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Original Research

Can Physical Therapy Deliver Clinically Meaningful Improvements in Pain and Function Through a Mobile App? An Observational Retrospective Study

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KEYWORDS
Delivery of health care;
Mobile applications;
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Telerehabilitation

Abstract *Objective:* To examine the effect of digital physical therapy (PT) delivered by mobile application (app) on reducing pain and improving function for people with a variety of musculoskeletal conditions.
Design: An observational, longitudinal, retrospective study using survey data collected pre- and postdigital PT to estimate multilevel models with random intercepts for patient episodes.
Setting: Privately insured employees participating in app-based PT as an employer health care benefit.
Participants: The study sample included 814 participants (N=814) 18 years or older who completed their digital PT program with reported final clinical outcomes between February 2019 (program launch) through December 2020. Mean age of the sample at baseline was 40.9± 11.89 years, 47.5% were female, 21% sought care for lower back pain, 16% for shoulders, 15% for knees, and 13% for neck.
Interventions: Digital PT consisted of a synchronous video evaluation with a physical therapist followed by a course of PT delivered through a mobile app.
Main Outcome Measures: Pain was measured by the visual analog scale from 0 “no pain” to 10 “worst pain imaginable” and physical function by the Patient-Specific Functional Scale on a scale from 0 “completely unable to perform” to 10 “able to perform normally.”
Results: After controlling for significant demographics, comorbid conditions, adverse symptoms, chronicity, and severity, the results from multilevel random intercept models showed decreased pain (−2.69 points; 95% CI, −2.86 to −2.53; $P<.001$) and increased physical function (+2.67 points; 95% CI, 2.45-2.89; $P<.001$) after treatment.
Conclusions: Digital PT was associated with clinically meaningful improvements in pain and function among a diverse set of participants. These early data are an encouraging indicator of the clinical benefit of digital PT.

List of abbreviations: app, application; ICC, interclass correlation coefficient; OSPRO-ROS, Optimal Screening for Prediction of Referral and Outcome Review of Systems; PSFS, Patient-Specific Functional Scale; PCP, primary care provider; PT, physical therapy; VAS, Visual Analog Scale.
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Musculoskeletal conditions affect over half of the American adult population and around 37% of working-age adults covered by private insurance.[1] More than 20 million working adults visit health care professionals to address their musculoskeletal symptoms each year.[1] More than one-third of these workers report physical impairment such as back pain that limits their ability to sit at a computer for more than 2 hours or neck pain accompanied by headaches that makes concentration difficult. These symptoms affect workers' performance, productivity, and overall quality of life.

Most musculoskeletal complaints are first attended to by primary care providers (PCPs). PCPs often lack specialized knowledge about musculoskeletal conditions required to direct their patients to the appropriate early interventions or treatments.[2] PCPs may prescribe addictive opioids,[3-5] recommend unnecessary imaging,[6-8] or refer patients to orthopedic specialists who may recommend operations that may or may not resolve their condition or, finally, refer them to physical therapy (PT).[9-12] Each touch point in this pathway is costly and may be unnecessary.

Direct access to PT addresses musculoskeletal conditions by inverting this traditional care pathway so that physical therapists, who are the most cost-effective practitioners with the most specialized knowledge about musculoskeletal health, triage patients on demand.[2] This means that patients expeditiously receive care, which may reduce the immediate use of prescription pain medications and imaging[13] as well as downstream injections and operations for common injuries and chronic conditions.[10,14-17] Digital PT, delivered via mobile applications (apps), is well positioned to provide patients direct access to PT as a workplace health benefit through employers.

Digital PT may also be just as effective at reducing pain and improving function as in-person PT.[18-21] However, evidence for the effectiveness of digitally delivered musculoskeletal care is limited by small sample sizes[2,22] or relegated to a few conditions where patients are not treated by physical therapists.[2,23] To our knowledge, we are unaware of any studies that evaluate the clinical effectiveness of digital PT controlling for comorbidities, chronicity, and severity of condition and symptoms, which can significantly affect clinical outcomes.[24-26] In this study, our objective is to demonstrate that digital PT delivered through a mobile app effectively improves pain and functionality across a variety of chronic and acute conditions in a population of commercially insured employees.

Methods

Study design

The study was an observational, longitudinal, retrospective study using data collected from commercial users of a digital PT program[27,a] that was offered as a health benefit to privately insured employees through their employers, with no cost or copay to the participants. The data used in the study were not originally collected for research purposes. Rather, they were used operationally to deliver care. The data were deidentified for analysis. On registering for the program via a landing page accessible from participants' employer benefits portals, verified eligible participants were issued a passphrase to download the app after which they read and accepted an in-app informed consent and completed a mandatory in-app baseline survey. The Western Institutional Review Board granted an exemption from human participant research for the study's protocol.

Setting

Twenty-eight different physical therapists treated participants during the study period. These physical therapists underwent a rigorous selection process including a written examination to assess their knowledge of evidence-based assessments and management principles for patients with musculoskeletal conditions. Therapists who received a passing score (above 75th percentile) were then interviewed. The resulting cohort of therapists had 10 years of experience on average, and more than 60% were board-certified specialists in areas including orthopedic, sports, and women's health PT.

Physical therapists were trained in evidence-based approaches to evaluate, diagnose, and treat patients on demand via a mobile app. Training consisted of approximately 10 hours of self-paced learning regarding the unique aspects of app-based PT such as how to conduct an objective examination remotely as well as training to familiarize therapists with care delivery software and the patient-facing app. All physical therapists completed at least 2 mock sessions with experienced telehealth physical therapists prior to seeing patients.

After downloading the app, participants entered demographic information (age, sex), entered their chief complaint, and provided pain and function ratings in an in-app baseline survey before they met with their physical therapist. We used established patient-reported outcomes measures for pain and function survey questions: the Visual Analog Scale (VAS) to measure pain and the Patient-Specific Functional Scale (PSFS) to measure function.[28] Participants then scheduled an initial video evaluation visit with a physical therapist licensed in their state who oversaw their care for the duration of the program.

During the initial evaluation, physical therapists conducted an in-depth interview and performed a digital physical examination over synchronous video using physical assessments such as range of motion, functional testing, and modified special tests to establish a functional baseline and arrive at a diagnosis. Based on the participant's diagnosis and treatment goals, physical therapists then prescribed a course of treatment that participants accessed through the

app. Therapists also assigned educational content specific to patients' conditions, therapeutic activities (eg, icing or going for a walk), and asynchronous digital physical assessments through the app. Physical therapists modified their patients' care plans in response to direct feedback from patients via in-app chat messages, twice weekly pain and function surveys, or follow-up video visits.

All activities in the program were collected and quantified, including completion of prescribed in-app exercises and therapeutic activities, in-app chats with physical therapists, and subsequent virtual visits Table 1. provides descriptive statistics for these features of the program. At the end of the program, participants were asked to complete a final survey, which included final, repeated measures of pain and function.

Participants

We included participants in the study who enrolled after the launch of the program on February 15, 2019, and completed the program by December 31, 2020, if they (1) were 18 years or older; (2) presented with a musculoskeletal condition such as low back pain, neck pain, arthritis, sprains, strains, or similar overuse injuries that would benefit from PT or presented for postoperative rehabilitation; and (3) completed a final survey at the end of their episode of care or reported reliable pain and function metrics toward the end of care in weekly clinical surveys. Pain and function observations from weekly surveys were only carried forward if they were reported less than 3 weeks before completing the program and more than 2 weeks after starting the program. Because weekly clinical surveys were not implemented until September 23, 2020, only 33 outcomes were carried forward from these surveys. The average time between baseline and outcome responses collected during either the final survey or last pain and function survey was approximately 44 days. A total of 978 participants met the inclusion criteria and completed the program with a final outcomes survey or reported valid clinical outcomes near the end of their episode (fig 1). On average, participants completed the survey within 2 weeks of finishing the program and were not incentivized to do so.

Participants were excluded if they (1) did not meet inclusion criteria and (2) endorsed symptoms or multiple conditions during the initial virtual evaluation that the physical therapist determined would preclude the use of digital PT as the first line of treatment (eg, fractures, cervical central cord lesion, subarachnoid hemorrhage/ischemic stroke, unexplained weight gain or loss, fatigue, malaise, among other conditions) and required referral for an in-person physical examination. Participants in our sample were not automatically excluded if they endorsed symptoms found on the Optimal Screening for Prediction of Referral and Outcome Review of Systems (OSPRO-ROS) tool, which has been previously validated with patients presenting to outpatient PT with musculoskeletal pain.[29] Rather, physical therapists assessed the appropriateness of digital PT given patients' explanations of their symptoms and the ongoing management of those conditions by a physician. According to fig 1, a total of 29 patients were referred to other providers after their initial evaluation.

Table 1 Descriptive statistics for intervention (N=814)

Patient—Provider Interactions	Mean	SD	Min	Max
No. of follow-up visits	2.11	2.99	0	30
Unique days therapist messaged/wk	1.81	1.06	0	7
Unique days participant messaged/wk	10.08	7.97	0	67
Engagement				
No. of workouts/wk	2.78	2.19	0	17
No. of in-app activities/wk	3.72	2.20	0	16
Wk in program	9.09	5.36	2	52

To eliminate outliers, we calculated the standardized individual difference by dividing participant-level pre-post outcome differences by the SD of those differences and eliminating observations above and below 1% of the distribution for both outcomes.[30] We also excluded 99 observations because of a known interface issue where function values were flipped in the opposing direction of the user interface causing people to report poorer function when the intended metrics were better scores. These participants reported improvement on a standard global rate of change final survey question (global rate of change>0) but reported that either their pain or function got worse and were moving in opposing directions. These procedures eliminated 128 observations (see fig 1).

Thirty-six participants had too little activity to make reliable conclusions about the program's outcomes (either no workouts or less than 2 weeks of in-app activity) and were excluded from the analysis. We estimated models with and without outlier removal, with 2.5% outlier elimination, as well as with and without carrying forward the final pain and function observations and procured similar results.

Measurements

Pre- and posttreatment clinical measures

In the baseline and end-of-program surveys, participants rated their maximum pain levels during the last 24 hours using the VAS,[28,31] on a continuous scale from 0 (no pain) to 10 (worst pain imaginable). Participants rated their level of functional impairment on a continuous scale from 0 (completely unable to perform) to 10 (able to perform normally) for up to 3 different self-identified activities affected by their condition using the PSFS.[28] We used the functional measure for the activity participants mentioned first because this is likely the activity that they struggle most with daily. In the app, participants saw this scale represented as a slider that ranged continuously from 0-10.

Controls

Chronicity, comorbid conditions, and severe or adverse symptoms can affect participants' recovery.[24-26] We controlled for comorbid conditions including hypertension, diabetes, cardiovascular disease, a family or personal history of cancer, or other conditions including behavioral health conditions. We also controlled for adverse symptoms found on the OSPRO-ROS such as night sweats, headaches, lightheadedness, or abnormal sensations.[26] We created 2 binary

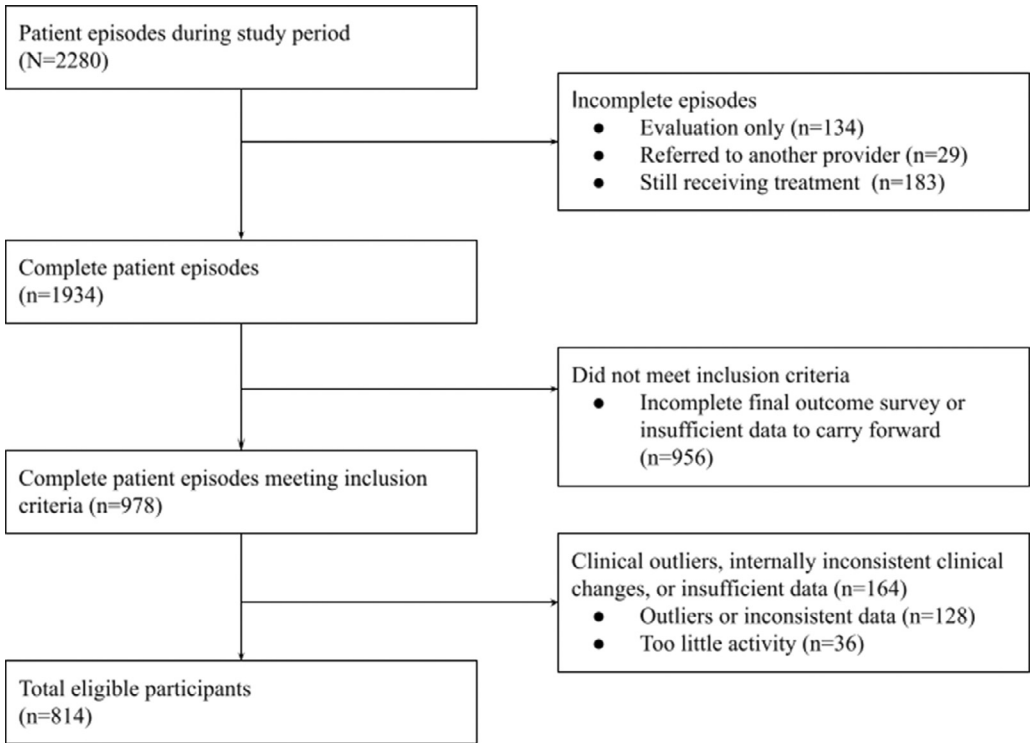

Fig 1 Study participation flow diagram.

variables equal to 1 if participants had 1 or more of these comorbid conditions or symptoms and 0 otherwise.

Patients with severe baseline pain (VAS>7.4) face larger physical and behavioral health obstacles to recovery than patients with better scores, who also have less room to improve.[32,33] We controlled for pain severity based on cut points for the VAS identified in the literature.[34] All controls are presented in the results when they are statistically significant ($P<.05$).

Statistical analysis plan

We estimated multilevel models with random intercepts for patient episodes to understand and control for within and between episode variation in pain and function. Using this model, we can estimate the degree to which individual-level clinical outcomes deviate from the entire population in the sample.[35]

$$Y_{it} = \beta_0 + \beta_1 treatment_{it} + \beta_2 D_i + \beta_3 C_i + \cdots + \upsilon_i + e_{it} e_{it} \sim N(0, \sigma_e^2)\ \ \upsilon_i \sim N(0, \sigma_\upsilon^2)$$

The variable Y_{it} is the observed clinical pain (VAS) or function (PSFS) response for a given patient episode i at time t, and $\beta_1 treatment_{it}$ is a covariate for app-based PT treatment for a given clinical outcome. In our case, a binary variable was equal to 1 if the measure was taken after treatment and 0 if it occurred at baseline; β_1 is the effect of the app-based PT program shared by all episodes. The remaining parts of the equation represent the intercept (β_0) and coefficients and covariates ($\beta_2 D_i + \beta_3 C_i + \cdots$) for all explanatory variables, including demographic variables and controls for chronicity, baseline pain severity, and the presence of adverse symptoms and comorbid conditions as described above. These are fixed parts of the model shared by all episodes. The random parts of the model, $\upsilon_i + e_{it}$, are allowed to vary, with υ_i representing the treatment effect that varies by patient episode with error term, e_{it}. The variances, σ_e^2 and σ_υ^2, are estimated for both the level 1 random term and the level 2 random term, respectively.

Table 2 Descriptive statistics for sample participants (N=814)

Demographics	Count	Mean	SD	Min	Max
Female	387	0.48	0.50	0	1
Age	814	40.85	11.89	18	74
Age ≥50 y	214	0.26	0.44	0	1
Access					
24 h to first visit	430	0.53	0.50	0	1
Diagnostic area					
Low back pain	172	0.21	0.41	0	1
Shoulder	132	0.16	0.37	0	1
Knee	118	0.15	0.35	0	1
Neck	104	0.13	0.33	0	1
Upper body, elbow, wrist, hand, or arm	84	0.10	0.30	0	1
Lower body, ankle, foot, or leg	83	0.10	0.30	0	1
Hip	70	0.09	0.28	0	1
Back or spine	46	0.06	0.23	0	1
Other	5	0.01	0.08	0	1

Table 3 Descriptive statistics for outcomes and predictors (N=814)

Clinical baselines	Count	Mean	SD	Min	Max
Pain baseline (VAS)	814	4.40	2.18	0	10
Function baseline (PSFS)	814	5.15	2.97	0	10
Clinical outcomes					
Pain outcome (VAS)	814	1.71	1.85	0	10
Function outcome (PSFS)	814	7.82	2.36	0	10
Chronicity					
Chronic (>3 mo)	497	0.61	0.49	0	1
Subacute (1-3 mo)	128	0.16	0.36	0	1
Acute (<1 mo)	189	0.23	0.42	0	1
Baseline pain level categories					
Little to no pain (VAS≤1)	61	0.07	0.26	0	1
Mild pain (3.4≤VAS>1)	218	0.27	0.44	0	1
Moderate (7.4≤VAS>3.4)	475	0.58	0.49	0	1
Severe pain (VAS>7.4)	60	0.07	0.26	0	1
Comorbid conditions and adverse symptoms					
No. of comorbid conditions	814	0.58	0.72	0	5
Reported comorbid conditions	383	0.47	0.50	0	1
No. of adverse symptoms	814	0.51	0.89	0	10
Reported adverse symptoms	281	0.35	0.48	0	1

Results

Table 2 presents the demographic and clinical profile of the participants in the sample at baseline. Nearly half (387/814, 47.5%) of participants were female and approximately 41 years of age, on average. Twenty-six percent were 50 years or older. Over half of the participants completed their initial video consultation within 24 hours of registering for the program.

Participants were treated for a variety of musculoskeletal conditions. Low back pain was the presenting diagnosis for 21% (172/814) of the population. Diagnoses affecting the shoulders made up 16% (132/814) of complaints, followed by knee complaints (118/814, 15%) and neck pain (104/814, 13%), conditions involving the upper and lower body or small joints of the limbs (84/814, 83/814, 10% each), and hip conditions (70/814, 9%). No single body region captured the majority of participants' conditions.

Table 3 presents descriptive statistics for outcomes and predictors in the analysis. Before treatment, participants reported 4.40±2.18 mean pain and 5.15±2.97 mean function on the VAS and PSFS, respectively. After treatment, mean pain improved to 1.71±1.85 and mean function to 7.82±2.36.

Most participants (497/814, 61%) entered the program with chronic conditions lasting more than 3 months, and 66% (535/814) reported moderate or severe pain at baseline. Participants, on average, had between 0-1 comorbid conditions (mean, 0.58±0.72) and adverse symptoms (mean, 0.51±0.89) found on the OSPRO-ROS such as abnormal sensations, headaches, or night sweats.[29] Approximately 47% (383/814) of participants had some history of comorbid conditions, and more than one-third (281) endorsed adverse symptoms found on the OSPRO-ROS.[29]

Table 4 presents the results for both pain and function from multilevel random intercept models with significant controls. The estimated effect of the digital PT program on pain was approximately −2.69 points (95% CI, −2.86 to −2.53; $P<.001$) on the VAS, which was a clinically significant level of change.[28,31] The random effects of the episode, calculated by taking the square root of the random-effects variance, was approximately 0.79, meaning that, on average, pain outcomes varied by <1 point after controlling for significant individual differences including sex, presence of comorbidities and adverse symptoms, and severe baseline pain. Age and chronicity were not significant and were excluded from the model.

The interclass correlation coefficient (ICC), which measures the similarity in pain measures before and after treatment within an episode of care, is 0.22 after controlling for significant demographics (sex), comorbid conditions and symptoms, and baseline pain severity. The ICC is calculated by dividing the random-effects variance by the unexplained model variance and varies from 0-1, where 1 indicates a perfect within-episode relationship and would denote no within episode change between pre- and post treatment. This means that participants' pre- and posttreatment pain levels were significantly dissimilar, denoting a clinically meaningful effect of the digital PT program within patients' episodes of care (ie, from baseline to final pain score).

Table 4 also shows that the estimated effect of the digital PT program on function was approximately 2.67 points (95% CI, 2.45-2.89; $P<.001$) on the PSFS. Function outcomes varied by about 1.4 points, on average, after controlling for significant comorbid conditions, chronicity, and baseline pain severity. Sex and age, along with adverse symptoms, were not significant and excluded from the model. The ICC for function was 0.39; function scores within an episode were not very similar pre- and post treatment. Participants saw significant functional improvement from baseline, regardless of the severity of their condition, after digital PT. Graphs of each models' residuals against the normal distribution can be found in supplemental appendix 1 (available online only at http://www.archives-pmr.org/).

Table 4 Multilevel random intercept results (814 episodes, 1628 observations)

Pain (VAS)	Coefficient	SE	*P* Value	95% CI	
Intercept	3.78	0.10	<.001	(3.59 to	3.97)
Treatment effect	−2.69	0.08	<.001	(−2.86 to	−2.53)
Female	0.29	0.10	.004	(0.09 to	0.49)
Comorbid conditions	0.24	0.10	.02	(0.03 to	0.44)
Adverse symptoms	0.53	0.11	<.001	(0.32 to	0.75)
Severe pain (VAS>7.4)	2.57	0.19	<.001	(2.19 to	2.95)
Random-effects variance	0.63	0.09			
Unexplained model variance	2.86				
Function (PSFS)					
Intercept	5.69	0.15	<.001	(5.40 to	5.98)
Treatment effect	2.67	0.11	<.001	(2.45 to	2.89)
Comorbid conditions	−0.42	0.15	.005	(−0.72 to	−0.13)
Chronic condition (>3 mo)	−0.46	0.15	.003	(−0.76 to	−0.16)
Severe pain (VAS>7.4)	−0.92	0.29	<.001	(−1.48 to	−0.36)
Random-effects variance	1.98	0.14			
Unexplained model variance	5.10				

Discussion

The digital PT program tested in this study resulted in reductions in pain and increases in functionality for participants across a variety of acute to chronic musculoskeletal conditions and after controlling for comorbidities, adverse symptoms, and baseline pain severity. These results meet published standards of minimal clinically important differences that signify a significant treatment effect on pain and function. The minimal clinically important differences for the VAS measure of pain typically exceed a 1.4-1.5 point reduction.[28,31,36] Our result lands squarely within this range (2.67 points; 95% CI, 2.45-2.89; $P<.001$). On average, we observed changes in function from digital PT that ranged from medium ($2.69 \leq \Delta PSFS > 2.29$) to large ($\Delta PSFS \geq 2.7$), which means that the digital PT program under study had a significant effect on patients' day-to-day lives.[28]

Digital PT was effective without commonly used interventions such as manual therapy, electrical stimulation, or therapeutic ultrasound, which highlights the importance of exercise and education in delivering clinically meaningful outcomes. Digital PT's effectiveness may stem from its emphasis on active, evidence-based interventions that focus on therapeutic exercise and education over passive interventions, such as therapeutic ultrasound or electrical stimulation, which can only be performed in person. Passive treatments offer little lasting benefit to patients, whereas active treatments are the therapist's best tools to improve a patient's condition.[37,38] Manual therapy (eg, soft tissue and joint mobilization), often considered a foundational PT intervention, is recommended as an adjunct to therapeutic exercise and patient education[39] early in an episode of care because its benefits diminish as patients progress in their recovery.[15] Future studies should compare the clinical outcomes of traditional, in-person PT to digital PT interventions in a randomized controlled trial to better understand how the clinical outcomes of digital PT compare with in-person care.

Our results imply that digital PT may be an efficient way to directly deliver effective musculoskeletal care because of its accessibility to patients, enhancement of therapists' ability to serve areas with provider shortages, and overall convenience. Rural Americans, who comprise approximately one-fifth of the population and whose numbers are rising as people leave expensive urban centers,[40] are underserved by physical therapists.[41,42] Access to PT is further limited in the south, Midwest, and a significant portion of California, irrespective of the urban-rural divide.[43]

Research indicates that telehealth and digital care gained broader acceptance in recent years and that acceptance extends to patients of all ages.[44] The pandemic dramatically increased the US population's interest in telehealth and digital care services, with interest increasing as COVID-19 cases increased.[45] In addition, patient satisfaction with telehealth PT services is reported to be equivalent to in-person care.[46]

Eliminating barriers to PT serves the long-term health trajectories of all patients with musculoskeletal conditions. Patients who access PT early in their care pathways have better clinical outcomes, are less likely to need opioids to manage pain, require less imaging, and require fewer injections or operations.[47,48] Digital PT may be a particularly effective way to deliver good clinical outcomes and prevent costly, invasive downstream care to patients with comorbid conditions, who may be more apt to delay PT because their co-occurring conditions make in-person visits too challenging or seem like less of a priority. Digital PT programs can also lessen barriers to treatment for patients with comorbidities, such as obesity, behavioral health disorders, and urinary incontinence, that make travel to providers' offices and interaction with the health care system onerous.[49] Future studies should test the hypothesis that digital PT provides better access to care compared with in-person direct access PT for a variety of patient populations.

Adherence is the enemy of good clinical outcomes in PT. Only an estimated one-third of patients undergoing PT in-person complete their prescribed course of care.[49] The convenience of digital PT may encourage better adherence to a

PT care plan by removing obstacles common to in-person care. Transportation problems, lack of childcare, and work schedules are commonplace reasons for failing to adhere to PT.[50] Adherent patients have better clinical outcomes and are less likely to need costly pain medications, injections, imaging, or surgery.[15,51] While it is beyond the scope of this article to thoroughly address adherence in app-based PT, some evidence suggests that synchronous and asynchronous digital communication between patients and providers may build strong patient-provider relationships that lead to adherence in app-based PT.[52] Future studies should compare adherence to PT and concomitant outcomes in app-based PT to those of traditional in-person care through a randomized controlled trial.

Study limitations

This study was limited by the observational nature of the data. Additionally, the study focused on an employer-based, privately insured population. Results may not be generalizable to broader populations of employees, retirees, or children. Some research suggests that digital PT may be comparable to in-person PT for osteoarthritis, low back pain, hip and knee replacement, and multiple sclerosis.[53] However, better quality research is needed across a variety of conditions that also accounts for chronicity, severity, and comorbidities. Future research should compare clinical outcomes of digital to in-person PT in controlled clinical trials for a range of conditions and populations.

It is also possible that patients could have received other medical treatments for their conditions during their participation in the digital PT program that could affect our results. Future studies should control for this possibility. One way to do so would be to link participants' medical claims data with programmatic data to understand the prevalence and associated effect of other care received for the same condition during the program.

Conclusions

The demand for PT is expected to grow in the next decade as the American population ages and is challenged with a growing number of musculoskeletal conditions.[54] Indeed, muscle and joint pain is not a problem relegated to old age—at the age of 50 musculoskeletal symptoms present with greater frequency and limit productivity on the job.[55] Aging workers with comorbid conditions as well as younger workers who face competing demands between work and family may find digital PT easier to access and adhere to than musculoskeletal care in traditional brick-and-mortar settings. Digital PT is well poised to respond to this demand given the shortage of physical therapists across the country if digital programs can deliver meaningful clinical outcomes like those found in this study. Future studies should systematically compare clinical outcomes between traditional, in-person PT and digital PT considering the barriers of access and adherence faced by different segments of the population in several large randomized controlled trials. If digital PT can deliver on its preliminary promises, patients stand to gain from broadened access to convenient and effective musculoskeletal care that will allow them to reduce their pain, improve their day-to-day functionality, and increase their quality of life.

Supplier

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