clinicians. JAMA Netw Open. 2020;3(6):e205873. [FREE Full text] [doi: 10.1001/jamanetworkopen.2020.5873] [Medline: 32585018]
19. Foster MV, Sethares KA. Facilitators and barriers to the adoption of telehealth in older adults: an integrative review. Comput Inform Nurs. 2014;32(11):523-533. [doi: 10.1097/CIN.0000000000000105] [Medline: 25251862]
20. Wang X, Luan W. Research progress on digital health literacy of older adults: A scoping review. Front Public Health. 2022;10:906089. [FREE Full text] [doi: 10.3389/fpubh.2022.906089] [Medline: 35991040]

XSL•FO
RenderX

21. Correia FD, Molinos M, Luís S, Carvalho D, Carvalho C, Costa P, et al. Digitally assisted versus conventional home-based rehabilitation after arthroscopic rotator cuff repair: a randomized controlled trial. Am J Phys Med Rehabil. 2022;101(3):237-249. [FREE Full text] [doi: 10.1097/PHM.0000000000001780] [Medline: 33935152]
22. Correia FD, Nogueira A, Magalhães I, Guimarães J, Moreira M, Barradas I, et al. Home-based rehabilitation with a novel digital biofeedback system versus conventional in-person rehabilitation after total knee replacement: a feasibility study. Sci Rep. 2018;8(1):11299. [FREE Full text] [doi: 10.1038/s41598-018-29668-0] [Medline: 30050087]
23. Costa F, Janela D, Molinos M, Lains J, Francisco GE, Bento V, et al. Telerehabilitation of acute musculoskeletal multi-disorders: prospective, single-arm, interventional study. BMC Musculoskelet Disord. 2022;23(1):29. [FREE Full text] [doi: 10.1186/s12891-021-04891-5] [Medline: 34983488]
24. Janela D, Costa F, Molinos M, Moulder RG, Lains J, Francisco GE, et al. Asynchronous and tailored digital rehabilitation of chronic shoulder pain: a prospective longitudinal cohort study. J Pain Res. 2022;15:53-66. [FREE Full text] [doi: 10.2147/JPR.S343308] [Medline: 35035234]
25. Areias AC, Costa F, Janela D, Molinos M, Moulder RG, Lains J, et al. Long-term clinical outcomes of a remote digital musculoskeletal program: an Ad Hoc analysis from a longitudinal study with a non-participant comparison group. Healthcare (Basel). 2022;10(12):2349. [FREE Full text] [doi: 10.3390/healthcare10122349] [Medline: 36553873]
26. Liu N, Yin J, Tan SSL, Ngiam KY, Teo HH. Mobile health applications for older adults: a systematic review of interface and persuasive feature design. J Am Med Inform Assoc. 2021;28(11):2483-2501. [FREE Full text] [doi: 10.1093/jamia/ocab151] [Medline: 34472601]
27. Dworkin RH, Turk DC, Wyrwich KW, Beaton D, Cleeland CS, Farrar JT, et al. Interpreting the clinical importance of treatment outcomes in chronic pain clinical trials: IMMPACT recommendations. J Pain. 2008;9(2):105-121. [doi: 10.1016/j.jpain.2007.09.005] [Medline: 18055266]
28. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. Arch Intern Med. 2006;166(10):1092-1097. [FREE Full text] [doi: 10.1001/archinte.166.10.1092] [Medline: 16717171]
29. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. J Gen Intern Med. 2001;16(9):606-613. [FREE Full text] [doi: 10.1046/j.1525-1497.2001.016009606.x] [Medline: 11556941]
30. Ospina MB, Dennett L, Waye A, Jacobs P, Thompson AH. A systematic review of measurement properties of instruments assessing presenteeism. Am J Manag Care. 2015;21(2):e171-e185. [FREE Full text] [Medline: 25880491]
31. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020;54(24):1451-1462. [FREE Full text] [doi: 10.1136/bjsports-2020-102955] [Medline: 33239350]
32. Zelaya CE, Dahlhamer JM, Lucas JW, Connor EM. Chronic pain and high-impact chronic pain among U.S. adults, 2019. NCHS Data Brief. Hyattsvile, MD. National Center for Health Statistics; 2020. URL: https://stacks.cdc.gov/view/cdc/97308 [accessed 2023-07-20]
33. Rikard SM, Strahan AE, Schmit KM, Guy GPJ. Chronic pain among adults—United States, 2019–2021. MMWR Morb Mortal Wkly Rep. 2023;72(15):379-385. [FREE Full text] [doi: 10.15585/mmwr.mm7215a1] [Medline: 37053114]
34. Weiss DJ, Nelson A, Vargas-Ruiz CA, Gligorić K, Bavadekar S, Gabrilovich E, et al. Global maps of travel time to healthcare facilities. Nat Med. 2020;26(12):1835-1838. [FREE Full text] [doi: 10.1038/s41591-020-1059-1] [Medline: 32989313]
35. healthsites.io. URL: https://healthsites.io/ [accessed 2023-05-02]
36. McNeish D, Matta T. Differentiating between mixed-effects and latent-curve approaches to growth modeling. Behav Res Methods. 2018;50(4):1398-1414. [FREE Full text] [doi: 10.3758/s13428-017-0976-5] [Medline: 29067672]
37. Xiao J, Bulut O. Evaluating the performances of missing data handling methods in ability estimation from sparse data. Educ Psychol Meas. 2020;80(5):932-954. [FREE Full text] [doi: 10.1177/0013164420911136] [Medline: 32855565]
38. Scheer J, Areias AC, Molinos M, Janela D, Moulder R, Lains J, et al. Engagement and utilization of a complete remote digital care program for musculoskeletal pain management in urban and rural areas across the United States: longitudinal cohort study. JMIR Mhealth Uhealth. 2023;11:e44316. [FREE Full text] [doi: 10.2196/44316] [Medline: 36735933]
39. Berkowsky RW. Exploring predictors of ehealth literacy among older adults: findings from the 2020 CALSPEAKS survey. Gerontol Geriatr Med. 2021;7:1-5. [FREE Full text] [doi: 10.1177/23337214211064227] [Medline: 34926723]
40. Iacobucci D. Structural equations modeling: Fit Indices, sample size, and advanced topics. J Consum Psychol. 2009;20(1):90-98. [doi: 10.1016/j.jcps.2009.09.003]
41. Brown TA. Confirmatory Factor Analysis for Applied Research Second Edition. New York. The Guilford Press; 2006.
42. Administration for Community Living. 2020 Profile of Older Americans. United States. U.S. Department of Health and Human Services; 2021. URL: https://acl.gov/sites/default/files/aging%20and%20Disability%20In%20America/2020Profileolderamericans.final_.pdf [accessed 2023-07-20]
43. Smith AS, Trevelyan E. The older population in rural America: 2012–2016. American Community Survey Reports. United States. U.S. Department of Commerce, U.S. Census Burreau; 2019. URL: https://www.census.gov/content/dam/Census/library/publications/2019/acs/acs-41.pdf [accessed 2023-07-20]
44. Wang G, Bailey JF, Yang M, Krauss J. Older adult use and outcomes in a digital musculoskeletal (MSK) program, by generation. Front Digit Health. 2021;3:693170. [FREE Full text] [doi: 10.3389/fdgth.2021.693170] [Medline: 34713170]

XSL•FO
RenderX

45. Bennell KL, Nelligan R, Dobson F, Rini C, Keefe F, Kasza J, et al. Effectiveness of an internet-delivered exercise and pain-coping skills training intervention for persons with chronic knee pain: a randomized trial. Ann Intern Med. 2017;166(7):453-462. [doi: 10.7326/M16-1714] [Medline: 28241215]
46. Gohir SA, Eek F, Kelly A, Abhishek A, Valdes AM. Effectiveness of internet-based exercises aimed at treating knee osteoarthritis: the iBEAT-OA randomized clinical trial. JAMA Netw Open. 2021;4(2):e210012. [FREE Full text] [doi: 10.1001/jamanetworkopen.2021.0012] [Medline: 33620447]
47. Jirasakulsuk N, Saengpromma P, Khruakhorn S. Real-time telerehabilitation in older adults with musculoskeletal conditions: systematic review and meta-analysis. JMIR Rehabil Assist Technol. 2022;9(3):e36028. [FREE Full text] [doi: 10.2196/36028] [Medline: 36048520]
48. Cranen K, Drossaert CHC, Brinkman ES, Braakman-Jansen ALM, Ijzerman MJ, Vollenbroek-Hutten MMR. An exploration of chronic pain patients' perceptions of home telerehabilitation services. Health Expect. 2012;15(4):339-350. [FREE Full text] [doi: 10.1111/j.1369-7625.2011.00668.x] [Medline: 21348905]
49. Cranen K, Groothuis-Oudshoorn CGM, Vollenbroek-Hutten MMR, IJzerman MJ. Toward patient-centered telerehabilitation design: understanding chronic pain patients' preferences for web-based exercise telerehabilitation using a discrete choice experiment. J Med Internet Res. 2017;19(1):e26. [FREE Full text] [doi: 10.2196/jmir.5951] [Medline: 28108429]
50. Wada T, Matsumoto H, Hagino H. Customized exercise programs implemented by physical therapists improve exercise-related self-efficacy and promote behavioral changes in elderly individuals without regular exercise: a randomized controlled trial. BMC Public Health. 2019;19(1):917. [FREE Full text] [doi: 10.1186/s12889-019-7270-7] [Medline: 31288781]
51. Miciak M, Mayan M, Brown C, Joyce AS, Gross DP. The necessary conditions of engagement for the therapeutic relationship in physiotherapy: an interpretive description study. Arch Physiother. 2018;8:3. [FREE Full text] [doi: 10.1186/s40945-018-0044-1] [Medline: 29468089]
52. O'Keeffe M, Cullinane P, Hurley J, Leahy I, Bunzli S, O'Sullivan PB, et al. What influences patient-therapist interactions in musculoskeletal physical therapy? Qualitative systematic review and meta-synthesis. Phys Ther. 2016;96(5):609-622. [FREE Full text] [doi: 10.2522/ptj.20150240] [Medline: 26427530]
53. Elliott T, Tong I, Sheridan A, Lown BA. Beyond convenience: patients' perceptions of physician interactional skills and compassion via telemedicine. Mayo Clin Proc Innov Qual Outcomes. 2020;4(3):305-314. [FREE Full text] [doi: 10.1016/j.mayocpiqo.2020.04.009] [Medline: 32542222]
54. Hayes D. Telerehabilitation for older adults. Top Geriatr Rehabil. 2020;36(4):205-211. [FREE Full text] [doi: 10.1097/TGR.0000000000000282]
55. El Tumi H, Johnson MI, Dantas PBF, Maynard MJ, Tashani OA. Age-related changes in pain sensitivity in healthy humans: a systematic review with meta-analysis. Eur J Pain. 2017;21(6):955-964. [FREE Full text] [doi: 10.1002/ejp.1011] [Medline: 28230292]
56. Artus M, Campbell P, Mallen CD, Dunn KM, van der Windt DAW. Generic prognostic factors for musculoskeletal pain in primary care: a systematic review. BMJ Open. 2017;7(1):e012901. [FREE Full text] [doi: 10.1136/bmjopen-2016-012901] [Medline: 28096253]
57. Pisters MF, Veenhof C, Schellevis FG, Twisk JWR, Dekker J, De Bakker DH. Exercise adherence improving long-term patient outcome in patients with osteoarthritis of the hip and/or knee. Arthritis Care Res (Hoboken). 2010;62(8):1087-1094. [FREE Full text] [doi: 10.1002/acr.20182] [Medline: 20235201]
58. Jordan JL, Holden MA, Mason EE, Foster NE. Interventions to improve adherence to exercise for chronic musculoskeletal pain in adults. Cochrane Database Syst Rev. 2010;2010(1):CD005956. [FREE Full text] [doi: 10.1002/14651858.CD005956.pub2] [Medline: 20091582]
59. Feldman DE, Carlesso LC, Nahin RL. Management of patients with a musculoskeletal pain condition that is likely chronic: results from a national cross sectional survey. J Pain. 2020;21(7-8):869-880. [doi: 10.1016/j.jpain.2019.11.014] [Medline: 31837448]
60. George SZ, Goode AP. Physical therapy and opioid use for musculoskeletal pain management: competitors or companions? Pain Rep. 2020;5(5):e827. [FREE Full text] [doi: 10.1097/PR9.0000000000000827] [Medline: 33490834]
61. Bories M, Bouzillé G, Cuggia M, Le Corre P. Drug-drug interactions in elderly patients with potentially inappropriate medications in primary care, nursing home and hospital settings: a systematic review and a preliminary study. Pharmaceutics. 2021;13(2):266. [FREE Full text] [doi: 10.3390/pharmaceutics13020266] [Medline: 33669162]
62. Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, et al. Lancet Low Back Pain Series Working Group. What low back pain is and why we need to pay attention. Lancet. 2018;391(10137):2356-2367. [FREE Full text] [doi: 10.1016/S0140-6736(18)30480-X] [Medline: 29573870]
63. Cochrane A, Higgins NM, Rothwell C, Ashton J, Breen R, Corcoran O, et al. Work outcomes in patients who stay at work despite musculoskeletal pain. J Occup Rehabil. 2018;28(3):559-567. [doi: 10.1007/s10926-017-9748-4] [Medline: 29236203]
64. Ackerman IN, Bucknill A, Page RS, Broughton NS, Roberts C, Cavka B, et al. The substantial personal burden experienced by younger people with hip or knee osteoarthritis. Osteoarthritis Cartilage. 2015;23(8):1276-1284. [FREE Full text] [doi: 10.1016/j.joca.2015.04.008] [Medline: 25887363]

XSL•FO
RenderX

65. Viviani CA, Bravo G, Lavallière M, Arezes PM, Martínez M, Dianat I, et al. Productivity in older versus younger workers: a systematic literature review. Work. 2021;68(3):577-618. [FREE Full text] [doi: 10.3233/WOR-203396] [Medline: 33612506]
66. Palmer KT, Goodson N. Ageing, musculoskeletal health and work. Best Pract Res Clin Rheumatol. 2015;29(3):391-404. [FREE Full text] [doi: 10.1016/j.berh.2015.03.004] [Medline: 26612237]
67. Choi NG, Dinitto DM. The digital divide among low-income homebound older adults: Internet use patterns, eHealth literacy, and attitudes toward computer/Internet use. J Med Internet Res. 2013;15(5):e93. [FREE Full text] [doi: 10.2196/jmir.2645] [Medline: 23639979]

Abbreviations

CBT: cognitive behavioral therapy
DCP: digital care program
GAD-7: Generalized Anxiety Disorder 7-item scale
mLGCA: multiple-group latent growth curve analysis
OR: odds ratio
PHQ-9: Patient Health Questionnaire 9-item scale
WPAI: Work Productivity and Activity Impairment Questionnaire

Edited by A Mavragani; submitted 05.Jun.2023; peer-reviewed by K Laver; comments to author 17.Jul.2023; revised version received 18.Jul.2023; accepted 19.Jul.2023; published 15.Aug.2023

Please cite as:
Areias AC, Janela D, Molinos M, Moulder RG, Bento V, Yanamadala V, Cohen SP, Correia FD, Costa F
Managing Musculoskeletal Pain in Older Adults Through a Digital Care Solution: Secondary Analysis of a Prospective Clinical Study
JMIR Rehabil Assist Technol 2023;10:e49673
URL: https://rehab.jmir.org/2023/1/e49673
doi: 10.2196/49673
PMID: 37465960

©Anabela C Areias, Dora Janela, Maria Molinos, Robert G Moulder, Virgílio Bento, Vijay Yanamadala, Steven P Cohen, Fernando Dias Correia, Fabíola Costa. Originally published in JMIR Rehabilitation and Assistive Technology (https://rehab.jmir.org), 15.Aug.2023. This is an open-access article distributed under the terms of the Creative Commons Attribution License (https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in JMIR Rehabilitation and Assistive Technology, is properly cited. The complete bibliographic information, a link to the original publication on https://rehab.jmir.org/, as well as this copyright and license information must be included.

XSL•FO
RenderX