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Effectiveness of an Internet-Delivered Exercise and Pain-Coping Skills Training Intervention for Persons With Chronic Knee Pain

A Randomized Trial

Kim L. Bennell, BAppSci(Physio), PhD; Rachel Nelligan, BPhysio; Fiona Dobson, BAppSci(Physio), PhD; Christine Rini, PhD; Francis Keefe, BA, MS, PhD; Jessica Kasza, BSc(Hons), PhD; Simon French, BAppSc(Chiro), MPH, PhD; Christina Bryant, MA(Clin Psych), PhD; Andrew Dalwood, BAppSci(Physio), GradDipManipTherapy; J. Haxby Abbott, PhD, DPT; and Rana S. Hinman, BPhysio(Hons), PhD

Background: Effective, accessible biopsychosocial treatments are needed to manage chronic knee pain on a population level.

Objective: To evaluate the effectiveness of Internet-delivered, physiotherapist-prescribed home exercise and pain-coping skills training (PCST).

Design: Pragmatic parallel-group randomized, controlled trial. (Australian New Zealand Clinical Trials Registry: ACTRN12614000243617)

Setting: Community (Australia).

Patients: 148 persons aged 50 years or older with chronic knee pain.

Intervention: The intervention was delivered via the Internet and included educational material, 7 videoconferencing (Skype [Microsoft]) sessions with a physiotherapist for home exercise, and a PCST program over 3 months. The control was Internet-based educational material.

Measurements: Primary outcomes were pain during walking (11-point numerical rating scale) and physical function (Western Ontario and McMaster Universities Osteoarthritis Index) at 3 months. Secondary outcomes were knee pain, quality of life, global change (overall, pain, and functional status), arthritis self-efficacy, coping, and pain catastrophizing. Outcomes were also measured at 9 months.

Results: Of participants enrolled, 139 (94%) completed primary outcome measures at 3 months and 133 (90%) completed secondary outcome measures at 9 months; multiple imputation was used for missing data. The intervention group reported significantly more improvement in pain (mean difference, 1.6 units [95% CI, 0.9 to 2.3 units]) and physical function (mean difference, 9.3 units [CI, 5.9 to 12.7 units]) than the control group at 3 months, and improvements were sustained at 9 months (mean differences, 1.1 units [CI, 0.4 to 1.8 units] and 7.0 units [CI, 3.4 to 10.5 units], respectively). Intervention participants showed significantly more improvement in most secondary outcomes than control participants. At both time points, significantly more intervention participants reported global improvements.

Limitation: Participants were unblinded.

Conclusion: For persons with chronic knee pain, Internet-delivered, physiotherapist-prescribed exercise and PCST provide clinically meaningful improvements in pain and function that are sustained for at least 6 months.

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For author affiliations, see end of text.
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Osteoarthritis is the leading cause of persistent knee pain, affecting around one quarter of adults (1, 2), and is a major contributor to global disability (3). Knee osteoarthritis causes loss of function, reduced quality of life, and psychological disability (4). It has no cure and, given the aging population and increasing obesity rates, disease burden is rapidly increasing (5, 6). The urgent need for effective and accessible models of health service delivery that can be provided on a population level has been recognized as a research priority by key stakeholders (7). Such models should take a biopsychosocial approach; emphasize nondrug, nonsurgical treatment; and foster self-management, of which appropriate educational information is a core component (8).

Exercise has well-established benefits for pain and function in persons with knee osteoarthritis (9–11) and is recommended by clinical guidelines as the cornerstone of conservative management (12). It is often prescribed by a health professional and can be performed effectively at home (9). Evidence also supports pain-coping skills training (PCST), an approach based on cognitive behavioral principles, to target psychological factors, such as low self-efficacy, poor pain coping, and pain catastrophizing, that are common in persons with chronic pain (13, 14). However, for many, accessing specialist clinicians to prescribe and supervise these treatments may be difficult due to cost, transport issues, or geographic location, particularly in regional and rural areas where services may be limited or nonexistent (15, 16).

The Internet is a time-efficient and convenient method to deliver health interventions with broad

See also:

Editorial comment 1
Summary for Patients 2

Web-Only

Supplement
Supplement Video

reach (17, 18). Educational material is often accessed online by persons with chronic pain (19). Remotely delivered physiotherapy and exercise can benefit persons with knee pain and osteoarthritis (20–22) and those who have undergone knee joint replacement, albeit often using sophisticated technology (23). An Internet-based interactive PCST program (PainCOACH), designed to translate key therapeutic elements of clinician-delivered face-to-face PCST (24), showed improved outcomes in persons with hip or knee osteoarthritis (25). An online intervention combining these treatments aligns with a biopsychosocial approach to chronic disease management (8) but has not been investigated in this patient population.

This study aimed to evaluate the effectiveness of an innovative Internet-based intervention combining physiotherapist-prescribed home exercise delivered via videoconferencing (Skype [Microsoft]) and automated PCST in addition to educational material in persons with chronic knee pain. Our primary hypothesis was that the intervention would reduce pain and improve physical function after 3 months compared with educational material only.

METHODS

Design Overview

We conducted a parallel, 2-group pragmatic randomized, controlled trial. The protocol has been published (26). The trial was prospectively registered with the Australian New Zealand Clinical Trials Registry (ACTRN12614000243617). Initial registration erroneously listed the Depression, Anxiety and Stress Scale (DASS-21) as a secondary outcome rather than an eligibility screening tool. We amended the registry after enrolling 16 participants but before collecting follow-up data. No interim analyses were performed. The Institutional Human Ethics Committee approved the trial, and participants provided informed consent.

Recruitment occurred from March 2014 to May 2015, with follow-up completed in February 2016. Participants and physiotherapists were unblinded to group allocation and were aware of the alternative treatment components, but study hypotheses were not disclosed to participants. The statistician was blinded. A nested health economic evaluation and a qualitative study exploring patients' and physiotherapists' experiences will be published separately.

Setting and Participants

We recruited community-dwelling participants from Australia via print, radio, and social media advertisements and our database. Eligibility was confirmed using an online survey followed by a telephone interview. Inclusion criteria were age 50 years or older, knee pain for more than 3 months and on most days of the previous month, knee pain during walking (score of ≥4 on an 11-point numerical rating scale [NRS], with terminal descriptors of "no pain" and "worst pain possible") in the previous week, mild to moderate physical dysfunction (score >20 out of 68 on the physical function subscale of the Western Ontario and McMaster Universities Osteoarthritis Index [WOMAC]), and an active e-mail account and a computer with Internet access.

Exclusion criteria were joint replacement in the symptomatic knee, awaiting joint replacement surgery, intra-articular corticosteroid injection or knee surgery in the previous 6 months or planned joint surgery in the subsequent 9 months, treatment for knee pain or participation in a strengthening exercise or PCST program in the previous 6 months, systemic arthritic condition, neurologic condition affecting the lower limb or limiting exercise, pain at another site that was worse than knee pain or limited exercise, and high-level depression (score >21 on the depression subscale of the DASS-21 [27]).

Randomization and Interventions

Computer-generated randomization was conducted by random permuted blocks of size 2 to 8 stratified by sex and residence (metropolitan or regional/rural). The randomization schedule was prepared by an independent biostatistician and concealed from the researcher enrolling participants in sequentially numbered, opaque, sealed envelopes.

Intervention

Participants received 3 Internet-delivered treatments. The first was educational material about exercise and physical activity, pain management, emotions, healthy eating, complementary therapies, and medications (www.arthritisaustralia.com.au). Participants were encouraged to access the material at their leisure. The second was an interactive automated PCST program (PainCOACH) (24, 25). Participants were asked to complete eight 35- to 45-minute modules (1 per week commencing in week 1) and practice pain-coping skills daily (**Appendix Table 1**, available at Annals.org). These skills included progressive relaxation, activity–rest cycling, scheduling pleasant activities, changing negative thoughts, pleasant imagery and distraction techniques, and problem solving. The third was 7 Skype sessions with a physiotherapist over 12 weeks (in weeks 2, 3, 4, 6, 8, 10, and 12). Sessions lasted 45 minutes in weeks 2 and 12 and 30 minutes in the other weeks. Physiotherapists were allocated to participants on the basis of availability, and the same physiotherapist undertook all consultations with any given participant. The physiotherapist performed a brief assessment and prescribed a lower-limb–strengthening home exercise program to be performed 3 times per week (26, 28) (**Appendix Table 2**, available at Annals.org). Exercise progression was provided by varying the exercises, repetitions, load, or difficulty to approximate a 10-repetition maximum level and a self-rated effort level of at least 5 out of 10 (hard) on a modified Borg Rating of Perceived Exertion scale (29). Participants were provided with instructions, video demonstrations, and equipment (such as resistance bands and ankle weights). They also were encouraged to increase physical activity levels, received written information about

how to do so, and were given the option of using a pedometer for motivation (provided at no cost).

Generic e-mail reminders to complete PainCOACH modules were sent weekly during the first 8 weeks. At week 11 and at monthly intervals from week 13, participants received e-mails encouraging them to review the final module, revisit useful or meaningful modules, and continue home exercise and pain-coping skills practice.

Eight physiotherapists (4 men) with an average of 16 years (range, 3 to 28 years) of clinical musculoskeletal experience were trained to deliver the exercise component. Physiotherapists attended a 1-day training course conducted by the researchers and were given an exercise manual. They also were provided with an overview of PainCOACH and were asked to encourage participants to complete modules and practice skills. Regular telephone and Skype meetings between the physiotherapists and the researchers were held to discuss implementation of the intervention. A brief video showing a mock physiotherapy session is provided in Supplement 1 (available at Annals.org).

Control

The control group received access to the same online educational material as the intervention group.

Outcomes and Follow-up

Participants completed measurements online at baseline, 3 months (primary time point), and 9 months. They received a $50AUD gift voucher for completing all questionnaires. The primary outcomes were valid and reliable self-reported measures of pain and physical function that are recommended for knee osteoarthritis clinical trials (30). Overall average pain during walking over the previous week was measured with an NRS, with terminal descriptors of "no pain" (score of 0) and "worst pain possible" (score of 10) and a minimum clinically important difference (MCID) of 1.8 units (31). Difficulty with physical function over the previous 48 hours was measured with the WOMAC (Likert version 3.1) physical function subscale (32), with total scores ranging from 0 (no dysfunction) to 68 (maximum dysfunction) and an MCID of 6 units (33).

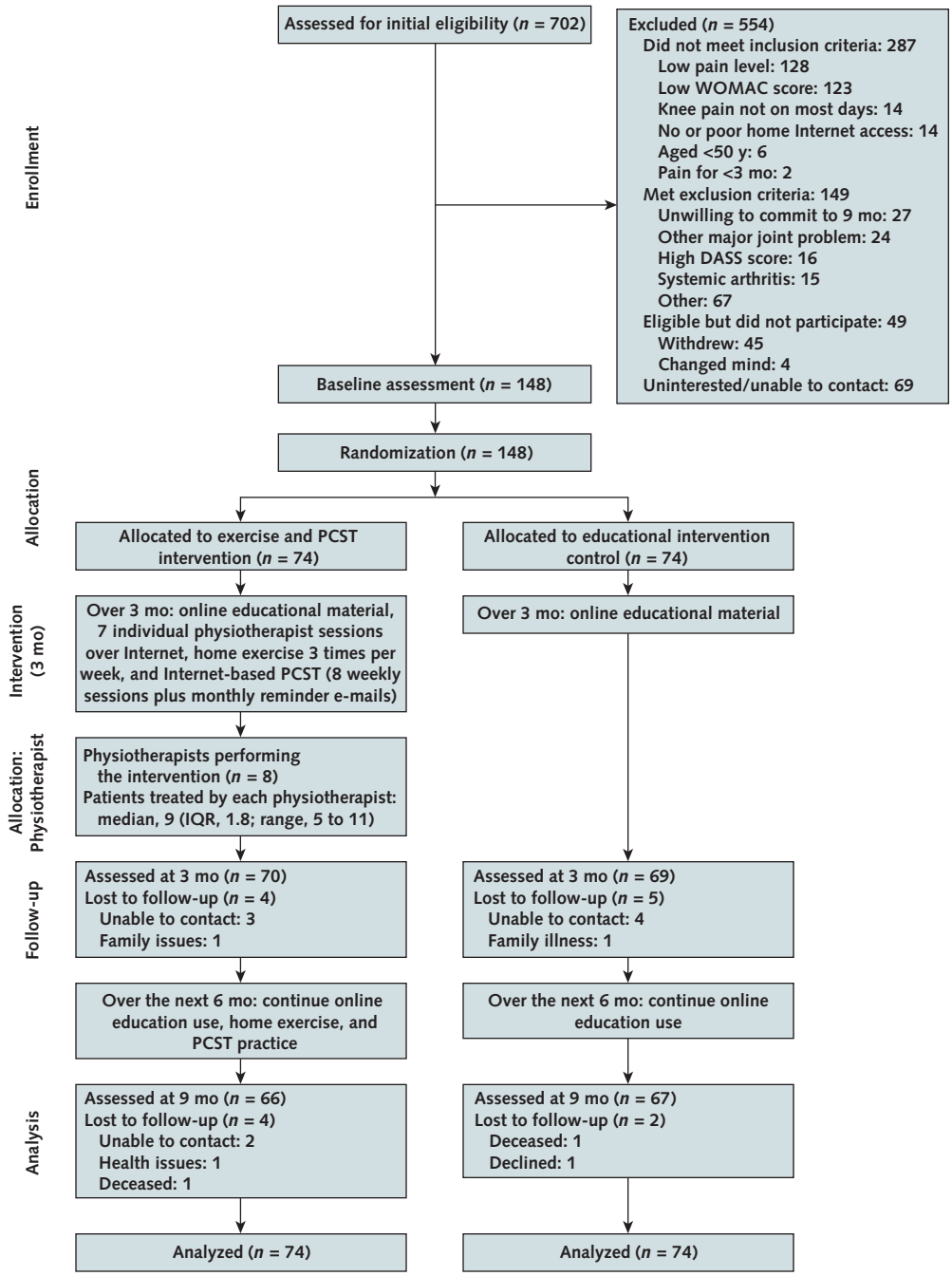
Secondary outcomes included knee pain over the previous 48 hours, measured using the WOMAC pain subscale (32) (scores range from 0 [no pain] to 20 [maximum pain]); global change overall, in pain, and in physical function, measured using 7-point Likert scales with terminal descriptors of "much worse" to "much better" (measured at 3 and 9 months); health-related quality of life, measured using the Assessment of Quality of Life instrument (34) (version 2, with scores ranging from −0.04 [lowest quality] to 1.00 [highest quality] [35]); self-efficacy for pain and function, measured using the Arthritis Self-Efficacy Scale (36) (scores range from 1 to 10, with higher scores indicating greater self-efficacy); pain catastrophizing, measured using the Pain Catastrophizing Scale (37) (scores range from 0 to 52, with higher scores indicating greater catastrophizing); and use of coping skills to manage pain, measured using the Coping Attempts Scale of the Coping Strategies

Table 1. Baseline Descriptive Characteristics*

Characteristic	Intervention (*n* = 74)	Control (*n* = 74)
Mean age (SD), *y*	60.8 (6.5)	61.5 (7.6)
Female, *n (%)*	43 (58)	40 (54)
Geographic location, *n (%)*		
Metropolitan	42 (57)	42 (57)
Regional/rural	32 (43)	32 (43)
Mean height (SD), *cm*	170.0 (5.9)†	168.3 (4.4)‡
Mean weight (SD), *kg*	92.1 (38.2)†	87.3 (30.5)‡
Mean body mass index (SD), *kg/m²*	32.0 (13.9)†	30.1 (10.2)‡
Symptom duration, *n (%)*		
<2 y	11 (15)	24 (32)
2–10 y	38 (51)	35 (47)
>10 y	24 (34)	15 (20)
Level of education, *n (%)*		
<3 y of high school	3 (4)	5 (7)
≥3 y of high school	13 (18)	19 (26)
Some education beyond high school	15 (20)	22 (30)
Tertiary or higher	43 (58)	28 (38)
Employment status, *n (%)*		
Currently employed	40 (54)	45 (61)
Retired (not due to health reasons)	23 (31)	21 (28)
Unemployed/student	4 (5)	2 (3)
Homemaker	2 (3)	3 (4)
Unable to work due to health reasons	5 (7)	3 (4)
Current drug/supplement use, *n (%)*§		
Analgesia (acetaminophen combinations)	28 (38)	29 (39)
Nonsteroidal anti-inflammatory drugs	17 (23)	17 (23)
Cyclooxygenase-2 inhibitors	3 (4)	4 (5)
Topical anti-inflammatory drugs	16 (22)	15 (20)
Glucosamine/chondroitin products	19 (26	22 (30)
Opioids	1 (1)	0 (0)
Other	23 (31)	27 (37)
Expectation of treatment outcomes, *n (%)*		
No effect	0 (0)	0 (0)
Minimal improvement	11 (15)	24 (32)
Moderate improvement	38 (51)	35 (47)
Large improvement	25 (34)	15 (20)
Complete recovery	0 (0)	0 (0)
Years using the Internet, *n (%)*		
>1	0 (0)‖	1 (2)¶
1–4	2 (3)‖	1 (2)¶
≥5	61 (97)‖	54 (96)¶
Internet use for social media, including Skype, *n (%)*		
Never	4 (6)‖	4 (7)¶
Once per month or less	5 (8)‖	7 (13)¶
Once per week	3 (5)‖	6 (11)¶
Several times per week	10 (16)‖	8 (14)¶
Daily	41 (65)‖	31 (55)¶
Self-rated ability to use the Internet, *n (%)*		
Poor	1 (2)‖	1 (2)¶
Fair	3 (5)‖	9 (14)¶
Good	28 (44)‖	23 (37)¶
Excellent	31 (49)‖	23 (37)¶

* Percentages may not sum to 100 due to rounding.
† 64 responses.
‡ 69 responses.
§ Defined as at least once per week.
‖ 63 responses.
¶ 56 responses.

Figure. Study flow diagram.



DASS = Depression, Anxiety and Stress Scale; IQR = interquartile range; PCST = pain-coping skills training; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

Questionnaire (38) (scores range from 0 to 163, with higher scores indicating more frequent use of coping skills [39]).

Adverse effects of treatment (any problem believed by the participant to be caused by treatment and lasting ≥2 days and/or requiring medication or treatment) and co-interventions were recorded via logbooks during the first 3 months and an online survey at 3, 6, and 9 months. Use of health services and co-interventions was collected using an online survey at 0, 3, and 9 months.

Demographic information was collected at baseline. Before randomization, participants were asked to rate their expected treatment effect using a 5-point Likert scale ranging from "no effect" to "complete recovery."

Adherence was measured by the number of Skype physiotherapy sessions attended; the number of Pain-

COACH sessions completed (extracted from the program); the self-reported number of exercise sessions and pain-coping skills practice sessions in the previous 2 weeks at 3, 6, and 9 months, converted to a percentage of total prescribed sessions; self-reported adherence to home exercise over the previous 3 months at 3, 6, and 9 months, measured using an 11-point NRS (with terminal descriptors of "not at all" and "completely as instructed"); and the percentage of participants accessing online educational material in the previous 3 months. Satisfaction with treatment was assessed at week 13 using a 5-point Likert scale ranging from "very satisfied" to "very dissatisfied" (9).

Statistical Analysis

Moderate between-group treatment effects of around 0.5 have previously been reported for pain and function after exercise programs in persons with knee osteoarthritis (9). Therefore, to detect an effect size of at least 0.5 between groups in either pain or function with 80% power, a 2-sided significance level of 0.05, and 15% attrition, we aimed to recruit 74 participants in each group.

Analyses were performed using Stata, version 14.1 (StataCorp). An intention-to-treat analysis was used that included all randomly assigned participants in their assigned treatment group, with 2-sided hypothesis tests and a *P* value less than 0.05 considered significant. Missing outcome data were imputed using chained equations with predictive mean matching drawing from the 3 nearest neighbors for continuous outcomes and logistic regression imputation models for global change outcomes, with data imputed for each treatment group separately (Stata mi impute chained command). Due to collinearity of global change variables, each was imputed separately while all continuous variables were imputed iteratively. Missing baseline body mass index values were imputed using single-mean imputation (40). Estimates from 20 imputed data sets were combined using Rubin rules (41). Each imputed data set was visually compared with the complete outcome data set. For continuous outcomes, mean between-group differences in change (baseline minus follow-up) and the corresponding 95% CIs were estimated using mixed linear regression models (Stata mixed command).

Longitudinal analyses were conducted, with differences between baseline and follow-up as outcomes, with adjustment for baseline scores and stratification variables (sex and residency) and an interaction between month and treatment group as fixed effects, and with random effects for physiotherapists and individuals included. Within-group differences from baseline at each follow-up time point were summarized using adjusted mean changes and 95% CIs; these were also computed by allocated physiotherapists for primary outcomes.

The proportion of participants in each group who attained the MCID for the primary outcomes (reduction of 1.8 units for pain and 6 units for function) was calculated. Based on perceived global change overall and in pain and function, participants reporting "moderately better" or "much better" function were classified as improved, and others were classified as not improved. Binary outcomes were compared across groups using risk differences calculated (Stata margins command) after fitting longitudinal logistic regression models that were adjusted for stratification variables using generalized estimating equations to account for clustering by physiotherapist (Stata xtgee command) (42).

Sensitivity analyses for the primary outcomes, assuming systematic differences between participants who withdrew and those who remained, were con-

Table 2. Mean Scores on Continuous Outcome Measures Across Time, by Group*

Outcome	Baseline		Month 3		Month 9	
	Intervention (*n* = 74)	Control (*n* = 74)	Intervention (*n* = 70)	Control (*n* = 69)	Intervention (*n* = 66)	Control (*n* = 67)
Primary						
Pain during walking (NRS)†	6.1 (1.4)	6.2 (1.3)	3.3 (2.2)	5.1 (2.0)	3.6 (2.2)	4.7 (2.5)
Physical function (WOMAC)‡	33.1 (8.0)	32.5 (8.3)	18.3 (10.7)	27.6 (11.7)	18.7 (10.2)	25.7 (11.6)
Secondary						
Knee pain (WOMAC)§	9.0 (2.4)	9.2 (2.5)	5.1 (2.7)	7.7 (3.3)	5.1 (2.9)	6.9 (3.5)
Quality of life (AQoL-2)‖	0.7 (0.2)	0.7 (0.1)	0.8 (0.1)	0.7 (0.1)	0.8 (0.2)	0.7 (0.2)
Self-efficacy (ASES)¶						
Pain	6.1 (1.8)	5.9 (1.8)	7.6 (2.0)	5.7 (2.1)	7.5 (2.0)	6.2 (1.8)
Function	7.6 (1.6)	7.5 (1.4)	8.6 (1.4)	7.8 (1.6)	8.6 (1.8)	7.9 (1.4)
Pain catastrophizing (PCS)**	8.8 (9.2)	10.1 (9.6)	5.7 (6.3)	9.4 (9.4)	6.2 (7.4)	9.3 (8.7)
Coping attempts (CSQ)††	61.7 (24.9)	65.7 (24.9)	72.7 (26.1)	69.8 (23.3)	74.6 (26.6)	67.0 (28.0)

AQoL-2 = Assessment of Quality of Life, version 2; ASES = Arthritis Self-Efficacy Scale; CSQ = Coping Strategies Questionnaire; NRS = numerical rating scale; PCS = Pain Catastrophizing Scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.
* Values in parentheses are SDs.
† Ranges from 0 to 10; lower scores indicate less pain.
‡ Ranges from 0 to 68; lower scores indicate better function.
§ Ranges from 0 to 20; lower scores indicate less pain.
‖ Ranges from −0.04 to 1.00; higher scores indicate better quality of life.
¶ Ranges from 1 to 10; higher scores indicate greater self-efficacy.
** Ranges from 0 to 52; higher scores indicate greater catastrophizing.
†† Ranges from 0 to 163; higher scores indicate more frequent use of coping skills.

Table 3. Mean Change Within Groups and Adjusted Mean Difference in Change Between Groups for Multiply Imputed Data*

Outcome	Change Within Group			
	Baseline − Month 3		Baseline − Month 9	
	Intervention (n = 70)	Control (n = 69)	Intervention (n = 66)	Control (n = 67)
Primary				
Pain during walking (NRS)‡§	2.7 (2.2 to 3.2)	1.2 (0.7 to 1.6)	2.5 (2.0 to 3.0)	1.5 (0.9 to 2.1)
Physical function (WOMAC)‡‖	14.4 (11.8 to 17.0)	4.9 (2.3 to 7.5)	13.9 (11.2 to 16.6)	6.6 (4.0 to 9.3)
Secondary				
Knee pain (WOMAC)‡¶	3.9 (3.1 to 4.7)	1.5 (0.7 to 2.3)	3.7 (2.9 to 4.5)	2.3 (1.4 to 3.1)
Quality of life (AQoL-2)**††	−0.1 (−0.1 to 0)	0 (−0.1 to 0)	−0.1 (−0.1 to 0)	0 (0 to 0)
Self-efficacy (ASES)**‡‡				
Pain	−1.5 (−2.0 to −1.0)	0.3 (−0.3 to 0.8)	−1.3 (−1.8 to −0.8)	−0.2 (−0.7 to 0.3)
Function	−0.9 (−1.3 to −0.5)	−0.3 (−0.7 to 0.1)	−0.8 (−1.3 to −0.4)	−0.4 (−0.7 to −0.1)
Pain catastrophizing (PCS)‡§§	0.6 (0.3 to 1.0)	0.1 (−0.3 to 0.5)	0.5 (0.1 to 1.0)	0.2 (−0.2 to 0.6)
Coping attempts (CSQ)**‖‖	−11.3 (−16.8 to −5.8)	−4.7 (−9.5 to 0.1)	−13.1 (−19.4 to −6.8)	−0.3 (−5.5 to 4.9)

AQoL-2 = Assessment of Quality of Life, version 2; ASES = Arthritis Self-Efficacy Scale; CSQ = Coping Strategies Questionnaire; NRS = numerical rating scale; PCS = Pain Catastrophizing Scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.
* Values in parentheses are 95% CIs.
† Adjusted for baseline value of outcome, sex, and geographic location, as well as clustering effects for physiotherapist and measurements from the same participant.
‡ For change within groups, positive values indicate improvement. For differences in change between groups, positive values favor the intervention and negative values favor the control.
§ Ranges from 0 to 10; lower scores indicate less pain.
‖ Ranges from 0 to 68; lower scores indicate better function.
¶ Ranges from 0 to 20; lower scores indicate less pain.
** For change within groups, negative values indicate improvement. For differences in change between groups, negative values favor the intervention and positive values favor the control.
†† Ranges from −0.04 to 1.00; higher scores indicate better quality of life.
‡‡ Ranges from 1 to 10; higher scores indicate greater self-efficacy.
§§ Square-root transformation of outcome due to nonnormality of residuals. Results are interpreted in terms of increases on the square-root scale of the outcome; relative to the control group, the intervention group increases the square root of the outcome by the amount shown. Ranges from 0 to 52; higher scores indicate greater catastrophizing.
‖‖ Ranges from 0 to 163; higher scores indicate more frequent use of coping skills.

ducted using a pattern-mixture model approach to quantify the degree of violation of the missing-at-random assumption (43). Three scenarios were considered: violation of the assumption in both groups and in each group only.

Role of the Funding Source

The National Health and Medical Research Council had no role in study design, conduct, or analysis or the decision to submit the manuscript for publication.

RESULTS

We enrolled 148 participants from 7 of 8 Australian states, 43% of whom were from regional or rural areas. Participants in both treatment groups were similar at baseline, although those in the intervention group had longer symptom duration and higher educational levels (Table 1). Three participants randomly assigned to the intervention group were not assigned a physiotherapist (1 could not be contacted and 2 declined because of other commitments). Nine (6%) and 15 (10%) of the 148 participants were lost to follow-up at 3 and 9 months, respectively, and loss to follow-up was similar across groups (Figure). Participants who were lost to follow-up at 3 months were more likely to live in regional or rural areas and to have higher body mass index and less likely to be retired than those who remained, with no differences at 9 months.

Adherence, adverse events, co-interventions, and treatment satisfaction are shown in Appendix Table 3 (available at Annals.org). In the first 3 months, educational material was accessed by 78% and 88% of participants in the intervention and control groups, respectively. Participants in the intervention group attended a mean of 6.3 (95% CI, 5.9 to 6.7) of 7 Skype physiotherapy sessions and completed 6.4 (CI, 5.7 to 7.0) of 8 PainCOACH modules. In the first 3 months, 68% (CI, 60% to 75%) of prescribed home exercise sessions and 64% (CI, 56% to 72%) of PCST practice sessions were completed, with numbers decreasing during follow-up to 47% (CI, 39% to 56%) and 41% (CI, 33% to 49%), respectively. During treatment, more participants in the intervention group (n = 22) than the control group (n = 3) reported adverse events. Adverse events were minor, with increased knee pain being most common in both groups (15 and 3 events, respectively). Co-interventions and medication use were similar between groups. Satisfaction with intervention components was high.

Table 2 summarizes continuous outcomes over time, and Table 3 shows changes between and within groups. For the primary outcomes at 3 months, the intervention group reported significantly greater improvement in pain (mean difference, 1.6 units [CI, 0.9 to 2.3 units]) and WOMAC physical function (mean difference, 9.3 units [CI, 5.9 to 12.7 units]) than the control group, and these effects were sustained at 9 months (mean differences, 1.1 units [CI, 0.4 to 1.8 units] and 7.0 units [CI, 3.4 to 10.5 units], respectively). Both groups

Table 3–Continued

Difference in Change Between Groups†			
Baseline to Month 3	***P* Value**	**Baseline to Month 9**	***P* Value**
1.6 (0.9 to 2.3)	<0.001	1.1 (0.4 to 1.8)	0.003
9.3 (5.9 to 12.7)	<0.001	7.0 (3.4 to 10.5)	<0.001
2.5 (1.5 to 3.5)	<0.001	1.6 (0.6 to 2.6)	0.003
−0.1 (−0.1 to 0)	0.023	−0.1 (−0.1 to 0)	0.018
−1.9 (−2.5 to −1.2)	<0.001	−1.2 (−1.9 to −0.6)	<0.001
−0.7 (−1.2 to −0.2)	0.006	−0.4 (−0.9 to 0.1)	0.093
0.7 (0.2 to 1.1)	0.006	0.5 (0 to 1.0)	0.049
−5.3 (−12.4 to 1.8)	0.142	−11.6 (−18.7 to −4.4)	0.002

showed significant improvements from baseline at 3 and 9 months, with a significantly greater proportion of participants in the intervention group exceeding MCIDs at both time points (**Appendix Table 4**, available at Annals.org). Although there was variability across physiotherapists in mean difference in change from baseline, sizes of observed differences were consistent across physiotherapists (**Appendix Table 5**, available at Annals.org). Sensitivity analyses indicated that relatively large systematic differences between participants who did and did not drop out were required to ameliorate estimated differences (**Appendix Figures 1** to **4**, available at Annals.org).

All secondary outcomes except coping attempts at 3 months and self-efficacy (function) at 9 months showed significant between-group differences favoring the intervention (**Table 3**). The intervention group had significant improvements in all secondary outcomes at both time points, whereas the control group improved only on WOMAC pain at 3 months and WOMAC pain and self-efficacy (function) at 9 months (**Table 3**). At both time points, significantly more participants in the intervention group reported global improvements (**Appendix Table 6**, available at Annals.org).

Sensitivity analyses that adjusted for symptom duration and educational level revealed minor changes to the estimates that favored the intervention more strongly (**Appendix Tables 7** and **8**, available at Annals.org).

Discussion

In this study, an innovative online intervention combining physiotherapist-prescribed home exercise and an interactive PCST program provided substantial clinical benefits for persons with chronic knee pain. The intervention had broad reach, being accessed by participants from throughout Australia in both metropolitan and regional or rural localities. Of note, participants were highly satisfied with the intervention. Uptake of and adherence to Skype physiotherapy and PainCOACH were excellent, and home exercise adherence was consistent with that reported for face-to-face physiotherapy (44).

Improvements in pain and function with the intervention were large at 3 months and were significantly greater than those in the control group. Between-group differences exceeded the MCID for function and almost reached the MCID for pain. Significantly greater improvements with the intervention were also seen in almost all secondary outcomes. Benefits were apparent at 9 months, although between-group differences were slightly reduced; this was mainly due to improvement in the control group rather than loss of benefit in the intervention group. These results support the short- and longer-term effectiveness of this intervention across several patient-relevant domains for persons with chronic knee pain.

Although there are no directly comparable studies, our findings align with several studies investigating remote delivery of care in persons with knee pain or osteoarthritis. A 6-week exercise program provided by telephone was as beneficial as in-clinic exercise for 50 patients with knee osteoarthritis in Nigeria (21, 45), and an exercise program delivered via group-based videoconferencing improved clinical outcomes in an uncontrolled study of 22 older patients with knee pain in Hong Kong (22). Research investigating sophisticated telerehabilitation service models has involved patients who had knee arthroplasty for osteoarthritis, with outcomes similar to those with face-to-face delivery (23, 46–50). In the only study of Internet-delivered PCST, Rini and colleagues (25) found that in a racially diverse sample of persons with osteoarthritis in the hip, the knee, or both—some of whom had low income, lived in a rural area, or had little computer experience—PainCOACH led to significant pain reductions in women and improvements in self-efficacy in both men and women. The larger benefits in our study are likely due to the combination of exercise and PCST. This is consistent with the finding that an intervention consisting of in-clinic physiotherapist-prescribed exercise and face-to-face PCST is more effective than either alone in persons with knee osteoarthritis (14), emphasizing the benefits of addressing both biological and psychosocial factors to optimize outcomes.

Given that Internet use is increasing among older adults (51), our online intervention offers an effective, safe, acceptable, and viable alternative to traditional treatment delivery. Participants were highly satisfied with the physiotherapy component. This agrees with limited telerehabilitation research in patients after knee arthroplasty, who valued development of a bond with the therapist while maintaining privacy and personal space (50, 52). Similarly, satisfaction with and adherence to PainCOACH were high, which is notable because adherence to online treatment resources can be low (53, 54). Cognitive behavioral treatments from clinical psychologists are rarely available to persons with chronic knee pain (55). Because PainCOACH requires no clinician input, it can be an economical approach to self-management. We are in the process of making PainCOACH freely and publicly available on the Internet.

We found significant improvements in pain and function outcomes in our control group. However, these improvements were smaller than those in the intervention group and were of questionable clinical relevance because they did not reach MCIDs for primary outcomes. Furthermore, only 32% of participants in the control group exceeded the MCID for change in pain during walking and change in WOMAC physical function compared with 76% and 72%, respectively, in the intervention group. The extent to which improvements in the control group can be attributed to online educational material, which was accessed by 88% of participants, cannot be determined. Nevertheless, although education is a key component of self-management and a core recommended treatment for knee osteoarthritis (12), a systematic review of 29 studies investigating various osteoarthritis educational interventions showed that they resulted in no or small benefits (56). This suggests that other contextual factors, such as attention from the researchers, natural symptom improvement, or regression to the mean, may explain the observed improvements in the control group (57).

Strengths of our study include the pragmatic treatment delivery by practicing physiotherapists, use of freely and readily available videoconferencing technology (Skype) and an automated PCST program not requiring clinician input, and the inclusion of participants in metropolitan and regional settings. Other strengths include outcomes recommended for osteoarthritis clinical trials covering various patient-relevant domains, longer follow-up, and good participant retention and adherence.

The study also has limitations. We could not determine the contribution of each treatment component to the observed benefits or the minimum number of Skype sessions required for clinical effectiveness. Although participants were blinded to study hypotheses, they were not blinded to treatment, which could have resulted in overestimation of the benefits. We did not control for nonspecific treatment effects. Although participants had chronic knee pain, we did not perform a clinical examination or radiography to confirm a diagnosis of knee osteoarthritis; this prevented us from examining whether radiographic severity influenced response to treatment. Participants in the intervention group had longer symptom duration and higher educational levels than those in the control group. However, sensitivity analyses showed that this imbalance did not alter the findings. Our results may not necessarily be generalizable to persons with lower educational levels or with less competence and experience using the Internet.

In conclusion, an Internet model of service delivery combining education, physiotherapist-prescribed home exercise, and interactive PCST, consistent with a biopsychosocial approach to chronic disease management, conferred clinically relevant benefits in both the short term and the longer term for persons with chronic knee pain. Such a model may greatly improve access to these effective treatments.

From the University of Melbourne, Monash University, Royal Women's Hospital, and Physioworks Health Group, Melbourne, Victoria, Australia; UNC Gillings School of Global Public Health, Chapel Hill, North Carolina; Duke University, Durham, North Carolina; Queen's University, Kingston, Ontario, Canada; and Dunedin School of Medicine, University of Otago, Dunedin, New Zealand.

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Requests for Single Reprints: Kim L. Bennell, BAppSci(Physio), PhD, Centre for Health, Exercise and Sports Medicine, Department of Physiotherapy, The University of Melbourne, Level 7 Alan Gilbert Building, 161 Barry Street, Melbourne 3010, Victoria, Australia; e-mail, k.bennell@unimelb.edu.au.

Current author addresses and author contributions are available at Annals.org.

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Current Author Addresses: Prof. Bennell, Ms. Nelligan, and Drs. Dobson and Hinman: Centre for Health Exercise and Sports Medicine, Department of Physiotherapy, The University of Melbourne, Level 7 Alan Gilbert Building, 161 Barry Street, Melbourne 3010, Victoria, Australia.
Dr. Rini: Gillings School of Global Public Health, University of North Carolina at Chapel Hill, Department of Health Behavior, Campus Box 7440, 319C Rosenau Hall, Chapel Hill, NC 27599-7440.
Dr. Keefe: Duke Pain Prevention and Treatment Research Program, Suite 340, 2200 West Main Street, Durham, NC 27705.
Dr. Kasza: Department of Epidemiology and Preventive Medicine, Monash University, The Alfred Centre, 99 Commercial Road, Melbourne 3004, Victoria, Australia.
Dr. French: School of Rehabilitation Therapy, Faculty of Health Sciences, Queen's University, Louise D. Acton Building, 31 George Street, Kingston, Ontario K7L 3N6, Canada.
Dr. Bryant: Chelsea House, Suite 225, 55 Flemington Road, North Melbourne 3051, Victoria, Australia.
Mr. Dalwood: Waverley Park Physiotherapy Centre, 439 Police Road, Mulgrave 3170, Victoria, Australia.
Dr. Abbott: Centre for Musculoskeletal Outcomes Research, Orthopaedic Surgery Section, Department of Surgical Sciences, Dunedin School of Medicine, University of Otago, PO Box 913, Dunedin 9054, New Zealand.

Author Contributions: Conception and design: K.L. Bennell, F. Dobson, F. Keefe, S. French, C. Bryant, A. Dalwood, J.H. Abbott, R.S. Hinman.
Analysis and interpretation of the data: K.L. Bennell, R. Nelligan, J. Kasza, J.H. Abbott, R.S. Hinman.
Drafting of the article: K.L. Bennell, R. Nelligan, F. Dobson, C. Rini, F. Keefe, J. Kasza, S. French, C. Bryant.
Critical revision of the article for important intellectual content: K.L. Bennell, R. Nelligan, F. Dobson, F. Keefe, J. Kasza, S. French, C. Bryant, J.H. Abbott, R.S. Hinman.
Final approval of the article: K.L. Bennell, R. Nelligan, F. Dobson, C. Rini, F. Keefe, J. Kasza, S. French, C. Bryant, A. Dalwood, J.H. Abbott, R.S. Hinman.
Provision of study materials or patients: K.L. Bennell, R. Nelligan, C. Rini, F. Keefe.
Statistical expertise: J. Kasza.
Obtaining of funding: K.L. Bennell.
Administrative, technical, or logistic support: K.L. Bennell, R. Nelligan, F. Dobson, C. Rini, C. Bryant, A. Dalwood.
Collection and assembly of data: R. Nelligan.

Appendix Table 1. Summary of the Internet-Based PainCOACH Content*

Module Number	Coping Skill	Content
1	Progressive relaxation	Teach Gate Control Theory (how thoughts, feelings, and actions affect and are affected by pain). Introduce and demonstrate progressive relaxation with animation; walk user through use of the technique and active practice; help user identify/address circumstances that might impede relaxation and chose strategies to overcome obstacles; plan regular practice times; set practice goal.
2	Mini-practices	Review prior session content and practices; introduce and demonstrate "mini-practices" (brief relaxation) with animation; walk user through use of the technique and active practice, gather/evaluate pre- and postactivity pain; help user identify/address circumstances that might impede relaxation and choose strategies to overcome obstacles; discuss benefits and reminders for practicing; plan regular practice times; set and review practice goals.
3	Activity–rest cycling	Review prior session content and practices; introduce concept of activity–rest cycling; identify activities user tends to overdo; vicarious learning exercise demonstrate how to change overdone activities; create personal plan to fit daily routine and personal goals; review how other skills help with use of this one; plan regular practice times; set and review practice goals.
4	Pleasant activity scheduling and identify negative automatic thoughts	Review prior session content and practices; introduce concept of pleasant activity scheduling; lead user through exercise for adding pleasant activities to their lives; mini-practice of 10-minute pleasant activity to be done immediately (gather/evaluate pre- and postactivity pain); schedule 3 pleasant activities for week; problem-solve barriers with interactive vicarious learning exercise; introduce concept of negative automatic thoughts; describe connections between thoughts, emotions, behaviors, and pain; walk user through a thoughts exercise; plan regular practices; set and review practice goals.
5	Identify/change negative automatic thoughts and coping thoughts	Review prior session content and practices; continue and advance prior session's activities related to automatic thoughts and introduce coping thoughts. Practice identifying negative thoughts and accompanying emotional and physical reactions of virtual patients, then self; exercise to teach generation of alternative thoughts, then practice and record accompanying sensations. Focus on teaching generation of alternative thoughts, practice generating calming self-statements; practice skills and get feedback; identify and address circumstances that impede use of these skills and strategies to overcome obstacles; "mini-practices" for specific circumstances; plan regular practices; set and review practice goals.
6	Pleasant imagery and distraction techniques	Review prior session content and practices; introduce pleasant imagery and auditory and focal point distraction techniques; complete exercises with audio instructions; plan regular practices; set and review practice goals.
7	Problem solving	Review prior session content and practices; introduce concept of problem solving and describe steps; demonstrate problem solving with character stories; generate list of challenging situations; exercise to help users select skills for each situation, with personalized plan for overcoming barriers; plan regular practices; set and review practice goals.
8	Monitoring for maintenance	Review all session content; evaluate skill frequency, helpfulness, and comparison to other users; exercises to develop plan for maintenance of skills; motivate further practice and skill development; remind how skills facilitate personal goals; review practice goals.
–	Monthly reminder e-mails	Review module 8 as well as revisit any useful/meaningful sessions.

* Originally published by Springer Open (26).

Appendix Table 2. Home Exercise Program Protocol*

Maximum of 6 exercises (with progression as appropriate)			
2 knee extensor strengthening exercises			
1 hip abductor strengthening exercise			
1 hamstring strengthening exercise			
1 calf strengthening exercise			
1 other exercise chosen based on assessment findings			
1. Quads strengthening (each program must include 2 exercises)			
Knee extension	Non–weight-bearing	A. Seated knee extension (with resistance) with 5-second hold	Indications: Suggested as an initial exercise Progression: Increase cuff weight or theraband resistance—red through to black Simplification: Eliminate weight or use 1B
	Non–weight-bearing	B. Inner range quads over roll (with resistance) with 5-second hold	Indications: Usually only required when any flair ups with seated knee extension (1A) Progression: Use appropriate level of ankle cuff weight Simplification: Eliminate weight if flare up
Sit-to-stand	Weight-bearing	C. Sit to stand without using hands	Indications: Suggested as an initial exercise Progression: Lower chair height, hover above the seat without touching down, more weight on affected leg, slit leg position (affected leg closer to seat) Simplification: Use hands
Steps	Weight-bearing	D. Step-ups	Indications: Suitable progression from sit to stand (1C) Progression: Increase step height, hold extra weight (in hands or backpack) Simplification: Sit to stand (1C)
	Weight-bearing	E. Forward touchdowns from a step	Indications: Suitable progression from step-ups (1D) Progression: Increase step height, hold extra weight (in hands or backpack), don't touch down Simplification: Step-ups (1D)
Partial squats	Weight-bearing	F. Partial wall squats	Indications: Suitable progression from sit to stand (1C) Progression: Increase to 5-second hold, more weight on study side Simplification: If find flare/problematic step back to sit to stand (1C)
2. Hip abductor strengthening (1 exercise)			
Standing hip abduction	Non–weight-bearing	A. Side leg raises in standing	Indications: Suggested as an initial exercise Progression: Increase cuff weight or theraband resistance—red through to black Simplification: Eliminate weight
Side stepping	Weight-bearing	B. Crab walk with resistance band	Indications: Good progression from standing leg side raises (2A) Progression: Increase theraband resistance—red through to black Simplification: Side leg raises in standing (2A)
Standing hip abduction	Weight-bearing	C. Wall push standing on study leg	Indications: Good progression from crab walking (2B) and for variety at final session Progression: Increase step height. Hold extra weight (in hands or backpack) Simplification: If unable to tolerate static standing on joint then avoid and use 2B or 2A. Precaution in those with increased varus.
3. Hamstring strengthening (1 exercise)			
Standing knee flexion	Non–weight-bearing	Standing over bench knee curls with weight	Progression: Increase cuff weight or theraband resistance—red through to black Simplification: Eliminate weight
4. Calf strengthening (1 exercise)			
Standing plantar-flexion	Weight-bearing	Double heel raises	Progression: Single heel raises, raises from the edge of a step
5. Others (1 exercise if appropriate)			
Knee range	Weight-bearing	A. Deep squats holding onto a bench/chair	Progression: Increase squat depth
Hip range	Weight-bearing	B. Deep lunges holding onto back of chair/bench	Progression: Increase lunge depth
Hip extensors	Weight-bearing	C. Bridging	Progression: Split leg bridge, single bridge with a hold, bridging 1 leg

* Originally published by Springer Open (26).

Appendix Table 3. Adherence, Adverse Events, Co-interventions, and Treatment Satisfaction, by Group*

Measure	Intervention	Control
Adherence		
Mean physiotherapy sessions attended (0–7) (95% CI), *n*	6.3 (5.9–6.7)	–
Mean self-rated home exercise adherence during treatment (0–10) (95% CI)†	7.9 (7.4–8.5)	–
Mean self-rated home exercise adherence during follow-up (0–10) (95% CI)‡	4.7 (3.9–5.5)	–
Mean home exercise sessions completed during treatment (95% CI), %†§	68 (60–75)	–
Mean home exercise sessions completed during follow-up (95% CI), %‡§	47 (39–56)	–
Mean PainCOACH sessions completed (0–8) (95% CI), *n*†	6.4 (5.7–7.0)	–
Mean home PCST practices completed during treatment (95% CI), %†‖	64 (56–72)	–
Mean home PCST practices completed during follow-up (95% CI), %‡‖	41 (33–49)	–
Participants who accessed online education during treatment, *n/N (%)*†	51/65 (78)	59/67 (88)
Participants who accessed online education during follow-up, *n/N (%)*‡¶	27/64 (42)	40/70 (57)
Adverse events, *n/N (%)*		
Participants reporting adverse events during treatment†**	22/65 (34)	3/67 (4)
Adverse events during treatment	26	3
Increased knee pain	15/65 (23)	3/67 (4)
Muscle cramping/soreness	5/65 (8)	0/67 (0)
Pain in other area	5/65 (8)	0/67 (0)
Swelling	1/65 (2)	0/67 (0)
Participants reporting adverse events during follow-up‡¶**	5/64 (8)	5/70 (7)
Adverse events during follow-up‡¶**	5	6
Increased knee pain	3/64 (5)	2/70 (3)
Muscle cramping/soreness	0/64 (0)	2/70 (3)
Pain in other region	2/64 (3)	2/70 (3)
Medication use/co-interventions, *n/N (%)*		
Participants using medication in the past month at month 3	40/65 (62)	46/67 (69)
Medications used in past month at month 3	59	74
Analgesia (acetaminophen combinations)	24/65 (37)	25/67 (37)
Nonsteroidal anti-inflammatory drugs	10/65 (15)	12/67 (18)
Cyclooxygenase-2 inhibitors	4/65 (6)	5/67 (7)
Topical anti-inflammatory drugs	7/65 (11)	13/67 (19)
Oral corticosteroids	0/65 (0)	1/67 (1)
Glucosamine/chondroitin products	14/65 (22)	18/67 (27)
Participants using medication in past month at month 9	36/62 (58)	42/64 (66)
Medications used in past month at month 9	54	75
Analgesia (acetaminophen combinations)	21/62 (34)	24/64 (38)
Nonsteroidal anti-inflammatory drugs	11/62 (18)	14/64 (22)
Cyclooxygenase-2 inhibitors	3/62 (5)	7/64 (11)
Topical anti-inflammatory drugs	6/62 (10)	12/64 (19)
Oral corticosteroids	0/62 (0)	1/64 (2)
Oral opioids	0/62 (0)	1/64 (2)
Glucosamine/chondroitin products	13/62 (21)	16/64 (25)
Other treatments used during treatment phase†		
Weight loss efforts	41/65 (63)	43/67 (64)
Exercise	56/65 (86)	54/67 (81)
Shoe insoles	18/65 (28)	28/67 (42)
Heat/cold treatment	25/65 (38)	34/67 (51)
Other treatments used during follow-up††		
Weight loss efforts	44/62 (71)	45/64 (70)
Exercise	55/62 (89)	52/64 (81)
Shoe insoles	27/62 (44)	35/64 (55)
Heat/cold treatment	21/62 (34)	30/64 (47)
Mean treatment satisfaction (95% CI)‡‡		
Satisfaction with online education	1.8 (1.6–2.0)	2.2 (2.0–2.4)
Satisfaction with Internet-delivered physiotherapy	1.2 (1.1–1.4)	–
Satisfaction with Internet-delivered PCST (PainCOACH)	2.0 (1.7–2.3)	–

PCST = pain-coping skills training.
* Denominators for adverse events and medication use/co-interventions are the numbers of participants who provided data in each group. *P* values for continuous variables are based on *t* tests, and those for binary variables are based on chi-square tests.
† Data obtained at 3 mo.
‡ Data obtained at 6 and 9 mo.
§ Participants were asked how many times they had completed the exercises in the past 2 wk (maximum of 6).
‖ Participants were asked how many days they practiced PCST in the past 2 wk (maximum of 14).
¶ *n* = 70 for control group because 3 participants who did not provide data at 3 mo provided data during follow-up.
** An adverse event was defined as any problem from the treatment that lasted >2 d and/or caused the participant to take medication or seek other treatment.
†† Data obtained at 9 mo.
‡‡ Scale of 1 to 5; where 1 = very satisfied and 5 = very dissatisfied.

Appendix Table 4. Percentage of Participants Exceeding the MCID for Primary Outcomes of Change in Pain During Walking and Change in WOMAC Physical Function With Risk Differences for the Intervention Group Relative to the Control Group*

Variable	Participants Reaching MCID, %†		Risk Difference (95% CI), *percentage points*‡	*P* Value
	Intervention	Control		
MCID in pain during walking (NRS) (1.8 units of improvement)				
Month 3	73.0	39.4	33.8 (19.7–48.0)	<0.001
Month 9	67.3	50.6	17.0 (3.3–30.6)	0.015
MCID in physical function (WOMAC) (6 units of improvement)				
Month 3	80.5	39.4	40.0 (24.9–55.1)	<0.001
Month 9	76.4	48.9	26.5 (10.0–43.0)	0.002

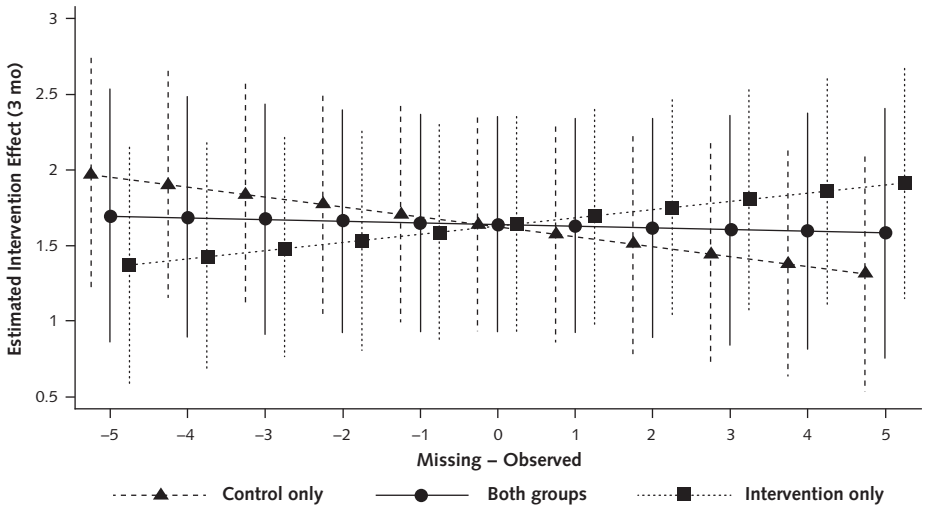
MCID = minimum clinically important difference; NRS = numerical rating scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.
* Adjusted for clustering of intervention participants within physiotherapists and stratifying variables of sex and geographic location for multiply imputed data.
† Averaged across 20 multiple imputation data sets.
‡ Values >0 favor the intervention group.

Appendix Table 5. Number of Participants Assigned to Each Physiotherapist With Mean Change Within Groups for Complete-Case Data for the Primary Outcomes*

Variable	Change Within Groups			
	Baseline – Month 3		Baseline – Month 9	
	Participants, *n*	Mean Change (95% CI)	Participants, *n*	Mean Change (95% CI)
Pain during walking (NRS)				
Physiotherapist 1	6	2.5 (1.4 to 3.6)	5	2.0 (–0.3 to 4.3)
Physiotherapist 2	11	2.7 (1.1 to 4.4)	11	3.1 (1.7 to 4.5)
Physiotherapist 3	8	1.8 (–0.3 to 3.8)	8	1.8 (–0.6 to 4.1)
Physiotherapist 4	8	3.8 (2.0 to 5.5)	8	3.1 (0.9 to 5.4)
Physiotherapist 5	10	2.5 (1.1 to 3.9)	10	2.9 (1.6 to 4.2)
Physiotherapist 6	9	2.7 (1.2 to 4.1)	8	2.6 (0.5 to 4.8)
Physiotherapist 7	9	3.0 (1.3 to 4.7)	9	2.8 (0.8 to 4.8)
Physiotherapist 8	6	3.3 (1.3 to 5.4)	5	1.6 (0.2 to 3.0)
Control participants	69	1.1 (0.7 to 1.6)	67	1.5 (0.9 to 2.1)
Physical function (WOMAC)				
Physiotherapist 1	6	19.5 (5.9 to 33.1)	5	17.0 (5.1 to 28.9)
Physiotherapist 2	11	15.5 (9.3 to 21.6)	11	17.7 (11.4 to 24.1)
Physiotherapist 3	8	12.8 (–0.3 to 25.8)	8	16.1 (4.7 to 27.5)
Physiotherapist 4	8	14.6 (5.2 to 24.1)	8	10.8 (–0.4 to 21.9)
Physiotherapist 5	10	13.6 (6.2 to 21.0)	10	14.4 (7.9 to 20.9)
Physiotherapist 6	9	13.9 (7.8 to 20.0)	8	14.1 (5.9 to 22.4)
Physiotherapist 7	9	14.8 (11.0 to 18.6)	9	12.4 (4.1 to 20.8)
Physiotherapist 8	6	16.3 (0.2 to 32.5)	5	10.8 (–1.6 to 23.2)
Control participants	69	5.0 (2.4 to 7.6)	67	6.9 (4.4 to 9.4)

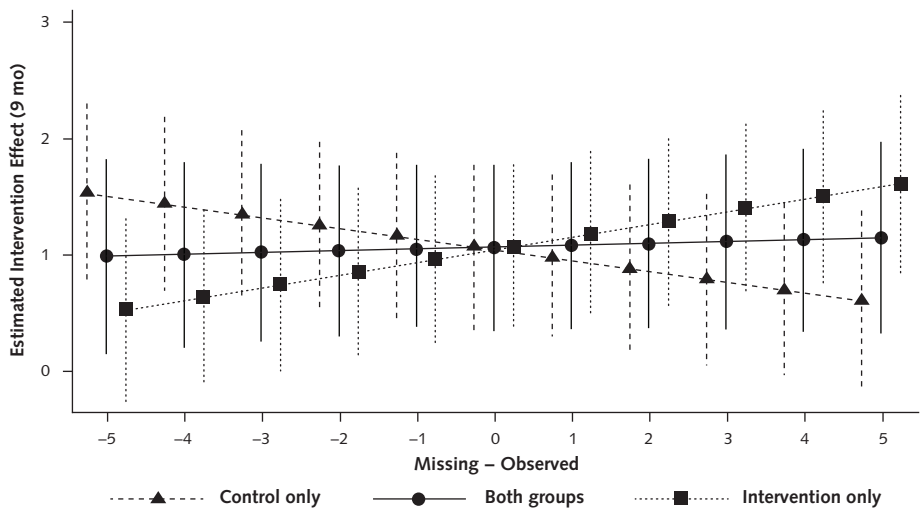
NRS = numerical rating scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.
* 3 participants assigned to the intervention group did not visit a physiotherapist; these participants have been included in the analyses assigned to their randomized group but have been excluded from this table.

Appendix Figure 1. Sensitivity analysis for pain during walking (measured with numerical rating scale) at 3 mo.



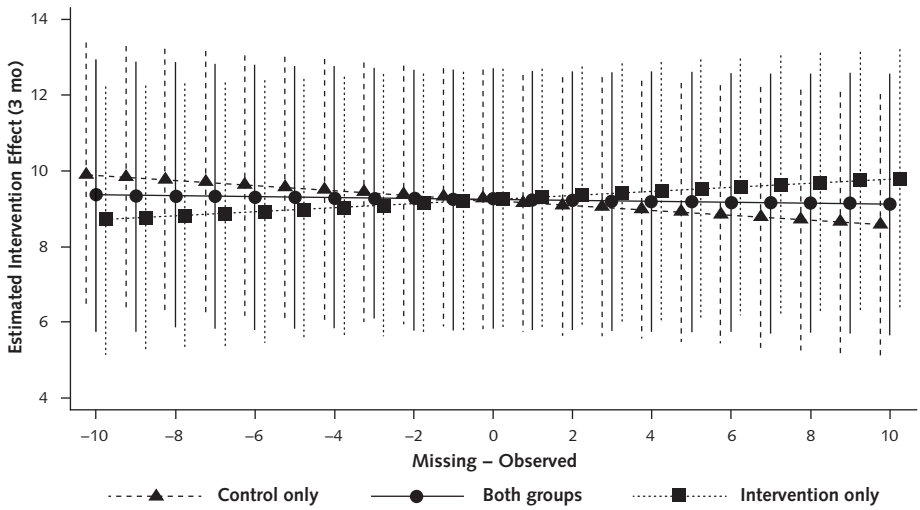
"Missing − Observed" quantifies the systematic difference in outcomes between nonresponders and responders. When Missing − Observed = 0, the results in Table 3, under the assumption that data are missing at random, are returned. Results for 3 scenarios are included. The "both groups" line indicates when deviations from the missing-at-random assumption are equal in the control and intervention groups. "Control only" assumes that the missing-at-random assumption is violated in the control group only. "Intervention only" assumes that the missing-at-random assumption is violated in the intervention group only.

Appendix Figure 2. Sensitivity analysis for pain during walking (measured with numerical rating scale) at 9 mo.



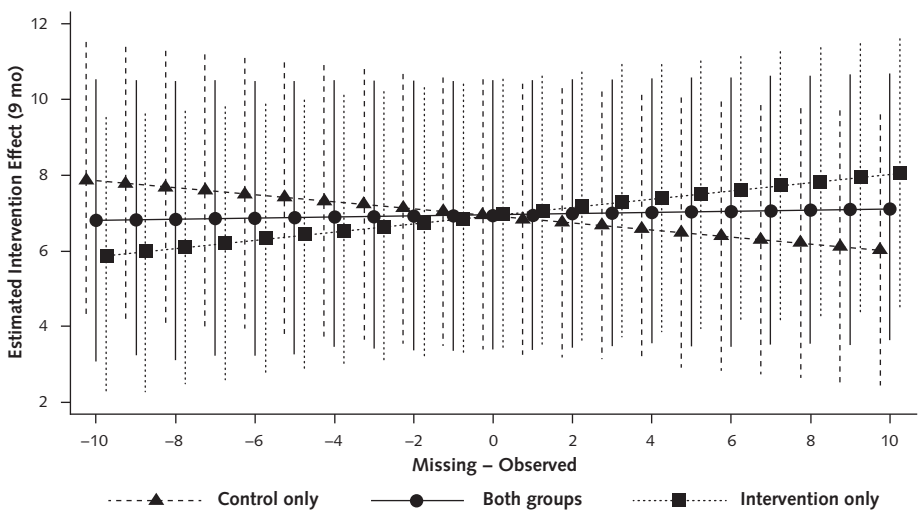
A description of the plot is provided in Appendix Figure 1.

Appendix Figure 3. Sensitivity analysis for Western Ontario and McMaster Universities Osteoarthritis Index physical function at 3 mo.



A description of the plot is provided in Appendix Figure 1.

Appendix Figure 4. Sensitivity analysis for Western Ontario and McMaster Universities Osteoarthritis Index physical function at 9 mo.



A description of the plot is provided in Appendix Figure 1.

Appendix Table 6. Percentage of Participants Reporting Global Improvement in the Intervention Group Relative to the Control Group for Multiply Imputed Data*

Variable	Month 3				Month 9			
	Intervention Participants (*n* = 74), %	Control Participants (*n* = 74), %	Risk Difference (95% CI), *percentage points*†	*P* Value	Intervention Participants (*n* = 74), %	Control Participants (*n* = 74), %	Risk Difference (95% CI), *percentage points*†	*P* Value
Improvement in pain	73.0	16.8	55.8 (40.9–70.6)	<0.001	41.5	23.0	18.3 (1.8–34.7)	0.030
Improvement in function	64.3	17.1	46.6 (30.0–62.9)	<0.001	38.3	21.8	15.9 (0.5–31.4)	0.044
Improvement overall	69.3	16.6	51.9 (36.0–67.8)	<0.001	43.4	22.9	19.9 (3.9–35.9)	0.015

* Averaged across 20 multiple imputation data sets.
† Values >0 favor the intervention; adjusted for sex and geographic location as well as clustering effects for physiotherapist. Improvement defined as "moderately better" or "much better" based on a 7-point Likert scale.

Appendix Table 7. Adjusted Mean Difference in Change Between Groups for Multiply Imputed Data: Sensitivity Analysis Including Symptom Duration and Educational Level

Outcome	Difference in Change Between Groups*			
	Baseline to Month 3 (95% CI)	*P* Value	Baseline to Month 9 (95% CI)	*P* Value
Primary				
Pain during walking (NRS)†‡	1.8 (1.1 to 2.5)	<0.001	1.2 (0.5 to 1.9)	<0.001
Physical function (WOMAC)†§	9.7 (6.4 to 13.0)	<0.001	7.4 (4.0 to 10.8)	<0.001
Secondary				
Knee pain (WOMAC)†‖	2.6 (1.6 to 3.6)	<0.001	1.7 (0.7 to 2.8)	<0.001
Quality of life (AQoL-2)¶**	−0.1 (−0.1 to 0)	0.013	−0.1 (−0.1 to 0)	0.010
Self-efficacy (ASES)¶††				
Pain	−2.0 (−2.6 to −1.3)	<0.001	−1.3 (−1.9 to −0.6)	<0.001
Function	−0.7 (−1.1 to −0.2)	0.006	−0.4 (−0.9 to 0.1)	0.111
Pain catastrophizing (PCS)†‡‡	0.7 (0.2 to 1.2)	0.003	0.6 (0 to 1.1)	0.033
Coping attempts (CSQ)¶§§	−5.1 (−12.4 to 2.3)	0.177	−11.3 (−18.6 to −3.9)	0.003

AQoL-2 = Assessment of Quality of Life, version 2; ASES = Arthritis Self-Efficacy Scale; CSQ = Coping Strategies Questionnaire; NRS = numerical rating scale; PCS = Pain Catastrophizing Scale; WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.
* Adjusted for baseline value of outcome, sex, geographic location, symptom duration, and educational level, as well as clustering effects for physiotherapist and measurements from the same participant.
† For change within groups, positive values indicate improvement. For differences in change between groups, positive values favor the intervention and negative values favor the control.
‡ Ranges from 0 to 10; lower scores indicate less pain.
§ Ranges from 0 to 68; lower scores indicate better function.
‖ Ranges from 0 to 20; lower scores indicate less pain.
¶ For change within groups, negative values indicate improvement. For differences in change between groups, negative values favor the intervention and positive values favor the control.
** Ranges from −0.04 to 1.00; higher scores indicate better quality of life.
†† Ranges from 1 to 10; higher scores indicate greater self-efficacy.
‡‡ Square-root transformation of outcome due to nonnormality of residuals. Results are interpreted in terms of increases on the square-root scale of the outcome; relative to the control group, the intervention group increases the square root of the outcome by the amount shown. Ranges from 0 to 52; higher scores indicate greater catastrophizing.
§§ Ranges from 0 to 163; higher scores indicate more frequent use of coping skills.

Appendix Table 8. Percentage of Participants Reporting Global Improvement in the Intervention Group Relative to the Control Group for Multiply Imputed Data: Sensitivity Analysis Including Symptom Duration and Educational Level*

Variable	Month 3		Month 9	
	Risk Difference (95% CI), %†	*P* Value	Risk Difference (95% CI), %†	*P* Value
Improvement in pain	58.8 (44.4–73.1)	<0.001	22.3 (6.6–37.9)	0.005
Improvement in function	50.3 (35.1–65.5)	<0.001	20.6 (5.8–35.3)	0.006
Improvement overall	55.3 (39.6–71.1)	<0.001	24.3 (9.1–39.4)	0.002

* Averaged across 20 multiple imputation data sets.
† Values >0 favor the intervention; adjusted for sex, geographic location, symptom duration, and educational level, as well as clustering effects for physiotherapist. Improvement defined as "moderately better" or "much better" based on 7-point Likert scale.