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Physical therapist-delivered pain coping skills training and exercise for knee osteoarthritis: randomized controlled trial

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ABSTRACT

Objective

To investigate whether a 12-week physical therapist-delivered combined pain coping skills training and exercise (PCST+EX) is more efficacious and cost-effective than either treatment alone for knee OA.

Methods

This was an assessor-blinded, 3-arm randomized controlled trial in 222 (73 PCST+EX, 75 EX, 74 PCST) people aged ≥50 years with knee OA. All participants received 10 treatments over 12 weeks plus a home program. PCST covered pain education and training in cognitive and behavioral pain coping skills. EX comprised strengthening exercises. PCST+EX integrated both. Primary outcomes were self-reported average knee pain (0-100mm visual analogue scale) and physical function (Western Ontario and McMaster Universities Osteoarthritis Index 0-68) at week 12. Secondary outcomes included other pain measures, global change, physical performance, psychological health, physical activity, quality-of-life and cost-effectiveness. Analyses were by intention-to-treat with multiple imputation for missing data.

Results

201 (91%), 181 (82%) and 186 (84%) completed week 12, 32 and 52 measurements, respectively. At week 12, there were no significant between-group differences for reductions in pain comparing PCST+EX versus EX (mean difference 5.8mm, 95%CI -1.4,13.0) and PCST+EX versus PCST (6.7mm, 95%CI -0.6,14.1). Significantly greater improvements in function were found for PCST+EX versus EX (3.7units, 95%CI 0.4,7.0) and PCST+EX versus PCST (7.9units, 95%CI 4.7,11.2). These differences persisted at weeks 32 (both) and

52 (PCST). Benefits favoring PCST+EX were seen on several secondary outcomes. Cost effectiveness of PCST+EX was not demonstrated.

Conclusion

This model-of-care could improve access to psychological treatment and augment patient outcomes from exercise in knee OA although it did not appear to be cost effective.

Key words: Exercise, psychological treatment, knee osteoarthritis, pain coping, physical therapy

Trial registration: Australia and New Zealand Clinical Trials Registry (www.anzctr.org.au/): ACTRN12610000533099.

SIGNIFICANCE AND INNOVATION

- Knee OA is a major public health problem. Our RCT investigated an intervention combining exercise and PCST delivered by physiotherapists for people with knee OA. The study was adequately powered to detect clinically relevant changes in pain and physical function in knee OA, involved rigorous physiotherapist training in PCST and extensive assessment of treatment fidelity, and included longer-term follow-up and a cost effectiveness analysis.
- The results showed that combined exercise and PCST treatment gave greater improvements in physical function, but not pain, compared to either treatment alone as well as benefits across a range of secondary measures that were often seen at longer-term follow-up. However, we found no evidence that combined treatment was cost-effective.
- Overall our results suggest that physiotherapist-delivered PCST and exercise warrants consideration as a novel biopsychosocial model of care for patients with chronic knee pain due to OA, particularly given the often limited access to psychological treatments.

Knee osteoarthritis (OA) is a prevalent chronic condition often causing pain, disability, psychological distress and reduced quality-of-life (1). Clinical guidelines emphasise patient self-management and recommend conservative non-pharmacological treatments, in particular strengthening exercise (2). Although exercise has well-established benefits for pain and physical function, effect sizes are small to moderate (3). Furthermore, exercise does not directly target psychological factors, such as reduced self-efficacy and pain catastrophizing, that contribute to patient morbidity (4, 5). A model-of-care combining psychological treatment with exercise is consistent with a biopsychosocial approach to chronic disease management and may offer greater benefits.

Evidence for psychological treatment for knee OA is limited and mostly pertains to pain coping skills training (PCST), a treatment derived from cognitive behavioral therapy, delivered by psychologists (6-12). While positive effects of PCST on psychological outcomes have been found, effects on pain and function are inconsistent. Two studies combining exercise and PCST, with treatments provided separately by exercise practitioners and psychologists, showed improvements over several outcomes in knee OA (8, 10). If instead, both treatments were delivered by a single practitioner, such as a physical therapist, there are potential advantages including better integration, greater access, and reduced health care costs. A recent study (13) showed a non-psychology practitioner could provide PCST with similar patients, but exercise was not included.

Following our feasibility trial, (14) our primary aim was to test the hypothesis that a 12-week physical therapist-delivered treatment combining PCST and exercise (PCST+EX) would lead to greater improvements in pain and physical function than either alone at 12 weeks. Several secondary outcomes, cost effectiveness and 52-week follow-up were also evaluated to address

additional hypotheses (eMethods). Moderators and mediators of the effects of treatment on pain and disability will be examined in a subsequent paper.

PATIENTS AND METHODS

Study design

We conducted a multi-site (Melbourne and Brisbane, Australia) assessor-blinded, parallel-group (1:1 allocation ratio) randomized controlled trial. Data were collected at the Departments of Physiotherapy, Universities of Melbourne and Queensland. The protocol is reported elsewhere (15). Institutional Human Ethics Committees approved the study. All participants provided written informed consent.

Participants

Community participants were recruited between May 2010 and January 2012, with follow-up completed January 2013. Inclusion criteria were: aged ≥ 50, knee OA fulfilling American College of Rheumatology criteria (pain on most days in the past month and radiographic changes) (16); knee pain for ≥ 3 months; average pain during previous week ≥ 40 on 100mm visual analogue scale (VAS), and; at least moderate difficulty with daily activities (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) physical function subscale ≥25/68 units). Exclusion criteria are listed in the eMethods. The most symptomatic knee at enrolment was evaluated in those with bilaterally eligible knees.

Randomisation and masking

After baseline assessment, participants were randomized in permuted blocks of 4 to 6 (using computer-generated random numbers table generated by A.F.), stratified by site and gender, to one of three treatment groups. Allocations were sealed in opaque consecutively numbered

envelopes by an independent person and stored in a locked location. A different independent person opened the next sequential envelope and informed the therapist of treatment allocation by email. We were unable to blind physical therapists while participants were blinded to study hypotheses. Blinded assessors collected strength and physical performance measures and entered questionnaire data.

Interventions

Participants attended 10 individual sessions with a physical therapist over 12 weeks. In line with clinical practice, sessions were 45 minutes for PCST, 25 minutes for EX and 70 minutes for PCST+EX. Participants also performed home-based practice during the study. Physical therapists telephoned participants at weeks 22, 38 and 46 to discuss progress and adherence to the home program.

PCST involved 10 physical therapist-delivered modules covering pain education and training in cognitive and behavioral pain coping skills (activity-rest cycling, pleasant activity scheduling, problem solving, identifying and challenging negative thoughts, developing coping thoughts, pleasant imagery, counting backwards, and auditory stimulation) and their application (7). Participants were asked to practice skills daily during the 12 weeks and then as needed during follow-up. EX comprised 6 exercises to strengthen the quadriceps, hamstrings and hip abductor muscles (15) performed 4 times weekly for 12 weeks and 3 times weekly thereafter. Weights and resistance elastic bands as well as exercise handouts were provided. PCST+EX integrated both treatments. This was facilitated by using exercise and physical activity examples as material for skills being taught and by encouraging participants to incorporate learned PCST skills into home exercises (eTables 1-2).

Physical therapist training and treatment fidelity

Physical therapists worked in private practice and had ≥ 5 years of musculoskeletal clinical experience. To avoid contamination, 11 physical therapists delivered PCST+EX and PCST treatments while 11 different physical therapists delivered EX (eTable 3). Relevant physical therapists underwent extensive PCST training by two psychologists per site (17). This involved an initial 4-day group workshop (F.J.K) followed by regular group tutorials, individual practice and formal accreditation (2 physical therapists undertook an initial 3 day workshop as it was conducted individually rather than in a group). All physical therapists undertook a 4-hour workshop for training in delivery of the exercise treatment. Physical therapist adherence to the PCST protocol and session quality were monitored by regular (approximately fortnightly) group meetings with a site-psychologist, and feedback from review of audio-recordings of PCST sessions. Physical therapist adherence to EX was monitored by random site visits. Treatment fidelity for PCST was assessed by psychologists formally rating randomly-selected audiotapes of 10% of sessions (17).

Outcome measures

At baseline, 12 and 52 weeks, participants were assessed at University sites by the same blinded assessors. Week 32 measures were collected via mailed questionnaires with adherence questionnaires also mailed at weeks 22 and 42.

Primary outcomes were two valid and reliable self-report measures recommended for OA clinical trials (18): i) Overall average knee pain intensity in the past week - rated using a 100mm horizontal VAS where 0mm='no pain' and 100mm='worst pain possible' (minimal clinically important difference (MCID) 18mm (19)); and ii) Physical function measured using the physical function subscale of the WOMAC (Likert version 3.1) (20) where 0='no

difficulty' and 68='extreme difficulty' (21) (MCID 6 units) (22). The primary time-point was week 12.

Secondary outcomes are described further in the protocol (15) and included: VAS average knee pain on walking in past week (19)); WOMAC pain subscale (21); Assessment of Quality of Life (AQoL-6D) (23); and Physical Activity Scale for the Elderly (24). Psychological measures included: total score of Arthritis Self-Efficacy Scale (25); Pain Catastrophizing Scale (26); Coping attempts score of Coping Strategies Questionnaire (27); and Depression, Anxiety and Stress 21 questionnaire (28). At weeks 12, 32 and 52, participants reported their global rating of change i) overall, ii) in pain and iii) in physical function using a 7-point ordinal scale (1='much worse' to 7='much better').

Maximum isometric quadriceps strength (Nm/kg) (15) and physical performance measures including 30-second sit-to-stand test (n) (29); 20 meter fast-paced walking velocity (m/sec); and step test (dynamic standing balance (n)) (30) were measured at baseline and weeks 12 and 52.

Participant treatment session attendance was recorded. Adherence, adverse events and co-interventions were recorded in a log-book during treatment and via questionnaire during follow-up. Health care costs and direct non-health care costs over the previous month were collected via a customised questionnaire at weeks 0, 4, 8, 12, 32 and 52.

Sample size

We aimed to detect a minimum clinically important difference in VAS pain of 18mm (19) and function of 6 non-normalized WOMAC units (31). Calculations were based on analysis of

covariance adjusting for baseline scores, assuming between-participant standard deviations of 30mm for pain and 12 units for function and pre-post correlations of 0.50 (32). The clustering of participants within physical therapists was accounted for assuming an intra-physical therapist correlation of 0.050 (32). Assuming physical therapists each treated on average 7 participants (clustering effect=1+6*0.050=1.30), 63 participants per arm were required. Assuming 10% dropout, the sample size was 70 per arm. Slight loss of power was expected due to imbalances in participant numbers per physical therapist; however with 11 physical therapists in PCST arms, any loss would be negated.

Statistical analysis

Analyses were performed by a blinded biostatistician using Stata (v12) software. We used intention-to-treat with missing data imputed using chained equations with predictive mean matching, imputing data for each arm separately. Estimates from 10 imputed datasets were combined using Rubin's rules. Testing was two-sided with a significance level of $p<0.05$. For each pairwise between-group comparison (PCST+EX versus EX (primary comparison); PCST+EX versus PCST; PCST versus EX), the mean (95% confidence interval) difference in change (baseline minus follow-up) was estimated using a linear mixed model. This model included random effects for physical therapists and baseline outcome score as a covariate, together with adjustment for stratification variables (site and gender). Global change ratings were *a priori* dichotomized as improved (those scoring 'much better' or 'moderately better') or not improved ('slightly better' to 'much worse') and compared between group-pairs using the modified Poisson regression approach, taking clustering by physiotherapists into account using generalized estimating equations, with results presented as relative risks (33). These analyses were also used to compare the proportion of participants reaching the MCID for the primary outcomes in each group.

Sensitivity analyses were performed including complete case analyses with all available data and analyses adjusting for further baseline variables of age, body mass index, symptomatic knee, education level, employment status, and co-morbidities.

Cost effectiveness evaluation

We estimated the incremental cost per quality-adjusted life years (QALYs) at week 52 (eMethods). Costs included therapy and other health care-related costs, but excluded initial fixed cost of physical therapist training and any impact on patient incomes, or travel/time costs. Analysis of costs and QALYs used mixed linear statistical models of baseline levels and treatment group with a random intercept for each physical therapist clustered by site. Quality-adjusted life years were estimated as the area under the curve of preference-based quality-of-life scores (AQoL) in the month prior to baseline, week 12, 32 and 52. Cost-effectiveness, using a societal perspective, was calculated, using recycled predictions of costs and QALYs, as the ratio of mean difference in cost to mean difference in between-group QALYs and compared to a range of critical values. To assist interpretation, the cost-effectiveness ratio (95% confidence intervals) were re-calculated as the mean net benefit for PCST+EX over individual treatments (equal to between-group difference in QALYs times assumed willingness to pay per QALY less cost difference) (34). In addition, analyses were repeated using a generalized linear model with appropriate distribution and link functions (chosen using modified Park (35) and Prebigon link (36) tests). Analyses were performed using Stata (v13) via intention-to-treat with multiple imputation for missing data.

RESULTS

Of 1082 volunteers, 860 (79%) were ineligible or did not wish to participate (Figure 1) and 222 were enrolled (111 per site). Treatment groups were similar at baseline (Table 1). Loss to follow-up was 21/222 (9%), 41/222 (18%) and 36/222 (16%) at weeks 12, 32 and 52 respectively, with rates comparable across groups. Those lost to follow-up had less severe radiographic disease and showed differences in some outcome measures at baseline (eTable 4).

Continuous outcomes at each time-point are summarized in Table 2 and changes between- and within-groups in Table 3. Following treatment, all groups showed large and clinically important improvements in primary outcomes and most secondary outcomes. Improvements were generally sustained to week 52.

For week 12 primary outcomes, there were no significant between-group differences for reductions in average pain (PCST+EX versus EX: mean difference 5.8mm, 95% CI -1.4, 13.0; PCST+EX versus PCST: 6.7mm, 95% CI -0.6, 14.1; PCST versus EX: -0.9mm, 95% CI -8.1, 6.3). However, a significantly greater proportion of participants in PCST+EX (83%) improved pain by ≥MCID of 18mm compared to EX (62%) (Relative risk 1.3, 95% CI 1.1, 1.6) and compared to PCST (60%) (Relative risk 1.4, 95% CI 1.2, 1.7). Significantly greater improvements in WOMAC function were found for PCST+EX compared with EX (mean difference 3.7 units, 95% CI 0.4, 7.0) and compared with PCST (7.9 units, 95% CI 4.7, 11.2) (Table 3, Figure 2). A significantly greater proportion of participants in PCST+EX improved pain by ≥MCID of 6 units (94%) compared with EX (80%) (Relative risk 1.2, 95% CI 1.0, 1.3) and with PCST (69%) (Relative risk 1.4, 95% CI 1.2, 1.6).

For week 12 secondary outcomes (Table 3), PCST+EX was significantly more efficacious than EX for walking pain and coping strategies and more efficacious than PCST for WOMAC

pain, self-efficacy, sit-to-stand and step test. EX was significantly more efficacious than PCST for WOMAC function and all physical performance measures but less efficacious for coping strategies. A greater proportion of participants in PCST+EX reported global improvements in function (80% versus 62%) and in pain (75% versus 55%) compared with PCST (Table 4).

At weeks 32 and/or 52, PCST+EX showed significantly greater improvements compared with: i) EX for WOMAC function, walking pain, self-efficacy, coping strategies, depression, anxiety, stress and quality-of-life and; ii) PCST for average pain, WOMAC function, WOMAC pain, self-efficacy, physical activity and quadriceps strength (Table 3). Comparing PCST with EX, improvements in coping strategies, depression and stress were greater with PCST while improvements in quadriceps strength and sit-to-stand were greater with EX.

No between-group differences were seen for any global change measure at week 32. A significantly greater proportion of participants in PCST+EX reported improvements overall and in pain and function compared to both other groups at week 52 (Table 4).

Results of sensitivity analyses using complete cases (eTables 5-6) as well as multiple imputation analyses adjusted for baseline characteristics (eTables 7-8) were generally similar.

Treatment costs per participant were AUD$439 for EX, $730 for PCST and $1065 for PCST+EX (eResults). PCST+EX did not lead to significant resource savings compared with EX (saving $717, 95% CI -3329, 1795) or PCST (saving $844, 95% CI -3325, 1638) (eTable 9). There was no significant difference in QALYs over 52 weeks for PCST+EX versus EX

(0.03 QALYs, 95%CI -0.01, 0.07) or versus PCST (0.03 QALYs, 95%CI -0.01, 0.06) or for PCST versus EX (0.01 QALYs, 95% CI -0.03, 0.04).

Adherence, adverse events and co-intervention details are found in eTable 10. Most participants attended all 10 physical therapy sessions with a mean (SD) number of 8.9 (2.5) for PCST+EX, 8.8 (2.7) for EX and 8.6 (2.7) for PCST. Home exercise adherence was higher in EX than in PCST+EX with the mean (SD) percentage of requested sessions performed being 84% (23%) versus 76% (29%) respectively (p=0.03) during the treatment phase, but was similar during follow-up. Adherence to home PCST practice was comparable between PCST+EX (mean (SD) percentage of requested sessions performed 69% (32%)) and PCST (77% (29%)) groups. A greater number of adverse events were reported by participants in both PCST+EX (n=31) and in EX (n=38) compared with PCST (n=7) (both p<0.01) during the treatment phase but the adverse events were mild mostly being transient increases in knee pain or pain in other regions. Few participants reported use of other treatments during the study and medication use was similar across groups (eTable 10).

Physical therapist adherence to treatment protocols and delivery quality were excellent based on blinded review of 74 randomly-selected sessions per site (eTable 11). In particular, the mean (SD) adherence to the PCST protocol by the physical therapists was 96% (4%) while delivery performance and higher-level communication skills were rated as 3.7 (0.4) and 3.6 (0.4) respectively on a 1 (poor) to 5 (excellent) scale.

DISCUSSION

Based on the primary outcomes, our results showed that a physical therapist-delivered combined psychological and exercise intervention was significantly more efficacious for

improving physical function, but not pain, than either treatment alone for knee OA. Greater improvement with combined treatment was also evident for several secondary outcomes, spanning pain, physical and psychological domains. However, cost-effectiveness was not demonstrated. Taken together, the results provide evidence for the benefits of combined treatment.

The finding of significantly greater improvement in WOMAC physical function with combined treatment supports our primary hypothesis. Effect sizes (calculated with SDs of 9.5 for PCST+EX, 10.9 for EX and 10.6 for PCST) for combined treatment were moderate when compared with exercise alone (cohen's d 0.41) and large when compared with PCST alone (cohen's d 0.82) at week 12, with effects persisting during follow-up. The benefits are likely due to combined treatment targeting a greater range of physical and psychological factors linked to better function in knee OA (37). Improved physical function is clinically important because functional activities are key components of the International Classification of Functioning, Disability and Health OA core set (38), patients rate improvement in function as one of their most important treatment outcomes alongside pain reduction (39), and patients who report better function are less likely to undergo knee joint replacement (40). Furthermore, improving physical function may have an indirect effect on work disability as it mediates the relationship between pain and work productivity loss (41).

Contrary to our hypothesis, combined treatment did not confer significantly greater pain reduction than the other treatments alone, based on the primary pain outcome at week 12. In the face of additional benefits with combined treatment for physical function, this may seem somewhat paradoxical given that PCST involves training in pain coping. However, PCST can provide patients with strategies to better accept and tolerate pain, thereby giving them the

confidence to exercise and increase their functional ability despite no additional pain effect. Nonetheless, a significantly greater number of participants receiving combined treatment achieved reductions in the primary pain outcome that exceeded the minimal clinically important difference, and greater improvements were seen on other secondary pain outcomes across all time points. Thus, the results suggest that enhanced pain relief with combined treatment may be possible.

The results of our cost effectiveness analysis suggest that combined treatment has a higher cost of delivery, due to longer treatment sessions, that is not offset by significant savings in other health resource use. Although we observed improved quality-of-life and overall cost savings with combined treatment compared to either treatment alone, these were non-significant. Consequently, there were no significant positive net benefits from combined treatment and we cannot be confident that it represents value for money, based on cost and quality-of-life, compared to either treatment alone over 12-months. It should be acknowledged however, that the sample size was determined by clinical outcomes. The planned cost effectiveness analysis had 85% power to detect a net benefit of AUD$5000 with a critical threshold of $60,000 (eMethods). In fact the trial showed a cost saving from combined treatment but a smaller gain in QALYs such that the mean net benefit of $2,600 was not statistically significant. It is possible that a future trial with a larger sample size and/or longer duration could have the power to demonstrate a significant net benefit from combined treatment, particularly if it helps avoid costly surgical or other invasive interventions.

All groups showed large clinically relevant improvements (Figure 2) in the primary outcomes of VAS pain (42-54%) and WOMAC physical function (32-55%), as well as in many

secondary outcomes at week 12, which were generally sustained to week 52. Consistent with treatment targets and content, exercise effects were more apparent for physical outcomes, PCST effects were more apparent for psychological outcomes while effects with combined treatment were apparent across a range of outcomes. In particular, the combined group improved their use of coping strategies at all time points and to a greater extent than the exercise group where changes in this outcome were not evident. The extent to which improvements can be explained by the interventions and/or by other factors, such as spontaneous recovery or regression to the mean, cannot be determined as we did not include a 'no treatment' control group. However, minimal changes over time are seen in such control groups in other studies (3) suggesting that the improvements we observed are at least partly related to the interventions.

There are a limited number of studies investigating psychological interventions in knee OA (6-13) and few combined with exercise (8, 10). In one, PCST and weight management (including exercise) was more effective for pain and disability than either treatment alone (10), while in another, spouse-assisted group PCST and exercise improved psychological measures, strength and fitness but not pain (8). In both studies, PCST was delivered by a psychologist while a separate health professional delivered exercise. Given lack of access to psychologists, particularly ones specializing in pain management, there is interest in extending the scope of practice of other health professionals (42). Recently, nurse-delivered PCST led to a small but significant reduction in pain compared with usual care in knee OA (13). Using physical therapists to deliver a psychological intervention can facilitate its integration with exercise given their pre-existing skills in exercise prescription. This was found in another study where a community rehabilitation program combining exercise,

education and active coping strategies (ESCAPE-knee pain) was more effective and cost-effective than usual care in the short- (43, 44) and longer-term (45).

A major strength of our study was rigorous physical therapist training and comprehensive assessment of treatment fidelity (17). Physical therapist adherence and delivery competence were excellent. Contributing factors included motivated physical therapists, a lengthy accreditation process and ongoing training and monitoring of physical therapists by psychologists specializing in PCST. Other strengths were a sufficient level of pain and physical dysfunction to allow scope for improvement, comparable groups at baseline, outcomes covering a range of domains, economic analyses, longer-term follow-up, good participant retention and adherence, and a multisite trial using multiple physical therapists to enhance generalizability.

Our study has limitations. Participant and physical therapist blinding was not possible, but performance bias was minimized by blinding participants to hypotheses, and contamination prevented by using different physical therapists to deliver the exercise alone intervention. The effect of different physical therapists on treatment outcomes was controlled for statistically and also accounted for in the sample size calculation. We lost 17% of participants to week 52 follow-up, and those who withdrew differed on some baseline characteristics to those completing; however, this was accounted for with multiple imputation and results were similar when presented as complete cases and adjusted for baseline factors. To ensure the interventions reflected real-world, the contact time differed between interventions and as such it is unclear to what extent this explained the outcomes. Our results cannot necessarily be generalised to physical therapists undergoing less rigorous PCST training or to other health professional groups, to different psychological interventions, to group-based programs or to

participants with milder symptoms or more severe psychopathology.

In conclusion, our results suggest that an exercise intervention has a better functional outcome if the physical therapist has additional competencies in terms of ability to elicit pain coping skills in the patient. However, the treatment did not appear to be cost effective. This biopsychosocial management approach using a non-psychologist to deliver PCST combined with exercise could improve the limited access to psychological treatment with subsequent patient benefits.

Author's contributions

KB and FK conceived the project and KB coordinated the trial. KB, FK, GJ, CB, AF, MH, JAK, MN and AH developed the protocol and procured the project funding. TE and BM assisted with establishing the procedures, recruiting the physical therapists and producing the study manuals. YA was responsible for project management across both sites. FK designed the pain coping skills training program and FK, CB and JAK trained the physical therapists in this aspect and oversaw accreditation and ongoing supervision. KB and GJ designed the exercise treatment and KB, GJ and YA trained the physical therapists in this aspect. KB and GJ graded the x-rays. BM and TE performed the blinded outcome assessments. AF performed the sample size calculations and designed the statistical analyses. MA, AF and JK performed the statistical analyses. AH oversaw collection of health care usage data and performed the cost-effectiveness analysis. YA recruited and screened participants and performed blinded data entry. KB wrote the first and final drafts of the manuscript. All authors provided feedback on drafts of this paper and read and approved the final manuscript.

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The study sponsor had no role in: the design and conduct of the study; collection, management, analysis, and interpretation of the data; and preparation, review or approval of the manuscript; and decision to submit the manuscript for publication.

KLB had full access to all the data in the study and takes full responsibility for the integrity of the data and the accuracy of the data analysis.

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Table 1: Baseline characteristics by group presented as mean (standard deviation) or number (%) unless otherwise stated

Characteristic	EX n=75	PCST n=74	PCST+EX n=73
Age (years)	62.7 (7.9)	63.0 (7.9)	64.6 (8.3)
Gender - Female	44 (59%)	45 (61%)	44 (60%)
Height (cm)	167.2 (9.9)	168.2 (9.1)	167.6 (9.0)
Body mass (kg)	88.3 (19.1)	86.9 (20.0)	87.6 (16.1)
Body mass index (kg/m^2)	31.5 (5.9)	30.8 (6.4)	31.0 (6.0)
Symptom duration (years) ¥	6 (3-10)	5.5 (4-10)	5.5 (2-10)
Unilateral symptoms	18 (24%)	19 (26%)	23 (32%)
Level of education, n (%)‡			
Less than 3 years of high school	4 (5%)	10 (14%)	4 (6%)
Three or more years of high school	24 (32%)	20 (27%)	25 (34%)
Tertiary and post-graduate	46 (62%)	44 (59%)	44 (61%)
Employment status, n (%)‡			
Currently employed	39 (52%)	37 (50%)	37 (51%)
Unable to work due to health reasons	9 (12%)	3 (4%)	4 (6%)
Retired (not due to health reasons)	23 (31%)	29 (39%)	25 (34%)
Not employed	3 (4%)	5 (7%)	7 (10%)
Co-morbidities – current/past, n (%)‡			
Heart disease/hypertension	31 (41%)	28 (38%)	31 (43%)
Osteoporosis/osteopenia	8 (11%)	10 (14%)	11 (15%)
Depression ø	6 (8%)	7 (10%)	15 (21%)
Stomach ulcer/pains	10 (13%)	8 (11%)	6 (8%)
Cancer	3 (4%)	9 (12%)	8 (11%)
Radiographic disease severity, n (%)†			
Grade 2	30 (40%)	33 (45%)	27 (37%)
Grade 3	19 (25%)	21 (28%)	23 (32%)
Grade 4	26 (35%)	20 (27%)	23 (32%)
Medication use, n (%)††			
Any medication use	54 (72%)	57 (77%)	51 (70%)

Analgesia (paracetamol combinations)	35 (47%)	36 (49%)	36 (49%)
Non-steroidal anti-inflammatories	16 (21%)	14 (19%)	17 (23%)
COX-2 inhibitors	3 (4%)	3 (4%)	4 (6%)
Topical NSAIDs	7 (10%)	9 (12%)	12 (16%)
Opioids	1 (1%)	3 (4%)	2 (3%)
Glucosamine/chondroitin products	35 (47%)	28 (38%)	26 (36%)
Oral corticosteroids	1 (1%)	0 (0%)	0 (0%)

‡ n=74 for EX group, one participant missing. ¥ median and interquartile range

† using Kellgren and Lawrence grading system where Grade 2= definitive osteophytes with possible narrowing of joint space; Grade 3= Moderate multiple osteophytes, definite narrowing of joint space and some sclerosis and possible deformity of bone ends; Grade 4= Large osteophytes, marked narrowing of joint space, severe sclerosis and definite deformity of bone ends

ø no participant had current doctor-diagnosed depression as this was an exclusion criteria

†† current medication or supplement use defined as at least once per week

Table 2. Mean (standard deviation) unadjusted scores on outcome measures over time according to group

	Groups											
	Week 0			Week 12			Week 32			Week 52		
Primary outcomes	**EX**	**PCST**	**PCST+EX**	**EX**	**PCST**	**PCST+EX**	**EX**	**PCST**	**PCST+EX**	**EX**	**PCST**	**PCST+EX**
	n=75	**n=74**	**n=73**	**n=67**	**n=66**	**n=68**	**n=61**	**n=60**	**n=60**	**n=61**	**n=61**	**n=64**
VAS overall pain §	59.1 (12.4)	58.7 (12.6)	58.4 (12.8)	31.8 (22.3)	33.2 (22.3)	26.4 (18.4)	36.0 (24.6)	35.7 (23.9)	28.2 (21.6)	34.5 (23.8)	34.8 (21.2)	31.7 (22.6)
WOMAC function §	34.3 (7.2)	35.0 (7.4)	35.6 (7.3)	19.2 (10.1)	23.5 (10.6)	15.4 (9.2)	21.4 (12.0)	23.4 (12.2)	17.5 (10.8)	18.1 (11.2)	21.3 (9.8)	16.0 (10.3)
Secondary outcomes												
VAS walking pain §	60.9 (17.1)	61.3 (17.3)	61.3 (17.5)	34.7 (23.7)	34.7 (24.0)	26.5 (18.1)	42.3 (26.0)	39.1 (25.2)	33.0 (24.4)	37.5 (26.2)	37.3 (23.3)	32.4 (24.1)
WOMAC pain §	8.6 (2.7)	8.7 (2.8)	9.0 (2.8)	5.2 (2.5)	6.0 (3.0)	4.5 (2.9)	6.3 (3.3)	6.2 (3.0)	5.3 (3.3)	5.4 (3.4)	5.8 (3.0)	5.2 (3.3)
Self Efficacy (ASES) ^	20.5 (4.1)	19.9 (4.9)	20.7 (3.8)	24.3 (3.9)	23.4 (4.0)	25.7 (3.5)	22.1 (5.0)	23.2 (3.6)	25.4 (3.5)	23.8 (4.0)	23.6 (3.8)	25.4 (3.2)
Pain coping (CSQ) ^	63.6 (26.3)	69.5 (23.7)	65.8 (25.7)	59.9 (29.6)	82.9 (26.2)	82.8 (27.0)	59.2 (24.4)	78.5 (24.8)	80.1 (26.6)	62.5 (26.0)	79.7 (25.9)	81.4 (26.3)
Catastrophizing (PCS)§	14.9 (8.1)	14.8 (9.3)	14.4 (9.7)	8.7 (8.5)	8.7 (7.5)	7.4 (7.5)	10.2 (9.2)	8.6 (7.2)	7.2 (7.1)	8.4 (7.8)	7.0 (6.6)	6.0 (6.7)
DASS-21 Depression §	5.7 (7.1)	6.4 (8.5)	5.4 (7.2)	4.6 (6.5)	4.9 (6.6)	4.0 (6.4)	5.5 (8.4)	4.3 (7.0)	3.0 (4.7)	4.9 (7.5)	3.5 (4.3)	3.6 (4.7)
DASS-21 Anxiety §	5.4 (6.5)	6.5 (6.5)	5.2 (5.2)	4.2 (5.0)	4.1 (5.9)	3.9 (5.4)	4.9 (6.9)	4.0 (4.3)	3.5 (4.6)	4.6 (6.0)	3.0 (3.4)	2.7 (3.3)
DASS-21 Stress §	9.4 (9.3)	9.4 (9.3)	8.5 (7.5)	7.8 (8.9)	8.4 (8.4)	7.6 (8.7)	9.3 (10.4)	7.5 (8.2)	6.8 (7.7)	8.5 (8.4)	5.6 (5.9)	6.0 (4.8)
AQoL-6D ^	0.71 (0.14)	0.71 (0.16)	0.74 (0.12)	0.78 (0.17)	0.78 (0.15)	0.80 (0.15)	0.76 (0.15)	0.79 (0.16)	0.84 (0.12)	0.78 (0.16)	0.81 (0.12)	0.84 (0.13)
PASE ^	151 (74)	144 (71)	150 (76)	172 (83)	156 (71)	179 (103)	163 (77)	148 (92)	190 (72)	180 (87)	164 (78)	188 (75)
Quadriceps strength ^	1.13 (0.49)	1.00 (0.45)	0.99 (0.43)	1.28 (0.52)	1.08 (0.49)	1.13 (0.48)	N/A	N/A	N/A	1.34 (0.52)	1.10 (0.44)	1.23 (0.44)
Timed up & go §	10.0 (2.2)	10.4 (3.1)	10.0 (2.3)	8.6 (2.4)	9.8 (2.8)	8.7 (2.3)	N/A	N/A	N/A	8.7 (1.7)	9.8 (2.5)	8.7 (1.6)
30-sec sit-to-stand ^	9.0 (2.6)	8.2 (3.0)	8.8 (2.4)	11.1 (3.0)	9.0 (3.3)	10.6 (3.0)	N/A	N/A	N/A	11.6 (2.8)	9.6 (3.5)	11.1 (2.3)
20m walk ^	1.54 (0.35)	1.51 (0.30)	1.53 (0.32)	1.73 (0.34)	1.58 (0.33)	1.68 (0.34)	N/A	N/A	N/A	1.74 (0.37)	1.63 (0.39)	1.78 (0.36)

Step test ^	9.9 (3.9)	8.8 (3.4)	8.6 (2.4)	12.2 (5.3)	9.6 (4.4)	11.1 (5.0)	N/A	N/A	N/A	12.5 (6.6)	10.6 (5.4)	11.7 (5.6)

VAS=Visual Analogue Scale (0-100); WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, physical function (0-68), pain (0-20); ASES=Arthritis Self-Efficacy Scale (3-30); CSQ=Coping Strategies Questionnaire (0-163); PCS=Pain Catastrophizing Scale (0-52) DASS-21=Depression, Anxiety & Stress Subscales (0-42); AQoL-6D=Assessment of Quality of Life Version 2, (-0.04-1.0); PASE=Physical Activity Scale for the Elderly (0->400); Quadriceps strength (Newton*meters/kilograms); Timed up and go (sec); 30-sec sit-to-stand (n); 20m walk (meters/second); Step test (n); N/A=not assessed at this time point

§ Lower scores = better ^ Higher scores = better

Table 3: Mean (standard error) changes within groups and adjusted mean (95% confidence interval) difference in change between-groups for continuous primary and secondary outcome measures using multiple imputation for missing data. Primary time point and primary comparisons are bolded.

Primary outcomes	Timeframe	Change within groups			Difference in change between-groups ‡		
		EX	PCST	PCST+EX	PCST+EX vs EX	PCST+EX vs PCST	PCST vs EX
VAS overall pain†	**Week 0-12**	26.0 (2.9) ¥	24.9 (2.6) ¥	31.4 (2.5) ¥	**5.8 (-1.4, 13.0)**	6.7 (-0.6, 14.1)	-0.9 (-8.1, 6.3)
	Week 0-32	21.7 (3.3) ¥	22.3 (3.2) ¥	30.6 (2.9) ¥	9.4 (1.0, 17.9) *	8.4 (0.3, 16.6) *	1.0 (-7.0, 9.0)
	Week 0-52	24.1 (3.2) ¥	23.9 (2.9) ¥	26.3 (2.8) ¥	2.8 (-5.2, 10.7)	2.6 (-5.2, 10.4)	0.2 (-8.2, 8.5)
WOMAC function†	**Week 0-12**	15.3 (1.3) ¥	11.3 (1.3) ¥	19.6 (1.1) ¥	**3.7 (0.4, 7.0)** *	7.9 (4.7, 11.2) ¥	-4.2 (-7.6, -0.9) *
	Week 0-32	12.5 (1.6) ¥	10.7 (1.7) ¥	17.6 (1.4) ¥	4.4 (0.2, 8.7) *	6.6 (2.3, 10.8) œ	-2.1 (-6.4, 2.1)
	Week 0-52	15.3 (1.6) ¥	13.1 (1.5) ¥	18.9 (1.3) ¥	2.8 (-1.0, 6.6)	5.5 (1.6, 9.3) œ	-2.7 (-6.9, 1.5)
Secondary outcomes							
VAS walking pain†	Week 0-12	25.4 (3.2) ¥	26.5 (3.0) ¥	33.7 (2.5) ¥	8.1 (0.2, 16.0) *	7.2 (-0.2, 14.7)	0.9 (-6.8, 8.5)
	Week 0-32	17.4 (3.7) ¥	23.5 (3.4) ¥	28.2 (3.2) ¥	10.6 (1.2, 20.0) *	4.5 (-4.8, 13.8)	6.1 (-3.2, 15.3)
	Week 0-52	22.2 (3.7) ¥	24.2 (2.8) ¥	27.5 (2.9) ¥	5.1 (-3.1, 13.4)	3.3 (-4.8, 11.4)	1.8 (-6.3, 9.9)
WOMAC pain†	Week 0-12	3.4 (0.4) ¥	2.6 (0.5) ¥	4.3 (0.4) ¥	0.7 (-0.3, 1.6)	1.5 (0.5, 2.5) œ	-0.9 (-1.9, 0.1)
	Week 0-32	2.4 (0.4) ¥	2.3 (0.5) ¥	3.7 (0.4) ¥	1.1 (0.0, 2.2)	1.2 (0.1, 2.4) *	-0.1 (-1.3, 1.1)
	Week 0-52	3.3 (0.5) ¥	3.0 (0.5) ¥	3.5 (0.5) ¥	0.0 (-1.3, 1.3)	0.3 (-1.0, 1.5)	-0.3 (-1.6, 1.1)
Self Efficacy (ASES) ^	Week 0-12	-3.8 (0.5) ¥	-3.1 (0.6) ¥	-4.8 (0.4) ¥	-1.1 (-2.3, 0.1)	-2.0 (-3.2, -0.7) œ	0.9 (-0.4, 2.1)
	Week 0-32	-1.7 (0.7) *	-3.0 (0.6) ¥	-4.5 (0.6) ¥	-3.0 (-4.5, -1.5) ¥	-1.9 (-3.4, -0.3) *	-1.2 (-2.8, 0.4)
	Week 0-52	-2.9 (0.7) ¥	-3.1 (0.7) ¥	-4.5 (0.5) ¥	-1.7 (-3.1, -0.3) *	-1.7 (-3.3, -0.2) *	0.1 (-1.4, 1.5)
Pain Coping (CSQ) ^	Week 0-12	0.1 (0.1)	-0.2 (0.0) ¥	-0.3 (0.0) ¥	-0.3 (-0.5, -0.2) ¥	0.0 (-0.2, 0.1)	-0.3 (-0.4, -0.2) ¥
	Week 0-32	0.2 (0.1)	-0.1 (0.1)	-0.2 (0.1) œ	-0.4 (-0.6, -0.2) ¥	0.0 (-0.2, 0.1)	-0.3 (-0.5, -0.2) ¥
	Week 0-52	0.0 (0.1)	-0.1 (0.0)	-0.2 (0.1) ¥	-0.3 (-0.5, -0.1) ¥	0.0 (-0.2, 0.1)	-0.3 (-0.4, -0.1) œ

Catastrophizing	Week 0-12	0.6 (0.1) ¥	0.7 (0.1) ¥	0.8 (0.1) ¥	0.2 (-0.2, 0.5)	0.1 (-0.3, 0.4)	0.1 (-0.2, 0.4)
(PCS) †	Week 0-32	0.5 (0.1) œ	0.6 (0.2) œ	0.6 (0.2) œ	0.2 (-0.3, 0.7)	0.1 (-0.4, 0.7)	0.1 (-0.4, 0.5)
	Week 0-52	0.6 (0.3)	0.9 (0.1) ¥	0.7 (0.2) œ	0.2 (-0.5, 0.9)	-0.1 (-0.6, 0.4)	0.3 (-0.3, 0.9)
DASS21 Depression †	Week 0-12	0.9 (0.8)	1.2 (0.9)	1.0 (0.6)	0.2 (-1.7, 2.1)	0.2 (-1.6, 1.9)	0.0 (-1.8, 1.9)
	Week 0-32	-1.0 (1.2)	-0.1 (1.1)	1.7 (1.0)	2.8 (0.1, 5.6) *	2.3 (-0.5, 5.1)	0.5 (-2.8, 3.8)
	Week 0-52	-0.4 (0.9)	2.3 (0.9) *	1.1 (0.8)	1.7 (-0.3, 3.7)	-0.6 (-2.5, 1.4)	2.2 (0.2, 4.3) *
DASS21 Anxiety †	Week 0-12	1.1 (0.5) *	1.8 (0.6) œ	1.0 (0.6)	0.0 (-1.5, 1.5)	-0.4 (-1.8, 1.0)	0.4 (-1.0, 1.8)
	Week 0-32	-0.6 (0.9)	1.8 (1.0)	0.9 (0.9)	1.8 (-0.4, 4.0)	-0.2 (-2.8, 2.5)	2.0 (-0.4, 4.3)
	Week 0-52	0.0 (1.1)	2.7 (0.7) œ	1.8 (0.6) œ	2.1 (0.0, 4.1) *	0.0 (-1.8, 1.8)	2.0 (-0.3, 4.4)
DASS21 Stress †	Week 0-12	1.3 (1.0)	0.8 (0.9)	0.6 (0.8)	-0.4 (-2.8, 2.0)	0.1 (-2.3, 2.4)	-0.5 (-2.7, 1.8)
	Week 0-32	-1.7 (1.3)	-0.6 (1.2)	0.0 (1.2)	1.9 (-1.6, 5.4)	0.9 (-2.5, 4.3)	1.1 (-2.2, 4.3)
	Week 0-52	-0.9 (1.5)	3.2 (1.1) œ	2.1 (0.8) *	3.7 (0.7, 6.7) *	-0.5 (-2.8, 1.9)	4.1 (1.1, 7.2) œ
AQoL-6D ^	Week 0-12	-0.1 (0.0) œ	-0.1 (0.0) ¥	-0.1 (0.0) ¥	0.0 (-0.1, 0.0)	0.0 (0.0, 0.0)	0.0 (-0.1, 0.0)
	Week 0-32	0.0 (0.0)	-0.1 (0.0)	-0.1 (0.0) ¥	-0.1 (-0.1, 0.0) œ	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.0)
	Week 0-52	0.0 (0.0)	-0.1 (0.0) œ	-0.1 (0.0) ¥	-0.1 (-0.1, 0.0) *	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.0)
PASE ^	Week 0-12	-17.8 (8.6) *	-16.6 (8.6)	-30.0 (10.3) œ	-12.2 (-36.5, 12.1)	-15.4 (-39.7, 8.9)	3.2 (-21.3, 27.7)
	Week 0-32	-15.0 (11.5)	-1.6 (15.9)	-37.6 (10.6) œ	-22.0 (-48.7, 4.6)	-39.6 (-72.4, -6.9) *	17.6 (-14.7, 49.8)
	Week 0-52	-27.1 (11.4) *	-20.8 (11.5)	-36.6 (9.1) ¥	-8.8 (-35.8, 18.2)	-18.4 (-45.8, 8.9)	9.6 (-21.3, 40.6)
Quadriceps strength ^	Week 0-12	-0.1 (0.1) œ	-0.1 (0.0) *	-0.1 (0.0) œ	0.0 (-0.1, 0.2)	0.0 (-0.2, 0.1)	0.1 (-0.1, 0.2)
	Week 0-52	-0.2 (0.1) œ	-0.1 (0.1)	-0.3 (0.1) ¥	0.0 (-0.2, 0.3)	-0.2 (-0.4, 0.0) *	0.2 (0.0, 0.4) *
30-sec sit-to-stand ^	Week 0-12	-2.1 (0.3) ¥	-0.7 (0.3) *	-1.7 (0.3) ¥	0.4 (-0.5, 1.3)	-1.1 (-2.0, -0.2) *	1.5 (0.6, 2.4) œ
	Week 0-52	-2.7 (0.4) ¥	-1.5 (0.5)	-2.2 (0.3) ¥	0.6 (-0.4, 1.5)	-0.9 (-2.2, 0.3)	1.5 (0.2, 2.8) *
20m walk ^	Week 0-12	-0.2 (0.0) ¥	-0.1 (0.0)	-0.1 (0.0) ¥	0.1 (0.0, 0.2)	0.0 (-0.1, 0.0)	0.1 (0.0, 0.2) œ

	Week 0-52	-0.2 (0.1) ¥	-0.2 (0.0) ¥	-0.2 (0.0) ¥	0.0 (-0.1, 0.1)	0.0 (-0.2, 0.1)	0.1 (-0.1, 0.2)
Step test ^	Week 0-12	-2.2 (0.4) ¥	-0.7 (0.3) *	-2.1 (0.6) ¥	0.4 (-0.7, 1.6)	-1.5 (-2.7, -0.3) *	1.9 (0.8, 3.0) œ
	Week 0-52	-2.4 (0.5) ¥	-1.8 (0.5)	-2.6 (0.6) ¥	0.2 (-1.3, 1.6)	-1.0 (-2.4, 0.3)	1.2 (-0.4, 2.7)

† For change within groups, positive change means improvement. For difference in change between-groups, positive difference favours the first named group in the pairwise comparison while a negative difference favours the second named group.

^ For change within groups, negative change means improvement. For difference in change between-groups, negative difference in change between-groups favours the first named group in the pairwise comparison while a positive difference favours the second named group.

*p<0.05; œ p<0.01; ¥ p<0.001 ‡ adjusted for gender, site, baseline value, and random effects for physiotherapist

VAS=Visual Analogue Scale (0-100); WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, physical function (0-68), pain (0-20); ASES=Arthritis Self-Efficacy Scale (3-30); CSQ=Coping Strategies Questionnaire (0-163); PCS=Pain Catastrophizing Scale (0-52) DASS-21=Depression, Anxiety & Stress Subscales (0-42); AQoL-6D=Assessment of Quality of Life Version 2, (-0.04-1.0); PASE=Physical Activity Scale for the Elderly (0->400); Quadriceps strength measure (Newton*meters/kilograms); Timed up and go (sec); 30-sec sit-to-stand (n); 20m walk (meters/second); Step test (n). Note: Analyses for CSQ and PCS outcome measures were performed on a logarithmically transformed outcome scale as assumptions of normality were violated.

Table 4: Number (percentage) of participants reporting improvement overall, and with respect to pain and physical function at different time points together with relative risks (95% confidence intervals) for comparisons between groups.

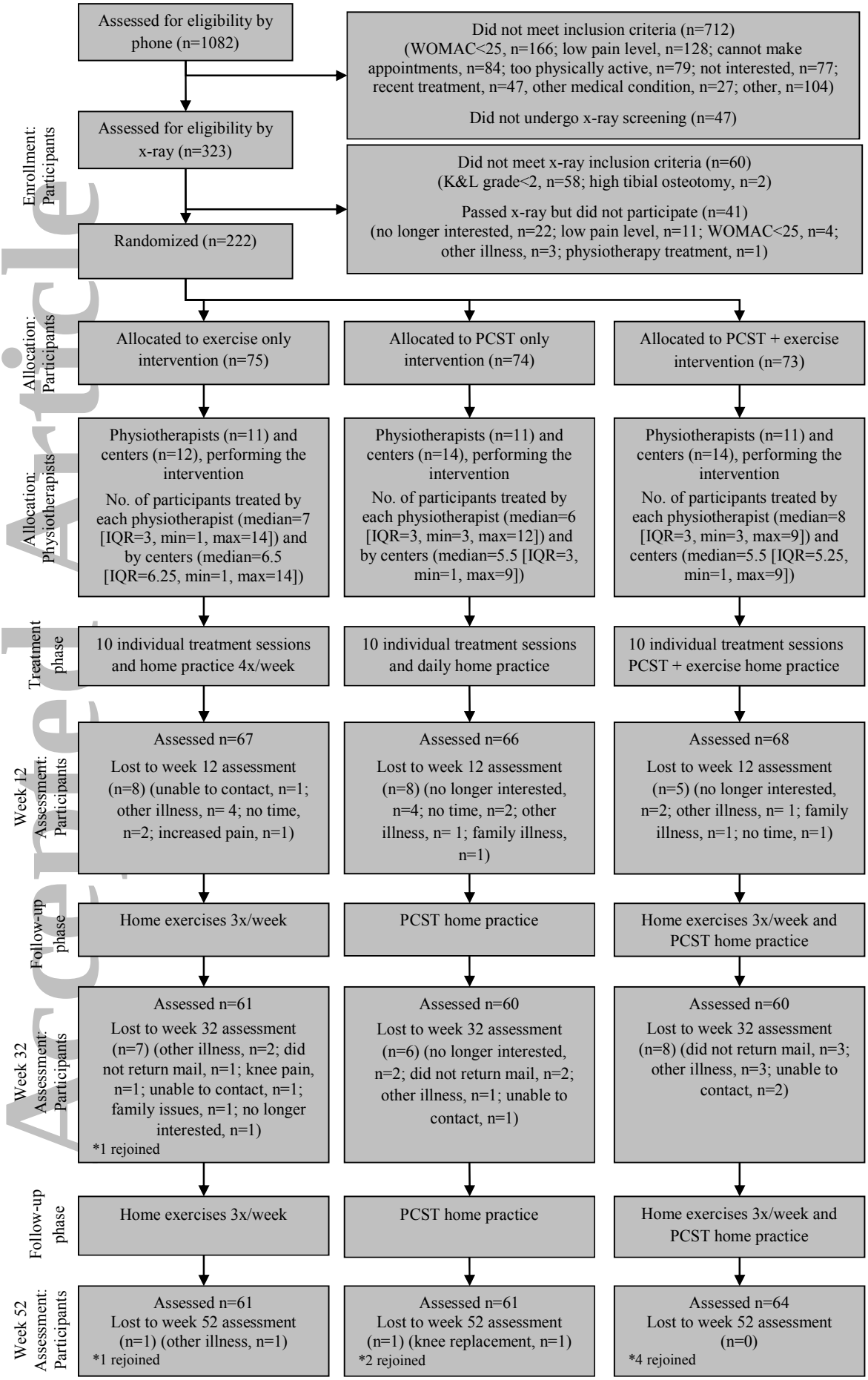
		Global Change Improvements					
		Number (%) reporting improvement			Relative risk (95% CI) † ‡		
		EX	PCST	PCST+EX	PCST+EX versus EX	PCST+EX versus PCST	PCST versus EX
Overall global change	Week 12	40/67 (60%)	40/66 (61%)	51/68 (75%)	1.3 (1.0, 1.8)	1.2 (1.0, 1.5)	1.1 (0.8, 1.4)
	Week 32	34/61 (56%)	33/59 (56%)	40/60 (67%)	1.2 (1.0, 1.6)	1.2 (0.9, 1.5)	1.1 (0.9, 1.3)
	Week 52	32/59 (54%)	32/57 (56%)	49/63 (78%)	1.3 (1.1, 1.6) *	1.4 (1.2, 1.6) *	1.0 (0.8, 1.2)
Pain global change	Week 12	42/67 (63%)	36/66 (55%)	51/68 (75%)	1.3 (0.9, 1.7)	1.3 (1.1, 1.6) *	0.9 (0.7, 1.2)
	Week 32	38/61 (62%)	32/59 (54%)	42/60 (70%)	1.1 (0.8, 1.4)	1.2 (0.9, 1.5)	1.0 (0.8, 1.2)
	Week 52	34/59 (58%)	35/57 (61%)	49/63 (78%)	1.3 (1.0, 1.7) *	1.3 (1.0, 1.5) *	1.1 (0.8, 1.4)
Function global change	Week 12	42/67 (63%)	41/66 (62%)	54/68 (80%)	1.3 (1.0, 1.7)	1.2 (1.0, 1.4) *	1.1 (0.8, 1.3)
	Week 32	35/61 (57%)	34/59 (58%)	41/60 (68%)	1.1 (0.9, 1.5)	1.2 (0.9, 1.6)	1.0 (0.8, 1.2)
	Week 52	32/59 (54%)	32/57 (56%)	47/63 (75%)	1.3 (1.1, 1.7) *	1.4 (1.1, 1.7) *	1.0 (0.7, 1.4)

*$p<0.05$

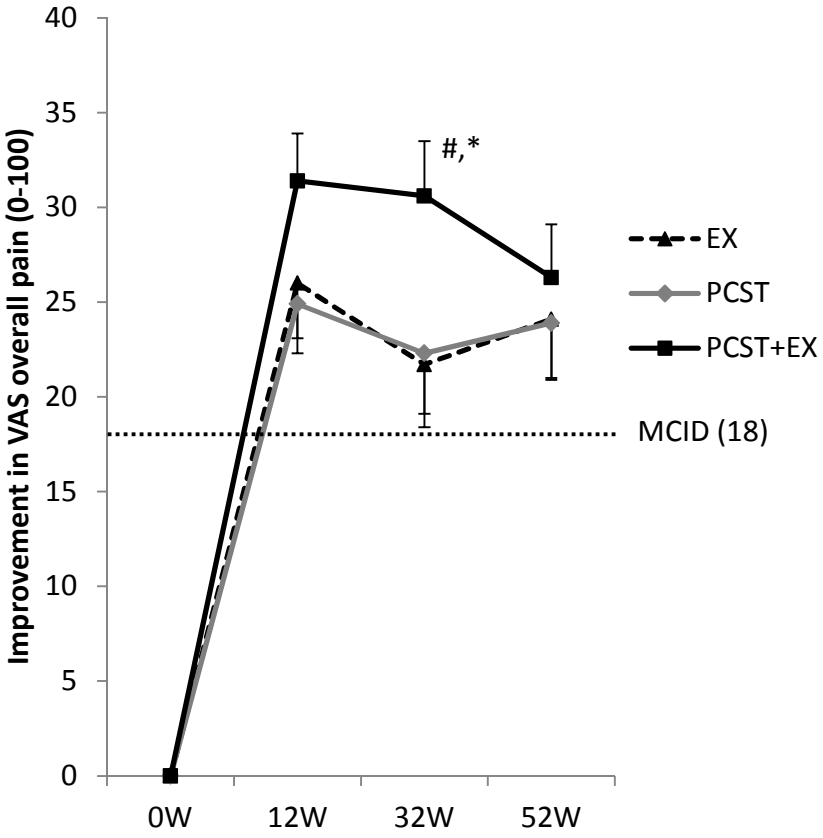
‡ adjusted for gender, site, baseline value, and random effects for physiotherapist

Figure 1: Flow chart describing progression of participants through the randomized controlled trial. Number of assessed participants is based on data obtained for the primary outcome measures.

Figure 2: Mean (SE) improvement in VAS overall pain (a) and WOMAC physical function (b) over time in the three groups. #p<0.05 for change between groups as compared to PCST. *p<0.05 for change between groups as compared to EX. MCID = minimal clinically important difference.



(a)



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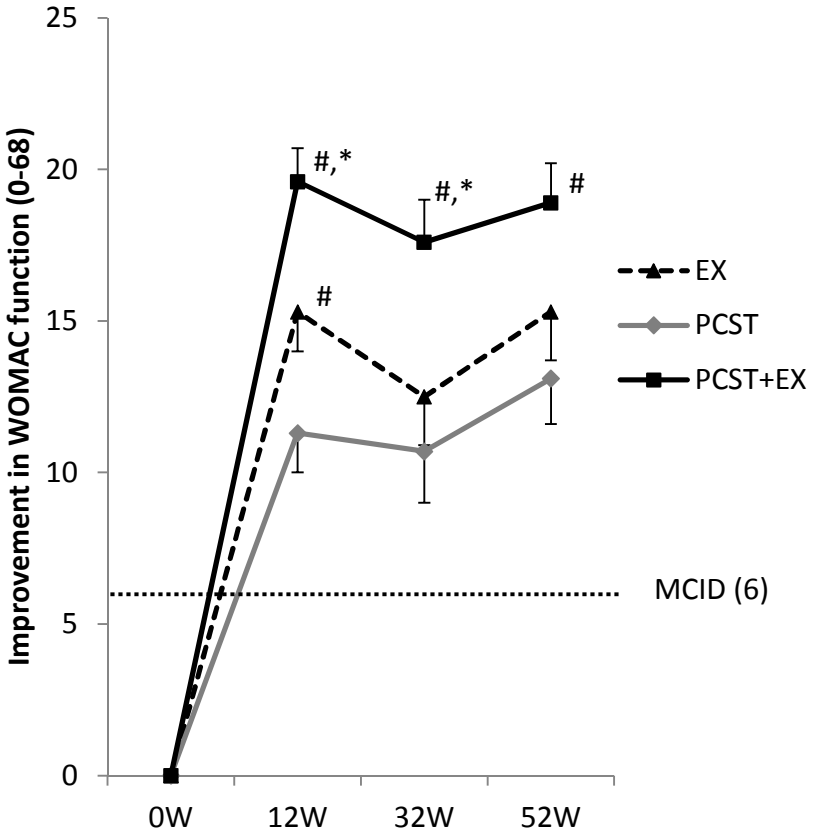

Supplementary Appendix:

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eMethods

Secondary hypotheses

- An integrated intervention of exercise and PCST will be more efficacious in improving pain and selfreported physical function than either PCST or exercise alone at 32 weeks and 52 weeks.
- An integrated intervention will be more efficacious in improving psychological function, functional performance, quality of life, physical activity levels and perceived response to treatment than either PCST or exercise alone immediately following the intervention and at 32 weeks and 52 weeks.
- Exercise will lead to greater improvements in muscle strength than PCST; PCST will lead to greater improvements in psychological parameters than exercise; and an integrated intervention will lead to greater improvements in both strength and psychological parameters at measured time points.
- Adherence to exercise during the 9-month unsupervised follow-up period will be greater with an integrated intervention than with an intervention of exercise alone.
- An integrated intervention will be more cost-effective than an intervention of exercise or PCST alone when costs are compared and related to the effects of the intervention at 52 weeks.

Exclusion Criteria

Exclusion criteria were: systemic arthritic conditions such as rheumatoid arthritis; medical condition precluding safe exercise such as uncontrolled hypertension or heart condition; self-reported history of serious mental illness, such as schizophrenia, or self reported diagnosis of current clinical depression; neurological condition such as Parkinson's disease, multiple sclerosis or stroke; knee surgery including arthroscopy within the past 6 months or total joint replacement; awaiting or planning any back or lower limb surgery within the next 12 months; current or past (within 3 months) oral or intra-articular corticosteroid use; physiotherapy, chiropractic or acupuncture treatment or exercises specifically for the knee within the past 6 months; walking exercise for >30 minutes continuously daily; participating in a regular (more than twice a week) structured and/or supervised exercise program such as attending exercise classes in a gym or use of a personal trainer; participating in or previous participation in a formal PCST program; inability to walk unaided; inadequate written and spoken English; inability to comply with the study protocol such as inability to attend physical therapy sessions or attend assessment appointments at the University.

Details about Exercise treatment

The exercise (EX) treatment used in this study was a standardised home-based exercise program designed to strengthen the lower limb muscles. It was based on clinical trials showing that such exercise programs improve pain and function, and reflects standard clinical practice. Participants were taught 6 exercises targeting the quadriceps, hamstrings and hip abductor muscles. Resistance was applied via the use of ankle cuffs with optional weight poles (0.5kg each), resistance elastic bands or body weight. Intensity was determined by the participant's ability to complete 10 repetitions for a given exercise and by perceived difficulty using the modified Borg Rating of Perceived Exertion Scale (RPE) scale for resistance training.(1) An intensity of 5-8 on the RPE scale corresponds to an appropriate intensity for strength gains. During physical therapy treatment sessions, the therapist monitored progression, ensured correct technique during performance of the exercises and evaluated adverse responses. Progression of intensity was an important component of the program. Intensity and progression were based on clinical judgment and on the amount of knee pain and difficulty experienced by the participant whilst performing the exercises. Home exercises were prescribed 4 times per week, aiming for a dosage of 3 sets of 10 repetitions, during the 12-week treatment phase, reducing to 3 times/week during the 9-month follow up. Handouts with descriptions of the prescribed exercises, level specific images and the prescribed repetitions were provided (eTable 1), as well as a study-specific log book to record performance. Exercise treatment sessions with the physical therapist lasted 25 minutes.

Details about the Pain Coping Skills Training treatment

The Pain Coping Skills Training (PCST) program involved 10 weekly sessions. The first session focused on educating the participant about the pain gate control theory that states that the pain experience is complex and is influenced by thoughts, behaviors and feelings. Sessions 1-4 focused on employing behavioral pain coping strategies. Participants developed practical applications of newly developed coping skills. Participants were taught progressive muscle relaxation which involved tensing and relaxing target muscles with the aim to use muscle tension as cues to relax. This relaxation would lead to reduce stiffness, tension, stress and fatigue, all factors that can influence the intensity of pain experienced. Participants were encouraged to incorporate mini-practices into daily life. Additional behavioral pain coping strategies were taught, such as 'activity-rest cycling', where participants were shown how to reduce pain by pacing their activity levels, and pleasant activity scheduling, which is the scheduling of pleasant activities as a strategy to control and decrease pain. Sessions 5-9 focused on cognitive pain coping strategies and taught cognitive restructuring techniques to identity maladaptive thoughts and how to replace them with more helpful coping thoughts, and identifying and challenging negative thoughts and replacing them with calming self-statements. These sessions utilized pleasant imagery, attention diversion, distraction and problem-solving techniques to aid in coping with pain. Session 10 provided a review of the entire treatment program and dealt with relapse prevention, developing a pain coping plan for the future and identification of coping strategies no longer being used. At each session the physical therapist discussed with the participant the potential benefits of what they had learnt and how it could be applied to manage their knee OA. A summary of the program is provided in eTable 2.

The type and amount of home practice prescribed differed from week to week but was cumulative as practice from each session was carried forward. Participants were provided with weekly PCST module handouts required for the home practice, a study-specific log book to record their PCST home practice, as well as two CDs. One CD was to facilitate the progressive muscle relaxation and the other for the mental imagery component of the program. Each PCST session with the physiotherapist lasted 45 minutes.

Combined Pain Coping Skills Training and exercise treatment

The combined treatment (PCST+EX) included all the components described in both the EX and PCST programs. While the exercises were identical to those in the EX intervention, the physical therapist delivered the exercises using a style that incorporated the PCST principles and techniques. The physical therapist would review the strengthening exercise and PCST home practice from the previous week and then introduce the new PCST concept. Once the participant had gained an understanding of the new PCST skill, the physical therapist would help them plan integration of the skill into their home exercises and daily life. For example, the participant could apply distraction techniques or mental imagery while performing the exercises to minimize the pain experienced. Participant's knowledge of the physiological processes causing pain was applied to the pain felt during the exercises so that they did not perceive the pain as a sign of further damage to their knee. Participants were provided with the same exercise equipment, exercise and PCST handouts and CDs, and log books to assist with their home practice. Each combined treatment session with the physical therapist lasted 70 minutes: 25 minutes for the exercise component and 45 minutes for the PCST component.

Cost effectiveness methods

The cost-effectiveness of PCST+EX compared to either EX or PCST alone was determined from a societal perspective that included total health care-related costs during the trial (irrespective of who paid), but excluded any impact on patient incomes, or travel or time costs associated with treatment. The initial fixed cost of training the physical therapists in the delivery of the interventions (labor cost for the psychologist trainers and the time costs for the physical therapist) was excluded, as its contribution to individual patient treatment costs over time would be small. The comparative effects of treatments on health care costs and quality of life during 52 weeks were estimated using mixed linear statistical model of baseline levels and treatment group with a random intercept for each practitioner clustered by state. We also estimated direct treatment costs and individual component health service costs separately. Quality-adjusted life years (QALYs) were estimated as the area under the curve of preference based quality of life scores in the month prior to baseline and weeks 12, 32 and 52. Cost-effectiveness was calculated, using recycled predictions of costs and QALYs, as the ratio of the mean difference in cost to the mean difference in QALYs between the groups. Ninety-five percent confidence intervals around the incremental cost effectiveness ratios were calculated using Fieller's theorem,(2) and compared to a critical ratio of $60,000 (assumed maximum willingness to pay for a QALY based on the likelihood of previous public reimbursements of medical technologies).(3) As an aid to interpretation, the cost-effectiveness ratio and the 95% confidence intervals were re-calculated as the mean net benefit for the combined treatment over individual treatments (= difference in QALYs between groups, multiplied by the assumed willingness to pay per QALY, less the difference in cost).(2) We varied the critical value and using a Bayesian

interpretation of the p-value calculated the probability that the PCST+EX treatment would have net social benefits as the willingness to pay for a QALY increased. In addition, analyses were repeated using a generalized linear model with appropriate distribution and link functions (chosen using a modified Park test(4) and Prebigon link test).(5) All analyses were performed using STATA13(6) via intention-to-treat with missing data replaced by multiple imputation as described in the main paper.

The size of the trial was determined by the primary clinical outcomes, but with actual sample sizes of 60-63 per group, the planned cost effectiveness analysis had 85% power to detect an incremental cost per QALY of less than the nominated critical threshold of $60,000. This was based on an assumed 0.1 absolute increase in QALYs and an increase in total costs of $1000 from PCST+EX compared to EX or PCST, a standard deviation of QALYs of 0.15, a standard deviation of costs in each arm of $5000, and a 0.2 correlation between costs and quality of life.(7)

The primary outcome was QALYs at 1 year, derived from the Assessment of Quality of Life 6D (AQoL) using the trapezoid method. The AQoL is a validated preference based measure of quality of life on a -0.04 (worse than death) to 1 (perfect health) scale with ratio properties such that equal absolute increments have equal value everywhere on the scale.(8) It is therefore suitable as a multi-attribute utility scale for the calculation of QALYs.

The direct cost of treatments was taken as the recorded number of treatment sessions multiplied by the payment rate for physical therapists in the trial ($103-$120 per hour). Health care-related resource use (hospital inpatient, prescription and non-prescription medications, medical services including hospital outpatient appointments, diagnostic tests, and other health practitioners) was taken from a questionnaire at baseline and at weeks 4, 8, 12, 32 and 52, and valued using published prices for medical and diagnostic costs,(9) prescription pharmaceuticals,(10) non-prescription pharmaceuticals,(11) and hospital unit costs(12).

Treatment fidelity

Treatment fidelity data are summarized in eTable11. Adherence to the PCST protocol was evaluated using a 'yes/no' format for specific criteria varying depending on the treatment session. Delivery performance was rated on 8 items: establishes/maintains rapport; remains on schedule with protocol or makes appropriate adjustments when indicated; applied PCST to participant's situation and current challenges; encourages participant's active involvement in the session; uses time effectively/appropriate pacing; demonstrates good interpersonal skills; demonstrates professionalism and clinical judgment; overall effectiveness/skill of the therapist. Higher level communication skills was rated on 9 items: open-ended questions; affirming statements; reflecting statements; ongoing summary statements; strategies to elicit talk; expressing support and acceptance; encouraging arguments for change; roll with resistance; support self-efficacy. The Melbourne psychologist rated the Brisbane physiotherapists and vice versa.

eResults

Results of cost effectiveness analyses

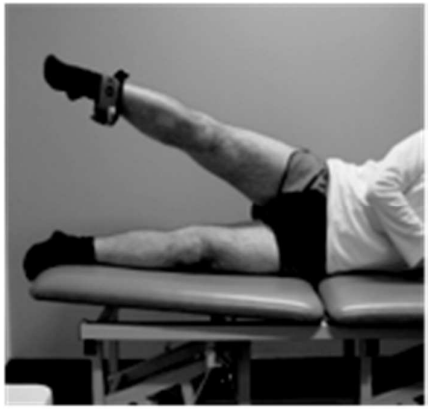
The cost of providing PCST alone was AUD$730 per participant and exercise alone was $439. The cost of PCST+EX treatment was $1065, slightly less than the sum of the two individual treatments. Twenty-five percent of reports on costs and the AQoL were missing at weeks 32 and 52 but this was similar across groups.

eTable 9 shows the results of the estimated cost of each treatment during the 52 weeks of the trial and follow-up, adjusted for baseline cost and the unobserved effects of the physical therapist and clustering by location. The additional cost of PCST+EX over either single treatment may be offset by a reduction in the cost of other health care service use. However we were not able to find evidence that PCST+EX saves other health service resources compared to either of the individual treatments on their own; compared to PCST (saving $844, 95% CI -3325, 1638) or EX (saving $717, 95% CI -3329, 1795). The point estimate of the reduction in cost of health care is largely from hospital inpatient services but none of the component costs showed significant differences across the three groups.

As reported in the main body of the paper (Table 2), patients in the trial had a mean quality of life (0.72, 95% CI 0.70, 0.74) that is considerably lower than the norm for the Australian population (0.80, 95% CI 0.78, 0.82).(13) The improvement in physical function in the PCST+EX treatment compared to single treatments translates to a small but non-significant improvement in quality-adjusted life years compared with EX (0.03 units, 95% CI -0.01, 0.07, p=0.07) and with PCST (0.03, 95% CI -0.01, 0.06, p=0.13). There was no difference comparing PCST vs EX (0.01, 95% CI -0.03, 0.04, p=0.64).

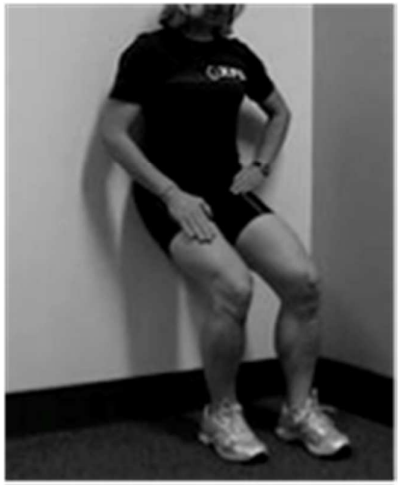
All of the predicted effects (and costs) were robust to alternative statistical analyses, although the precision of the individual estimates did vary across specifications. The estimate and the precision of the incremental cost effectiveness ratio (net benefits) were robust to variation in the specification of the regression model.

eTable 1: Strengthening exercise program.

Exercise Description	Images	Progression	Repetitions
1. Knee extensor strengthening Seated knee extensions with ankle weights. In a seated position, slowly straighten knee until it is fully straight. Hold for 5 seconds and then lower slowly.		Ankle weights.	3 sets of 10. 30 second break period in between sets.
2. Hip abductor strengthening Level 1: Side lying hip abduction with ankle weights. Keep body still and knee straight and lift affected leg up. Do not swing affected leg forward. Keep heel of foot higher than toes and behind hips while lifting straight upwards towards the ceiling. Hold for 5 seconds and then lower slowly.		Increase ankle weights or progress to level 2.	3 sets of 10. 30 second break period in between sets.

Exercise Description	Images	Progression	Repetitions
Level 2: Standing hip abduction with elastic resistance band. Place looped elastic resistance band around both legs just above the ankle. Ensure adequate tension on the elastic band and correct upright posture with shoulders and hips facing forward prior to starting the exercise. The back of a chair or a wall can be used to provide support. Hold for 5 seconds and then lower slowly.		Increase elastic band resistance.	3 sets of 10. 30 second break period in between sets.
3. Weight-bearing knee/hip extensor strengthening Level 1: Partial wall squats (option shown is to add elastic band around knees to incorporate the hip abductor muscles). Stand with feet about 30cm away from the wall and feet shoulder width apart. With back straight and trunk and buttocks against a wall, slowly slide down the wall (as if to sit) to approximately 60° of knee bend (less if painful) and then back up again while keeping contact with wall. Hold position for 5 seconds.		Increase resistance by adding elastic resistance band or increasing elastic band resistance strength. Progress further to level 2.	3 sets of 10. 30 second break period in between sets.

Exercise Description	Images	Progression	Repetitions
Level 2: Sit-to-stand (option to add elastic band around knees to incorporate hip abductor muscles). Seated with back against a chair of standard height with firm seat, slowly stand up without using hands for support. Lean forward over toes so that the buttocks are lifted and hips go under the trunk. Hold for 3 seconds with buttocks slightly off the chair before sitting back down slowly.		Increase resistance by adding elastic resistance band or increasing elastic band resistance strength. Progress further to level 3.	3 sets of 10. 30 second break period in between sets.
Level 3: Alternate split sit-to-stand Place the foot of the unaffected leg 10cm in front of the other foot. Slowly stand by leaning forward with back straight (nose in front of the toes) and squeeze buttock muscles. Most weight bearing must be on the symptomatic side. Hold for 3 seconds with buttocks slightly off the chair before sitting back down slowly.		Increase depth of squat.	3 sets of 10. 30 second break period in between sets.

Exercise Description	Images	Progression	Repetitions
Level 3+: Split partial wall squats Slowly slide down the wall (as if to sit) keeping the trunk and buttocks in contact with the wall. Knees must move over the toes. Most weight bearing must be on the symptomatic side. Stop when symptomatic knee is bent to approximately 60° (less if painful) Hold for 5 seconds and then slowly slide back up keeping trunk and buttocks in contact with the wall.		Increase depth of squat.	3 sets of 10. 30 second break period in between sets.
4. Hamstring strengthening seated knee extensions Place a looped elastic resistance band around the leg of a heavy table or chair. Seated in a chair, place the symptomatic leg in the looped elastic band with the knee slightly bent. Slowly pull the leg backwards into the elastic band until the knee is bent and a strong resistance is felt. Hold for 5 seconds and then straighten slowly.		Increase elastic band resistance	3 sets of 10. 30 second break period in between sets.

Exercise Description	Images	Progression	Repetitions
5. Step ups Place symptomatic leg onto the step. Slowly step up onto the step. Touch foot of non-affected leg onto the step then place both feet back onto the starting position on the ground.		First increase the height of the step and second add weight. Weight can be held across the chest with both hands or a weight in each hand.	3 sets of 10. 30-60 second break period in between sets.
6. Step downs Start with both legs standing on top of the step. Bend the knee of the affected leg slowly to lower the non-affected leg towards the ground. Then straighten the affected knee slowly to return to the starting position. The knee of the symptomatic leg must point forward during the movement.		First increase the height of the step and second add weight. Weight can be held across the chest with both hands or a weight in each hand.	3 sets of 10. 30-60 second break period in between sets.

eTable 2: Description of the Pain Coping Skills Training (PCST) program

PCST session	Content*	Home practice dosage during 12 week program
Session 1: Progressive Muscle Relaxation (PMR)	- Introduce gate control theory - Provide rationale for pain coping skills training - Train participant in PMR	2 PMR practices per day
Session 2: Mini-Practices	- Review PMR -Train participants on mini-practices	10 or more mini-practices per day
Session 3: Activity-Rest Cycling	- Review PMR and mini-practices - Introduce activity-rest cycling	Use technique twice per week
Session 4: Pleasant Activity Scheduling	- Describe how pleasant activity scheduling can be used to control and decrease pain - Set pleasant activity goals with participant - Discuss how to use mini-practices and activity-rest cycling in achieving pleasant activity goals.	3 pleasant activities per week
Session 5: Identifying Negative Thoughts, Thought Records	- Present cognitive model (ABC Model-how an event leads to **A**utomatic thoughts and result in specific **B**eliefs and certain **C**onsequences) - Teach participant how to use thought records to monitor negative thoughts	Record situations and thoughts daily
Session 6: Challenging Negative Thoughts, Calming Self-Statements	- Work with participant to challenge negative thoughts - Develop calming self-statements	Practice developing alternative coping thoughts daily
Session 7: Problem Solving I, Pleasant Imagery and Distraction Techniques I	- Training in problem solving - Training in pleasant imagery - Training in counting backwards	Problem solving activity: 1 per day Pleasant imagery: 2 per day
Session 8: Distraction Techniques II, Review of Skills	- Train use of focal points and auditory stimulation as distraction methods - Review skills from previous weeks	3 distraction techniques per week
Session 9: Problem Solving II (Applying Pain Coping Skills in Problem Situations)	- Review problem solving model - Identify problem situations - Develop coping plans	Record situations and thoughts daily
Session 10: Coping Skills Maintenance, Early Warning Signs/Developing a Coping Plan	- Review principles of relapse prevention - Identify early warning signs of reduced coping - Develop coping plans to address lapses	N/A

*Sessions 2-10 included a session overview and review of home practice from previous sessions. Sessions 1-9 included home practice planning.

eTable 3: Site-specific characteristic information of project physical therapists who administered the treatments

	Melbourne		Brisbane	
	PCST/PCST+EX	EX	PCST/PCST+EX	EX*
Total number of project physical therapists	6	5	5	6
Gender (Male/Female)	2/4	4/1	0/5	2/4
Age in years, median (min-max)	40 (32-55)	34 (25-50)	50 (50-58)	45 (33-53)
Clinical experience in years, median (min-max)	23 (11-35)	11 (5-20)	34 (26-35)	32 (10-34)
Number with post-graduate qualifications	4	1	2	3

* One project physical therapist withdrew after providing treatment for one participant.

eTable 4: Mean (SD) scores of baseline measures in those who completed the assessments versus those who withdrew before each time point.

Characteristic	12 weeks		32 weeks		52 weeks	
	Completed N=201	Withdrew N=21	Completed N=181	Withdrew N=41	Completed N=186	Withdrew N=36
Age (years)	63.6 (7.9)	61.1 (9.0)	63.4 (7.6)	63.4 (9.6)	63.6 (7.7)	62.5 (9.3)
Gender - Female	121 (60%)	12 (57%)	110 (61%)	23 (56%)	112 (60%)	21 (58%)
Height (cm)	1.68 (0.09)	1.68 (0.11)	1.68 (0.09)	1.67 (0.10)	1.68 (0.09)	1.67 (0.10)
Body mass (kg)	87.6 (18.6)	88.0 (17.4)	87.5 (18.2)	88.0 (19.9)	87.6 (18.5)	87.8 (18.4)
Body mass index (kg/m^2)	31.1 (6.1)	31.3 (5.8)	31.1 (6.1)	31.3 (6.1)	31.1 (6.1)	31.5 (6.1)
Symptom duration (years) ‡	6 (3, 10)	5 (4, 10)	6 (3, 10)	5 (4, 8)	6 (3, 10)	5 (3, 8)
Unilateral symptoms	51 (25%)	9 (43%)	45 (25%)	15 (37%)	48 (26%)	12 (33%)
Level of education, n(%)						
Less than 3 years of high school	18 (9%)	0 (0%)	16 (9%)	2 (5%)	17 (9%)	1 (3%)
Three or more years of high school	62 (31%)	7 (33%)	52 (29%)	17 (41%)	54 (29%)	15 (42%)
Tertiary and post-graduate	120 (60%)	14 (67%)	112 (62%)	22 (54%)	114 (62%)	20 (56%)
Employment status, n (%)						
Currently employed	95 (48%)	15 (7%)	90 (50%)	23 (56%)	91 (49%)	22 (61%)
Unable to work due to health	16 (8%)	0 (0%)	16 (9%)	0 (0%)	16 (9%)	0 (0%)
Retired (not due to health reasons)	72 (36%)	5 (24%)	62 (34%)	15 (37%)	65 (35%)	12 (33%)
Not employed	14 (7%)	1 (5%)	12 (7%)	3 (7%)	13 (7%)	2 (6%)
Co-morbidities, n (%)						
Heart disease/hypertension	79 (39%)	11 (52%)	72 (40%)	18 (44%)	75 (40%)	15 (42%)
Osteoporosis/osteopenia	26 (13%)	3 (14%)	24 (13%)	5 (12%)	25 (13%)	4 (11%)
Depression	26 (13%)	2 (10%)	23 (13%)	5 (12%)	25 (13%)	3 (8%)
Stomach ulcer/pains	19 (9%)	5 (24%)	17 (9%)	7 (17%)	17 (9%)	7 (19%)
Cancer	20 (10%)	0 (0%)	18 (10%)	2 (5%)	19 (10%)	1 (3%)

Radiographic disease severity, n (%) †						
Grade 2	76 (38%)	14 (67%)*	68 (38%)	22 (54%)*	68 (37%)	22 (61%)*
Grade 3	59 (29%)	4 (19%)	50 (28%)	13 (32%)	54 (29%)	9 (25%)
Grade 4	66 (33%)	3 (14%)	63 (35%)	6 (15%)	64 (34%)	5 (14%)
Medication use, n (%) ††						
Any medication use	147 (74%)	15 (71%)	132 (73%)	30 (73%)	137 (74%)	25 (69%)
Analgesia (paracetamol)	96 (48%)	11 (52%)	89 (49%)	18 (44%)	90 (49%)	17 (47%)
Non-steroidal anti-inflammatories	41 (21%)	6 (29%)	36 (20%)	11 (27%)	38 (21%)	9 (25%)
COX-2 inhibitors	10 (5%)	0 (0%)	10 (6%)	0 (0%)	10 (5%)	0 (0%)
Topical NSAIDs	25 (13%)	3 (14%)	21 (12%)	7 (17%)	22 (12%)	6 (17%)
Opioids	6 (3%)	0 (0%)	6 (3%)	0 (0%)	6 (3%)	0 (0%)
Glucosamine/chondroitin products	85 (43%)	4 (19%)	75 (42%)	14 (34%)	77 (42%)	12 (33%)
Oral corticosteroids	1 (0%)	0 (0%)	1 (1%)	0 (0%)	1 (1%)	0 (0%)
VAS overall pain §	58.7 (12.8)	59.1 (10.5)	58.8 (13.0)	58.5 (10.5)	58.5 (12.9)	60.1 (10.6)
WOMAC function §	34.7 (7.4)	37.6 (5.5)	34.7 (7.4)	36.4 (6.9)	34.5 (7.2)	37.5 (7.3)*
VAS walking pain §	60.9 (17.7)	63.3 (11.8)	61.3 (17.6)	60.5 (15.7)	60.8 (17.6)	62.9 (15.1)
WOMAC pain §	8.7 (2.6)	9.9 (2.5)*	8.7 (2.6)	9.1 (2.6)	8.6 (2.6)	9.5 (2.5)
ASES ^	20.5 (4.1)	19.6 (4.0)	20.7 (4.0)	19.4 (4.2)	20.6 (4.0)	19.5 (4.2)
CSQ ^	65.0 (25.3)	78.4 (21.8)*	65.4 (25.3)	70.2 (25.1)	65.3 (25.1)	71.5 (25.9)
PCS §	14.3 (9.1)	18.4 (7.3)*	14.1 (9.0)	17.4 (8.7)*	14.1 (9.0)	17.4 (8.4)*
DASS-21 Depression §	5.3 (7.3)	10.6 (9.0)*	5.3 (7.1)	8.2 (9.3)	5.3 (7.1)	8.7 (9.5)*
DASS-21 Anxiety §	5.4 (6.0)	8.7 (6.8)*	5.4 (5.6)	7.3 (7.8)	5.4 (5.5)	7.3 (8.2)
DASS-21 Stress §	8.7 (8.7)	12.8 (8.5)*	8.7 (8.7)	10.7 (8.8)	8.8 (8.7)	10.6 (9.1)
AQoL II ^	0.7 (0.2)	0.7 (0.1)	0.7 (0.2)	0.7 (0.1)	0.7 (0.2)	0.7 (0.1)
PASE ^	150 (75)	136 (59)	152 (73)	133 (73)	150 (73)	139 (73)
Quadriceps strength ^	1.1 (0.5)	0.9 (0.4)	1.1 (0.5)	1.0 (0.5)	1.0 (0.5)	1.0 (0.5)
30-sec sit-to-stand ^	8.7 (2.7)	7.9 (2.0)	8.8 (2.7)	8.0 (2.4)	8.8 (2.8)	8.1 (2.2)
20m walk ^	1.5 (0.3)	1.5 (0.3)	1.5 (0.3)	1.5 (0.3)	1.5 (0.3)	1.5 (0.3)

Step test ^	9.3 (3.7)	8.6 (2.7)	9.4 (3.7)	8.7 (2.9)	9.4 (3.7)	8.9 (2.9)

VAS=Visual Analogue Scale (0-100); WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, physical function (0-68), pain (0-20); ASES=Arthritis Self-Efficacy Scale (3-30); CSQ=Coping Strategies Questionnaire (0-163); PCS=Pain Catastrophizing Scale (0-52) DASS-21=Depression, Anxiety & Stress Subscales (0-42); AQoL II=Assessment of Quality of Life Version 2, (-0.04-1.00); PASE=Physical Activity Scale for the Elderly (0->400); Quadriceps strength (Newton*meters/kilograms); Timed up and go (sec); 30-sec sit-to-stand (n); 20m walk (meters/second); Step test (n); N/A=not assessed at this time point

‡ median (interquartile range); † using Kellgren and Lawrence grading system; †† current medication or supplement use defined as at least once per week

§ Lower scores = better

^ Higher scores = better

*p<0.05

eTable 5: Complete Case Analysis. Mean (SD) changes within groups and adjusted mean [95% confidence interval] difference in the change between-groups for continuous primary and secondary outcome measures.

Primary outcomes	Timeframe	Change within groups			Difference in change between-groups ‡		
		EX	PCST	PCST+EX	PCST+EX vs EX	PCST+EX vs PCST	PCST vs EX
VAS overall pain†	Week 0-12	27.4 (24.3)¥	24.9 (21.5)¥	31.4 (17.9)¥	4.6 (-2.5, 11.6)	6.7 (-0.3, 13.8)	-2.2 (-9.2, 4.9)
	Week 0-32	22.5 (26.7)¥	22.8 (24.1)¥	30.8 (20.1)¥	8.1 (0.0, 16.2)*	7.5 (-0.6, 15.7)	0.6 (-7.5, 8.7)
	Week 0-52	24.3 (27.1)¥	23.2 (22.0)¥	26.5 (22.4)¥	2.7 (-5.3, 10.7)	3.1 (-4.8, 11.0)	-0.5 (-8.5, 7.6)
WOMAC function†	Week 0-12	15.1 (10.9)¥	11.2 (10.3)¥	19.9 (9.1)¥	4.3 (1.0, 7.5)*	8.3 (5.1, 11.6)¥	-4.1 (-7.3, -0.8)*
	Week 0-32	12.4 (12.7)¥	11.1 (12.5)¥	18.7 (10.3)¥	5.2 (1.1, 9.4)*	6.7 (2.6, 10.9)œ	-1.5 (-5.6, 2.6)
	Week 0-52	15.9 (12.5)¥	12.3 (10.7)¥	19.1 (10.1)¥	2.5 (-1.2, 6.1)	5.8 (2.1, 9.5)œ	-3.4 (-7.1, 0.4)
Secondary outcomes							
VAS walking pain†	Week 0-12	26.1 (25.2)¥	26.8 (23.7)¥	33.9 (18.4)¥	7.9 (0.8, 15.0)*	7.7 (0.6, 14.9)*	0.2 (-7.0, 7.3)
	Week 0-32	17.1 (29.3)¥	22.5 (25.2)¥	28.9 (22.8)¥	10.4 (1.8, 19.0)*	5.9 (-2.6, 14.5)	4.5 (-4.1, 13.1)
	Week 0-52	22.7 (30.7)¥	23.9 (22.9)¥	28.2 (21.9)¥	5.2 (-3.1, 13.5)	4.4 (-3.9, 12.7)	0.9 (-7.5, 9.2)
WOMAC pain†	Week 0-12	3.3 (3.1)¥	2.6 (3.6)¥	4.4 (3.0)¥	0.8 (-0.1, 1.7)	1.7 (0.7, 2.6)¥	-0.9 (-1.8, 0.1)
	Week 0-32	2.2 (3.5)¥	2.3 (3.4)¥	3.8 (3.4)¥	1.2 (0.1, 2.4)*	1.1 (0.0, 2.3)	0.1 (-1.0, 1.3)
	Week 0-52	3.2 (3.7)¥	2.6 (3.3)¥	3.8 (3.4)¥	0.3 (-0.8, 1.4)	0.8 (-0.3, 2.0)	-0.6 (-1.7, 0.6)
ASES ^	Week 0-12	-3.5 (4.0)¥	-3.2 (4.4)¥	-4.8 (3.3)¥	-1.3 (-2.5, -0.2)*	-2.0 (-3.1, -0.8)¥	0.6 (-0.5, 1.8)
	Week 0-32	-1.4 (5.0)¥	-2.9 (4.3)¥	-4.2 (3.6)¥	-3.1 (-4.4, -1.7)¥	-1.7 (-3.1, -0.4)*	-1.3 (-2.7, 0.1)
	Week 0-52	-3.3 (4.9)¥	-3.1 (4.9)¥	-4.3 (3.2)¥	-1.4 (-2.7, -0.1)*	-1.6 (-2.9, -0.3)*	0.2 (-1.1, 1.5)
CSQ ^	Week 0-12	0.1 (0.5)¥	-0.2 (0.3)¥	-0.3 (0.4)¥	-0.3 (-0.5, -0.2)¥	0.0 (-0.2, 0.1)	-0.3 (-0.4, -0.2)¥
	Week 0-32	0.0 (0.5)¥	-0.1 (0.3)¥	-0.2 (0.4)¥	-0.3 (-0.4, -0.2)¥	-0.1 (-0.2, 0.1)	-0.2 (-0.4, -0.1)¥
	Week 0-52	0.0 (0.4)¥	-0.2 (0.3)¥	-0.3 (0.4)¥	-0.3 (-0.4, -0.2)¥	-0.1 (-0.2, 0.0)	-0.2 (-0.3, -0.1)¥
PCS †	Week 0-12	0.6 (0.7)¥	0.6 (0.8)¥	0.7 (0.8)¥	0.1 (-0.1, 0.4)	0.1 (-0.2, 0.4)	0.0 (-0.3, 0.3)
	Week 0-32	0.5 (0.8)¥	0.4 (0.8)¥	0.6 (1.0)¥	0.2 (-0.1, 0.6)	0.2 (-0.1, 0.5)	0.0 (-0.3, 0.3)
	Week 0-52	0.6 (0.7)¥	0.6 (0.7)¥	0.8 (0.9)¥	0.3 (0.0, 0.6)	0.2 (-0.1, 0.5)	0.1 (-0.3, 0.4)

DASS21 Depression †	Week 0-12	0.7 (5.8)	0.6 (6.3)	0.9 (4.8)	0.4 (-1.2, 2.1)	0.5 (-1.2, 2.1)	0.0 (-1.7, 1.6)
	Week 0-32	-0.1 (6.1)	0.4 (5.4)	1.9 (7.8)	2.2 (0.1, 4.3)*	1.3 (-0.7, 3.4)	0.8 (-1.3, 2.9)
	Week 0-52	0.5 (5.8)	0.9 (4.2)	1.4 (6.0)	1.1 (-0.6, 2.7)	0.2 (-1.4, 1.8)	0.9 (-0.8, 2.5)
DASS21 Anxiety †	Week 0-12	1.1 (3.9)	1.9 (4.1)¥	0.9 (4.1)	0.0 (-1.3, 1.3)	-0.7 (-2.0, 0.5)	0.7 (-0.6, 2.0)
	Week 0-32	0.3 (4.9)	0.9 (4.2)	1.3 (5.2)	1.2 (-0.5, 2.8)	0.4 (-1.2, 2.0)	0.8 (-0.9, 2.4)
	Week 0-52	0.7 (6.2)œ	2.1 (4.0)¥	2.0 (4.9)œ	1.7 (0.2, 3.2)*	0.2 (-1.3, 1.7)	1.5 (0.0, 3.0)
DASS21 Stress †	Week 0-12	1.5 (7.6)	0.3 (6.1)	0.5 (5.6)	-0.6 (-2.7, 1.5)	0.4 (-1.7, 2.5)	-1.0 (-3.1, 1.1)
	Week 0-32	0.0 (7.1)	0.4 (5.4)	1.2 (7.3)	1.5 (-0.9, 3.9)	0.7 (-1.6, 3.1)	0.7 (-1.6, 3.1)
	Week 0-52	0.8 (7.6)*	1.7 (6.7)	2.1 (6.3)*	2.0 (0.0, 4.0)	0.0 (-2.0, 2.0)	2.0 (0.0, 4.1)*
AQoL II ^	Week 0-12	-0.1 (0.2)œ	-0.1 (0.1)¥	-0.1 (0.1)¥	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
	Week 0-32	0.0 (0.1)*	-0.1 (0.1)¥	-0.1 (0.1)¥	-0.1 (-0.1, 0.0)œ	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.0)
	Week 0-52	-0.1 (0.1)¥	-0.1 (0.1)¥	-0.1 (0.1)¥	-0.1 (-0.1, 0.0)	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.0)
PASE ^	Week 0-12	-19.7 (72.8)*	-12.7 (66.1)	-25.3 (81.0)*	-6.2 (-30.2, 17.8)	-14.8 (-38.7, 9.2)	8.6 (-15.4, 32.6)
	Week 0-32	-7.1 (74.3)œ	-7.3 (95.3)	-27.4 (67.0)œ	-24.2 (-50.9, 2.5)	-30.5 (-57.3, -3.7)*	6.3 (-20.4, 32.9)
	Week 0-52	-22.7 (78.2)œ	-21.8 (73.8)*	-24.7 (62.4)œ	-5.3 (-29.9, 19.4)	-10.9 (-35.6, 13.7)	5.7 (-19.0, 30.3)
Quadriceps strength ^	Week 0-12	-0.1 (0.3)¥	-0.1 (0.3)*	-0.2 (0.3)¥	0.0 (-0.1, 0.1)	-0.1 (-0.2, 0.0)	0.0 (-0.1, 0.2)
	Week 0-52	-0.2 (0.3)¥	-0.1 (0.3)*	-0.2 (0.4)¥	0.0 (-0.1, 0.1)	-0.1 (-0.3, 0.0)*	0.1 (0.0, 0.2)*
30-sec sit-to-stand ^	Week 0-12	-1.9 (2.1)¥	-0.7 (2.1)œ	-1.6 (2.3)¥	0.3 (-0.4, 1.1)	-1.1 (-1.8, -0.3)œ	1.4 (0.7, 2.1)¥
	Week 0-52	-2.5 (2.6)¥	-1.3 (2.3)¥	-1.9 (2.2)¥	0.6 (-0.3, 1.4)	-0.9 (-1.7, -0.1)*	1.5 (0.6, 2.3)¥
20m walk ^	Week 0-12	-0.2 (0.2)¥	-0.1 (0.2)¥	-0.1 (0.2)¥	0.0 (0.0, 0.1)	0.0 (-0.1, 0.0)	0.1 (0.0, 0.2)*
	Week 0-52	-0.2 (0.2)¥	-0.1 (0.2)¥	-0.2 (0.3)¥	0.0 (-0.1, 0.1)	-0.1 (-0.2, 0.0)	0.0 (0.0, 0.1)
Step test ^	Week 0-12	-2.1 (3.6)¥	-0.8 (2.6)*	-1.6 (3.7)¥	0.7 (-0.3, 1.7)	-1.1 (-2.1, -0.1)*	1.8 (0.8, 2.8)¥
	Week 0-52	-2.3 (3.0)¥	-1.6 (2.7)¥	-2.0 (3.1)¥	0.4 (-0.5, 1.4)	-0.7 (-1.7, 0.2)	1.2 (0.2, 2.1)*

† For change within groups, positive change means improvement. For difference in change between-groups, positive difference favours the first named group in the pairwise comparison while a negative difference favours the second named group.
^ For change within groups, negative change means improvement. For difference in change between-groups, negative difference in change between-groups favours the first named group in the pairwise comparison while a positive difference favours the second named group.
*p<0.05; œ p<0.01; ¥ p<0.001
‡ adjusted for site, baseline value, physiotherapist and gender

VAS=Visual Analogue Scale (0-100); WOMAC=Western Ontario and McMaster Universities Osteoarthritis Index, physical function (0-68), pain (0-20); ASES=Arthritis Self-Efficacy Scale (3-30); CSQ=Coping Strategies Questionnaire (0-163); PCS=Pain Catastrophizing Scale (0-52) DASS-21=Depression, Anxiety & Stress Subscales (0-42); AQoL II=Assessment of Quality of Life Version 2, (-0.04-1.00); PASE=Physical Activity Scale for the Elderly (0->400); Quadriceps strength measure (Newton*meters/kilograms); Timed up and go (sec); 30-sec sit-to-stand (n); 20m walk (meters/second); Step test (n)
Note: Analyses for CSQ and PCS outcome measures were performed on a logarithmically transformed outcome scale as assumptions of normality were violated.

eTable 6: Complete case analysis. Relative risks (95% confidence intervals) for improvement between groups.

Global change measure	Time frame (wks)	Number (%) reporting improvement			Relative risks (95% CI)		
		EX	PCST	PCST + EX	PCST+EX vs EX	PCST+EX vs PCST	PCST vs EX
Global change overall	12	40/67 (60%)	40/66 (61%)	51/68 (75%)	1.3 (0.9, 1.7)	1.2 (1.0, 1.5)	1.0 (0.8, 1.4)
	32	34/61 (56%)	33/59 (56%)	40/60 (67%)	1.2 (1.0, 1.5)*	1.2 (0.9, 1.7)	1.0 (0.8, 1.2)
	52	32/59 (54%)	32/57 (56%)	49/63 (78%)	1.4 (1.2, 1.7)œ	1.4 (1.3, 1.6)œ	1.0 (0.8, 1.2)
Global change in pain	12	42/67 (63%)	36/66 (55%)	51/68 (75%)	1.2 (0.9, 1.7)	1.4 (1.1, 1.7)œ	0.9 (0.7, 1.2)
	32	38/61 (62%)	32/59 (54%)	42/60 (70%)	1.1 (0.9, 1.4)	1.3 (1.0, 1.7)	0.9 (0.7, 1.1)
	52	34/59 (58%)	35/57 (61%)	49/63 (78%)	1.3 (1.1, 1.6) œ	1.3 (1.1, 1.6) œ	1.0 (0.8, 1.3)
Global change in function	12	42/67 (63%)	41/66 (62%)	54/68 (80%)	1.3 (1.0, 1.7)	1.3 (1.1, 1.5) œ	1.0 (0.8, 1.3)
	32	35/61 (57%)	34/59 (58%)	41/60 (68%)	1.2 (0.9, 1.6)	1.2 (0.9, 1.6)	1.0 (0.8, 1.3)
	52	32/59 (54%)	32/57 (56%)	47/63 (75%)	1.3 (1.1, 1.7)*	1.4 (1.1, 1.7) œ	1.0 (0.7, 1.3)

*p<0.05; œ p<0.01

eTable 7: Adjusted mean (95% confidence interval) difference in the change between groups for continuous primary and secondary outcome measures, adjusting for age, sex, BMI, symptomatic knee, education level, employment and comorbidities.

Primary Outcomes	Time frame (wks)	Difference in change between groups		
		PCST+EX vs EX	PCST+EX vs PCST	PCST vs EX
VAS Average pain	12	5.0 (-2.1, 12.1)	7.0 (0.0, 14.1)	-2.1 (-9.1, 5.0)
	32	8.3 (0.0, 16.6)	7.6 (-0.8, 16.0)	0.7 (-7.7, 9.0)
	52	3.9 (-4.6, 12.3)	3.7 (-4.2, 11.7)	0.1 (-8.5, 8.7)
WOMAC function	12	4.7 (1.5, 8.0) œ	8.9 (5.6, 12.1) ¥	-4.1 (-7.3, -0.9) *
	32	5.5 (1.3, 9.7) *	7.1 (2.8, 11.4) œ	-1.5 (-5.7, 2.6)
	52	2.6 (-1.1, 6.2)	6.0 (2.3, 9.7) œ	-3.4 (-7.2, 0.3)
Secondary outcomes				
VAS Walking pain	12	8.2 (1.0, 15.4) *	8.3 (1.1, 15.5) *	-0.1 (-7.3, 7.1)
	32	11.3 (2.6, 20.1) *	6.7 (-2.1, 15.4)	4.7 (-4.1, 13.4)
	52	6.4 (-1.9, 14.7)	5.1 (-3.2, 13.4)	1.3 (-7.2, 9.7)
WOMAC pain	12	0.9 (-0.1, 1.8)	1.8 (0.8, 2.7) ¥	-0.9 (-1.9, 0.0)
	32	1.3 (0.1, 2.4) *	1.2 (0.0, 2.4)	0.1 (-1.1, 1.3)
	52	0.4 (-0.8, 1.5)	0.8 (-0.3, 2.0)	-0.5 (-1.6, 0.7)
ASES	12	-1.5 (-2.7, -0.3) *	-2.0 (-3.1, -0.8) œ	0.5 (-0.7, 1.7)
	32	-3.1 (-4.5, -1.8) ¥	-1.8 (-3.3, -0.4) *	-1.3 (-2.7, 0.1)
	52	-1.5 (-2.8, -0.1) *	-1.5 (-2.9, -0.2) *	0.1 (-1.3, 1.4)
CSQ	12	-0.4 (-0.5, -0.2) ¥	-0.1 (-0.2, 0.1)	-0.3 (-0.4, -0.2) ¥
	32	-0.3 (-0.4, -0.2) ¥	0.0 (-0.2, 0.1)	-0.3 (-0.4, -0.1) ¥
	52	-0.3 (-0.4, -0.2) ¥	-0.1 (-0.2, 0.0)	-0.2 (-0.3, -0.1) ¥
PCS	12	0.2 (-0.1, 0.5)	0.2 (-0.1, 0.4)	0.0 (-0.2, 0.3)
	32	0.2 (-0.1, 0.6)	0.2 (-0.1, 0.6)	0.0 (-0.3, 0.3)
	52	0.3 (0.0, 0.6)	0.2 (-0.1, 0.5)	0.1 (-0.2, 0.4)
DASS21 Depression	12	0.6 (-1.1, 2.3)	0.4 (-1.3, 2.0)	0.2 (-1.5, 1.9)
	32	2.2 (0.1, 4.4) *	1.4 (-0.8, 3.5)	0.8 (-1.3, 3.0)
	52	1.1 (-0.5, 2.8)	0.0 (-1.7, 1.7)	1.1 (-0.6, 2.8)
DASS21 Anxiety	12	0.1 (-1.2, 1.5)	-0.8 (-2.0, 0.5)	0.9 (-0.5, 2.2)
	32	1.3 (-0.4, 3.0)	0.5 (-1.1, 2.2)	0.8 (-0.9, 2.5)
	52	1.7 (0.2, 3.2) *	0.1 (-1.4, 1.6)	1.6 (0.1, 3.1) *
DASS21 Stress	12	-0.6 (-2.6, 1.5)	0.2 (-1.9, 2.3)	-0.8 (-2.9, 1.3)
	32	1.7 (-0.7, 4.1)	0.8 (-1.6, 3.1)	0.9 (-1.5, 3.3)
	52	2.0 (0.0, 4.1)	-0.1 (-2.2, 1.9)	2.1 (0.0, 4.2) *
AQoL II	12	0.0 (-0.1, 0.0)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
	32	-0.1 (-0.1, 0.0) œ	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.0)
	52	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.0)	0.0 (-0.1, 0.1)

PASE	12	-10.4 (-34.4, 13.6)	-18.2 (-42.3, 5.9)	7.8 (-16.1, 31.8)
	32	-26.8 (-52.7, -0.8) *	-32.8 (-59.3, -6.3) *	6.0 (-20.2, 32.2)
	52	-6.2 (-30.9, 18.6)	-9.3 (-34.5, 15.9)	3.1 (-22.0, 28.2)
Quadriceps strength	12	0.0 (-0.1, 0.1)	-0.1 (-0.2, 0.0)	0.0 (-0.1, 0.2)
	52	0.0 (-0.1, 0.1)	-0.2 (-0.3, 0.0) *	0.1 (0.0, 0.2)
30-sec sit-to-stand	12	0.3 (-0.5, 1.0)	-1.2 (-1.9, -0.4) œ	1.4 (0.7, 2.2) ¥
	52	0.4 (-0.4, 1.2)	-0.9 (-1.7, -0.1) *	1.3 (0.5, 2.1) œ
20m walk	12	0.0 (0.0, 0.1)	0.0 (-0.1, 0.0)	0.1 (0.0, 0.2) *
	52	0.0 (-0.1, 0.0)	-0.1 (-0.2, 0.0)	0.0 (-0.1, 0.1)
Step test	12	0.6 (-0.4, 1.6)	-1.2 (-2.2, -0.2) *	1.8 (0.8, 2.8) œ
	52	0.4 (-0.6, 1.3)	-0.8 (-1.7, 0.2)	1.1 (0.1, 2.1) *

*p<0.05; œ p<0.01; ¥ p<0.001

eTable 8: Relative risks (95% confidence intervals) for improvement between groups, adjusting for age, sex, BMI, symptomatic knee, education level, employment and comorbidities.

Global change measure	Time frame (wks)	Relative risk (95% CI)		
		PCST+EX vs EX	PCST+EX vs PCST	PCST vs EX
Global change overall	12	1.3 (1.0, 1.8)	1.2 (1.0, 1.5)	1.1 (0.8, 1.4)
	32	1.2 (1.0, 1.6)	1.2 (0.9, 1.5)	1.1 (0.9, 1.3)
	52	1.3 (1.1, 1.6) œ	1.4 (1.2, 1.7) œ	0.9 (0.8, 1.1)
Global change in pain	12	1.3 (0.9, 1.8)	1.3 (1.1, 1.6) œ	1.0 (0.7, 1.3)
	32	1.1 (0.8, 1.4)	1.1 (0.9, 1.5)	1.0 (0.8, 1.2)
	52	1.3 (1.1, 1.6) *	1.2 (1.0, 1.5) *	1.1 (0.8, 1.4)
Global change in function	12	1.3 (1.0, 1.7) *	1.2 (1.1, 1.4) œ	1.1 (0.8, 1.3)
	32	1.1 (0.9, 1.4)	1.2 (0.9, 1.5)	1.0 (0.8, 1.2)
	52	1.3 (1.1, 1.7) *	1.3 (1.1, 1.7) *	1.0 (0.7, 1.4)

*p<0.05; œ p<0.01

eTable 9: Difference in mean (95% confidence interval) health care costs by cost category between interventions over 12 months: mixed linear regression multiple imputation of total annual costs controlling for baseline and random intercept by physical therapist and clustering by location

	PCST+EX vs EX	*p*	PCST+EX vs PCST	*p*	PCST vs EX	*p*
Total cost	-717 (-3329, 1795)	0.92	-844 (-3325, 1638)	0.51	127 (-2741, 2725)	0.92
Intervention	626 (611, 641)	<0.001	335 (311, 358)	<0.001	291 (253, 330)	<0.001
Diagnostic	-61(-185,64)	0.34	-94 (-210,21)	0.11	33 (-91,158)	0.6
Drugs	309 (-234,853)	0.26	9 (-542,560)	0.98	300 (-252,853)	0.01
Hospital	-685 (-2468,1096)	0.45	-505 (-843, -330)	0.58	-180 (-1972, 1611)	0.84
Medical	-215 (-535,103)	0.19	-157 (-472)	0.32	-58 (-370, 254)	0.71
Other	-97 (-299,105)	0.35	-263 (-58, -469)	0.01	166 (-37, 370)	0.11

Ex=Exercise, PCST= Pain Coping Skills Training
Note: Negative difference favours the first named group in the pairwise comparisons

eTable 10: Adherence, adverse events and co-interventions data according to group allocation presented as mean (SD) or number (%)

Measure	EX	PCST	PCST+EX
Mean (SD) no. of treatment sessions attended (0-10)	8.8 (2.7)	8.6 (2.7)	8.9 (2.5)
Mean (SD) % of home exercise sessions completed during treatment [a]	84% (23%) **	N/A	76% (29%)
Mean (SD) % of home PCST practice completed during treatment [b]	N/A	77% (29%)	69% (32%)
Mean (SD) % of home exercise sessions completed during follow up [c]	63% (38%)	N/A	67% (33%)
Mean (SD) physiotherapist-rated adherence during treatment (0-10)	7.5 (2.7)	6.9 (2.9)	7.7 (2.4)
Mean (SD) self-rated adherence during treatment (0-10)	8.3 (1.9) *	7.3 (2.1)	7.9 (1.7)
Mean (SD) self-rated adherence during follow up (0-10) [c d]	4.9 (2.9)	4.7 (2.2)	5.2 (2.4)
Total number of participants reporting adverse events during treatment [e f]	28 (39%) ¥	4 (6%)	24 (33%) ¥
Total number of adverse events during treatment	38 ¥	7	31 œ
Increased knee pain	22 (31%)	2 (3%)	15 (21%)
Pain in other region	11 (15%)	3 (4%)	11 (15%)
Swelling/Inflammation	2 (3%)	2 (3%)	2 (3%)
Increased stiffness	2 (3%)	0 (0%)	3 (4%)
Knee instability	1 (1%)	0 (0%)	0 (0%)
Total number of participants reporting adverse events during follow up [c]	12 (20%)	4 (7%)	7 (11%)
Total number of adverse events during follow up	15 *	4	8
Increased knee pain	6 (10%)	4 (7%)	3 (5%)
Pain in other region	7 (11%) *	0 (0%)	2 (3%)
Swelling/Inflammation	2 (3%)	0 (0%)	2 (3%)
Increased stiffness	0 (0%)	0 (0%)	1 (1%)
Any medication use during treatment phase	42 (63%)	47 (70%)	39 (57%)
Total number of medications used during treatment	72	77	57
Analgesia (paracetamol combinations)	24 (34%)	21 (30%)	20 (28%)
Non-steroidal anti-inflammatories	10 (14%)	11 (15%)	10 (14%)
COX-2 inhibitors	3 (4%)	3 (4%)	3 (4%)
Topical anti-inflammatories	5 (7%)	9 (13%)	6 (8%)
Opioids	0 (0%)	2 (3%)	1 (1%)
Glucosamine/chondroitin products	30 (42%) **	29 (41%)	17 (24%)
Oral Corticosteroids	0 (0%)	2 (3%)	0 (0%)
Any medication use in previous month during follow up [c]	50 (81%)	50 (82%)	39 (63%)
Total number of medications used during treatment	124	106	93

Analgesia (paracetamol combinations)	35 (51%)	28 (42%)	27 (40%)
Non-steroidal anti-inflammatories	21 (31%)	19 (28%)	16 (24%)
COX-2 inhibitors	8 (12%)	9 (13%)	10 (15%)
Topical anti-inflammatories	14 (21%)	11 (16%)	11 (16%)
Opioids	9 (13%)	7 (10%)	7 (10%)
Glucosamine/chondroitin products	27 (40%)	28 (42%)	17 (25%)
Oral Corticosteroids	10 (15%)	4 (6%)	5 (7%)
Number of participants reporting use of co-interventions during treatment	3 (4%)	4 (6%)	4 (6%)
Total number of co-interventions during treatment	4	5	4
Other physiotherapy	1 (1%)	1 (1%)	0 (0%)
Exercise	2 (3%)	3 (4%)	3 (4%)
Hydrotherapy	1 (1%)	0 (0%)	0 (0%)
Acupuncture	0 (0%)	1 (1%)	1 (1%)
Number of participants reporting use of co-interventions during follow up [c]	7 (10%)	9 (13%)	9 (13%)
Total number of co-interventions during follow up	4	5	4
Other physiotherapy	3 (4%)	3 (4%)	1 (1%)
Exercise	2 (3%)	4 (6%)	5 (7%)
Hydrotherapy	5 (7%)	3 (4%)	0 (0%)
Joint injections	1 (1%)	0 (0%)	1 (1%)
Surgery	1 (1%)	2 (3%)	0 (0%)

Abbreviation: COX=cyclooxygenase.
[a] Number of home exercise sessions completed as recorded by participants in a log book (from a maximum of 48 and converted to a percentage).
[b] Number of home PCST practices completed as recorded by participants in a log book (from a maximum of 84 and converted to a percentage).
[c] Follow-up phase data includes an average of data collected at weeks 22, 32, 42 and 52.
[d] Participants were asked how many times in the previous week they had performed the home exercises (from a maximum of 33 and converted to a percentage).
[e] An adverse event was defined as any problem from the treatment that lasted for more than two days and/or caused participant to take medication or seek other treatment.
[f] Seventy-one log books were received from the EX group, 71 from the PCST group and 72 from the PCST+EX group
¥ p<0.001 compared to the PCST group
œ p<0.01 compared to the PCST group
* p<0.05 compared to the PCST group
** p<0.05 compared to the PCST+ EX group
Note: Analysed by Kruskal-Wallis test or chi-square test.

eTable 11: Summary of quality ratings for PCST for the individual physical therapists who delivered the PCST and PCST+EX treatments. Presented as mean (SD) or percentage.

Physical therapists	Adherence to treatment protocol	Delivery performance (1-5)†	Higher level communication skills (1-5)†	Audio sessions reviewed (n)
B1	98% (6%)	3.2 (0.5)	3.0 (0.5)	16
B2	100% (0%)	3.4 (0.5)	3.4 (0.4)	14
B3	100% (0%)	3.6 (0.4)	3.4 (0.3)	14
B4	96% (7%)	3.3 (0.4)	3.1 (0.4)	17
B5	100% (0%)	3.7 (0.3)	3.6 (0.3)	13
B Average	99% (2%)	3.4 (0.2)	3.3 (0.2)	Total =74
M1	95% (9%)	3.8 (0.4)	3.7 (0.5)	13
M2	87% (12%)	3.3 (0.4)	3.3 (0.3)	11
M3	96% (15%)	3.8 (0.5)	4.0 (0.4)	16
M4	98% (8%)	4.5 (0.3)	4.3 (0.3)	10
M5	98% (5%)	4.0 (0.4)	4.1 (0.4)	14
M6	94% (11%)	3.6 (0.4)	3.7 (0.3)	10
M Average	95% (4%)	3.8 (0.4)	3.8 (0.4)	Total = 74
All Average	96% (4%)	3.7 (0.4)	3.6 (0.4)	Total = 148

B= Brisbane physiotherapists, M=Melbourne physiotherapists.
† Rating 1=poor, 2=fair, 3=satisfactory, 4=very good, 5=excellent
Delivery performance was rated on 8 items: establishes/maintains rapport; remains on schedule with protocol or makes appropriate adjustments when indicated; applied PCST to participant's situation and current challenges; encourages participant's active involvement in the session; uses time effectively/appropriate pacing; demonstrates good interpersonal skills; demonstrates professionalism and clinical judgment; overall effectiveness/skill of the therapist.
Higher level communication skills was rated on 9 items: open-ended questions; affirming statements; reflecting statements; ongoing summary statements; strategies to elicit talk; expressing support and acceptance; encouraging arguments for change; roll with resistance; support self-efficacy.

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