



**QUEEN'S
UNIVERSITY
BELFAST**

Walking Exercise for Chronic Musculoskeletal Pain: Systematic Review and Meta-Analysis

O'Connor, S. R., Tully, M. A., Ryan, B., Bleakley, C. M., Baxter, G. D., Bradley, J. M., & McDonough, S. M. (2015). Walking Exercise for Chronic Musculoskeletal Pain: Systematic Review and Meta-Analysis. *Archives of Physical Medicine and Rehabilitation*, 96(4), 724-734. <https://doi.org/10.1016/j.apmr.2014.12.003>

Published in:

Archives of Physical Medicine and Rehabilitation

Document Version:

Peer reviewed version

Queen's University Belfast - Research Portal:

[Link to publication record in Queen's University Belfast Research Portal](#)

Publisher rights

© 2014 Elsevier.

This is the author's version of a work that was accepted for publication in Archives of Physical Medicine and Rehabilitation. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in Archives of Physical Medicine and Rehabilitation, [VOL 96, ISSUE 1, (April 2015)]
doi:10.1016/j.apmr.2014.12.003

General rights

Copyright for the publications made accessible via the Queen's University Belfast Research Portal is retained by the author(s) and / or other copyright owners and it is a condition of accessing these publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy

The Research Portal is Queen's institutional repository that provides access to Queen's research output. Every effort has been made to ensure that content in the Research Portal does not infringe any person's rights, or applicable UK laws. If you discover content in the Research Portal that you believe breaches copyright or violates any law, please contact openaccess@qub.ac.uk.

Open Access

This research has been made openly available by Queen's academics and its Open Research team. We would love to hear how access to this research benefits you. – Share your feedback with us: <http://go.qub.ac.uk/oa-feedback>

Accepted Manuscript

Walking Exercise for Chronic Musculoskeletal Pain: Systematic Review and Meta-Analysis

Seán R. O'Connor, PhD, Mark A. Tully, PhD, Brigid Ryan, BSc (Hons), Chris M. Bleakley, PhD, George D. Baxter, MPhil, Judy M. Bradley, PhD, Suzanne M. McDonough, PhD

PII: S0003-9993(14)01314-8

DOI: [10.1016/j.apmr.2014.12.003](https://doi.org/10.1016/j.apmr.2014.12.003)

Reference: YAPMR 56061

To appear in: *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION*

Received Date: 21 August 2014

Revised Date: 27 November 2014

Accepted Date: 8 December 2014

Please cite this article as: O'Connor SR, Tully MA, Ryan B, Bleakley CM, Baxter GD, Bradley JM, McDonough SM, Walking Exercise for Chronic Musculoskeletal Pain: Systematic Review and Meta-Analysis, *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION* (2015), doi: 10.1016/j.apmr.2014.12.003.

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.



Title: Walking Exercise for Chronic Musculoskeletal Pain: Systematic Review and Meta-Analysis

Seán R O'Connor PhD ^{1,2,5}, Mark A Tully PhD ^{1,2}, Brigid Ryan BSc (Hons)³, Chris M Bleakley PhD⁴, George D Baxter MPhil³, Judy M Bradley PhD⁵, Suzanne M McDonough PhD ^{*2,5}

¹ Centre for Public Health, Queens' University Belfast, United Kingdom

² UKCRC Centre of Excellence for Public Health (Northern Ireland), United Kingdom

³ Centre for Physiotherapy Research, University of Otago, New Zealand

⁴ Sport and Exercise Sciences Research Institute, University of Ulster, United Kingdom

⁵ Institute of Nursing and Health Research, University of Ulster, United Kingdom

Acknowledgment of financial support

This study was funded by a PhD award from the Department of Employment and Learning, Northern Ireland, UK

Conflicts of interest

None declared

* Corresponding author:

Professor Suzanne M McDonough, Room 01F118, School of Health Sciences, University of Ulster, Shore Road, Newtownabbey, Co. Antrim, BT37 0QB, United Kingdom

e-mail: s.mcdonough@ulster.ac.uk; Telephone: 00 44 2890 366459

Walking for Musculoskeletal Pain: Review**ABSTRACT**

Objective: To systematically review the evidence examining effects of walking interventions on pain and self-reported function in individuals with chronic musculoskeletal pain.

Data Sources: Six electronic databases (Medline, CINAHL, PsychINFO, PEDro, Sport Discus and the Cochrane Central Register of Controlled Trials) were searched from January 1980 up to March 2014.

Study Selection: Randomized and quasi-randomized controlled trials in adults with chronic low back pain, osteoarthritis or fibromyalgia comparing walking interventions to a non-exercise or non-walking exercise control group.

Data Extraction: Data were independently extracted using a standardized form. Methodological quality was assessed using the United States Preventative Services Task Force (USPSTF) system.

Data Synthesis: Twenty-six studies (2384 participants) were included and suitable data from 17 were pooled for meta-analysis with a random effects model used to calculate between group mean differences and 95% confidence intervals. Data were analyzed according to length of follow-up (short-term: ≤ 8 weeks post randomization; medium-term: > 2 months - 12 months; long-term: > 12 months). Interventions were associated with small to moderate improvements in pain at short (mean difference (MD) -5.31, 95% confidence interval (95% CI) -8.06 to -2.56) and medium-term follow-up (MD -7.92, 95% CI -12.37 to -3.48). Improvements in function were observed at short (MD -6.47, 95% CI -12.00 to -0.95), medium (MD -9.31, 95% CI -14.00 to -4.61) and long-term follow-up (MD -5.22, 95% CI -7.21 to -3.23).

Walking for Musculoskeletal Pain: Review

Conclusions: Evidence of fair methodological quality suggests that walking is associated with significant improvements in outcome compared to control interventions but longer-term effectiveness is uncertain. Using the USPSTF system, walking can be recommended as an effective form of exercise or activity for individuals with chronic musculoskeletal pain but should be supplemented with strategies aimed at maintaining participation. Further work is also required examining effects on important health related outcomes in this population in robustly designed studies.

Key words: Meta-analysis, walking, exercise, chronic musculoskeletal pain.

Walking for Musculoskeletal Pain: Review

Chronic musculoskeletal pain (CMP) is a major cause of morbidity.(1) Given the changing age profile of the population it is probable that its prevalence and associated costs will continue to rise.(1,2) Chronic low back pain (CLBP), osteoarthritis (OA) and fibromyalgia syndrome (FMS) are reported as being among the most common types of musculoskeletal disorder. These conditions may be associated with significant functional limitations.(2) There is also evidence that they can exert a substantial influence on long-term health status and overall quality of life.(1,3)

Current treatment recommendations support various non-pharmacological interventions, including aerobic exercise, in order to reduce pain and maintain or increase functional status.(4-6) However, randomized controlled trials have tended to report only short-term improvements in outcome with relatively small effect sizes.(7,8) This may be due to a number of factors, including heterogeneity of interventions.(9)

Walking may represent an ideal form of aerobic activity, due to its ease of accessibility and relatively low impact. It has a low risk of musculoskeletal injury,(10) and is considered safe to recommend for previously sedentary individuals.(11) Low to moderate intensity walking (described as exercising at a MET value of between 3-4 (12) or a pace that results in an increased respiratory and heart rate, but where the individual can still carry out a conversation) has been shown to lead to improvements in aerobic capacity, body mass index, systolic/diastolic blood pressures, triglyceride, and high density lipoprotein cholesterol levels in healthy sedentary individuals,(13,14) as well as in those with established cardiovascular disease (15) and type 2 diabetes.(16)

Walking for Musculoskeletal Pain: Review

Although it is widely recommended, there is currently limited evidence relating to the effectiveness of walking exercise for management of musculoskeletal disorders.(17)

The aim of this systematic review was to examine the effects of walking interventions on pain and self-reported function in adults with CMP.

METHODS

Data sources, searches and extraction

Comprehensive search strategies were carried out by at least two independent reviewers according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) recommendations and those of the Cochrane Musculoskeletal Review Group.(18,19) A review protocol was developed 'a priori' using the PICOS framework to define the research question and inclusion criteria. Six electronic databases (Medline, CINAHL, PsychINFO, PEDro, Sport Discus and the Cochrane Central Register of Controlled Trials) were searched for relevant papers published between January 1980 and March 2014 using combinations of key terms which included "walking", "aerobic exercise", "musculoskeletal pain", "low back pain", "arthritis" and "fibromyalgia" (A full list of the MeSH terms used is included in Supplementary data: Appendix A). Reference lists of included articles and key systematic reviews were also checked by hand.

All randomized or quasi-randomized studies published in full were considered for inclusion. No language restrictions were applied. Studies were required to include

Walking for Musculoskeletal Pain: Review

adults aged 18 years or over, with a diagnosis of CLBP, OA or FMS made according to clinical judgement or accepted diagnostic criteria.(6,20,21)

All land or treadmill based walking interventions were considered for inclusion. Studies were required to include a comparative non-exercise or non-walking exercise control group. Those including any form of assisted walking were excluded. Studies were also excluded if they involved peri-operative or post-operative interventions. Primary outcomes of interest were pain and self-reported function.

At least two reviewers independently examined titles and abstracts of identified studies. Full text copies of potentially eligible studies were assessed to determine whether walking formed at least half of the overall intervention. Final inclusion was determined by consensus between review authors. Data were extracted independently using a standardised form. Disagreements were resolved by consensus and involved a third author if required. Intervention and control group sample size, plus mean and standard deviation (SD) values for pain and function were extracted. Where the SD was not provided it was calculated from the standard error (SE) or 95% confidence intervals (95% CI). Where tabulated results were not presented, an attempt was made to extract data from graphs. All data were cross checked by a second author. For the purposes of comparability, outcomes were converted to a 0-100 scale (with higher scores indicating greater pain or functional limitation).

Assessment of methodological quality and adequacy of exercise interventions

The United States Preventative Services Task Force (USPSTF) system was used to assess methodological quality and form treatment recommendations based on an

Walking for Musculoskeletal Pain: Review

estimate of net benefit and the overall strength of evidence.(22) Internal validity and external validity were rated as “good”, “fair”, or “poor” according to pre-defined criteria specific to the study design.(23) (See supplementary data: Appendix B). Studies rated as “good” met all relevant criteria. Fair studies did not meet all criteria while “poor” studies were judged to contain a serious methodological flaw. Individual studies were given an overall rating, with internal and external validity considered to have equal weighting. Included studies were also screened for statements indicating sources of funding or support. Reviewers were not blinded with regards to study authors, institution, or journal of publication. All final decisions regarding quality assessment and overall recommendations were reached by consensus. Studies were also scrutinized independently to determine if the interventions met American College of Sports Medicine (ACSM) guidelines for the quantity and quality of aerobic exercise in inactive individuals based on frequency, intensity, timing, mode and duration of interventions.(24)

Data synthesis and analysis

The meta-analysis compared mean values for pain and function between walking intervention and control groups. To avoid double counting, where multiple treatment groups were included walking was compared only to minimal intervention controls. Suitable studies were considered to be clinically homogeneous on the basis of similarities in participant demographics and intervention methods. These data were pooled and analyzed using RevMan (v.5.2.8).(25) Statistical heterogeneity was assessed using the χ^2 and I^2 test statistics. Where the P value was less than 0.05 or the I^2 value greater than 50%, indicating large heterogeneity,(26) a random effects model for inverse variance was used to calculate the mean difference and 95%CI.

Walking for Musculoskeletal Pain: Review

Formal statistical tests were not used to assess publication bias, which was evaluated using visual assessment of funnel plots. Data were analyzed by length of follow-up which was categorized as short (≤ 8 weeks post randomization), medium (2-12 months) or long-term (> 12 months). Sensitivity analyses were carried out excluding studies where walking was combined with a co-intervention.

Nine articles were not included in the meta-analysis for the following reasons: no validated self-reported measure of pain or function (27,28) (one study used a functional scale that contained additional questions related to global health status and these data were therefore not included); unadjusted baseline differences between groups;(29,30) presented median data only;(31,32) change over time only(33) or did not include a measure of variability.(34) One study reported pain as an outcome but did not include these data in the paper.(35)

RESULTS**Description of studies**

The electronic database searches revealed a total of 2760 articles after exclusion of duplicates. Thirty seven of these met the inclusion criteria (see Appendix C for a list of excluded studies). Eleven were reports of follow-up data or sub-sample analyses. There were therefore 26 original studies in the review including a total of 2384 participants (Mean: 93) with an average age of 57 years (SD: 15), of whom 77% were female. The complete selection process, including reasons for exclusion is shown in Figure 1.

Walking for Musculoskeletal Pain: Review

Twenty four of the studies were randomized controlled trials. Twelve provided data for OA (27-29,31,36-43), eight for FMS (30,33-35,44-47), five for CLBP (32,48-51) and one included participants with chronic hip, lower back or knee pain.(52) Demographic details and study characteristics are summarized in Table 1 and Table 2.

In the majority of interventions (19/26, 73%) walking was supervised in a hospital clinic, gymnasium or other setting (Table 2). Some studies combined supervised walking with instructions to walk at home;(31,37,40) six were home-based only.(28,30,32,38,43,51) Three used pedometers to assist with step-based walking goals (28,43,51) while three used time-based walking goals.(30,32,38)

Thirteen studies included a walking only intervention group. The remaining combined walking with a co-intervention. The most common of which were educational interventions or alternative forms of exercise (Table 2). A range of controls were used including education; usual care; alternative forms of exercise; a passive intervention (relaxation/massage) and a 6-8 week pre-intervention baseline phase. Mean length of final follow-up was 1.8 months (SD: 0.4) for studies with short term outcomes (≤ 8 weeks post randomization); 4.9 months (SD: 1.9) for medium-term outcomes (> 2 -12 months); and 18.4 months (SD: 7.6) for long-term outcomes (> 12 months).

Eleven studies included a statement of associated adverse events. These included two falls resulting in distal radial fractures, one fall resulting in a hip fracture, one case of plantar fasciitis and two cases of allergic skin reactions to metal pedometer clips. Two studies including participants with fibromyalgia reported a general increase in reporting of pain and muscle stiffness in the intervention group. One study including participants

Walking for Musculoskeletal Pain: Review

with CLBP reported temporary exacerbations in pain levels in a small number of participants which was attributed to unaccustomed activity levels.

Methodological quality and exercise interventions

Overall, the included evidence was judged to be of at least fair methodological quality (Supplementary data: Appendix B). Six studies met all criteria for internal validity and were rated as good.(32,33,37,47,48,51) A small number of studies (n=5) contained serious potential sources of methodological bias and were therefore rated as poor.(27,28,30,31,43) This was as a result of inadequate allocation concealment during randomization,(28,30) unequal distribution of important confounding variables at baseline not accounted for during analysis,(27,30) no masking of outcome assessment,(31) or due to a substantial (>50%) drop-out rate and subsequent post hoc revision of the intervention groups examined.(29) For external validity most studies were rated as fair, with nine rated as good.(32,33,36,38,42,43,47,50,51) Studies generally included similar populations in terms of demographics and clinical presentation, as well as interventions that would be routinely available or feasible in clinical practice. Visual assessment of funnel plots indicated that there was no substantial evidence of publication bias. Only one study (27) did not include a statement indicating sources of funding or support. Ten studies (35-37,40,41,44-46,49,50) included interventions that met all ACSM criteria.(24) (Supplementary data: Appendix B) While the majority met minimum criteria for frequency of exercise and length of intervention, eleven either did not provide enough detail regarding exercise intensity, or it was not sufficient to effect any change in fitness. Eleven of the 26 studies (32,33,36,37,39,40,41,43,47,51,52) reported a measure of participant adherence (Table 2). These included attendance at exercise classes (n=7), self-

Walking for Musculoskeletal Pain: Review

- 223 reported completion of home exercise (n=2) or self-reported adherence to wearing a
224 pedometer (n=2).

Walking for Musculoskeletal Pain: Review**Meta-analysis**

Data from 17 of the included studies were suitable for meta-analysis. Although applying the alternative fixed effects model did not substantially alter any analyses, data are presented here using the more conservative random effects model. Analysis revealed significant differences in favour of walking interventions in terms of reduced pain at short (mean difference (MD) -5.31, 95% confidence interval (95% CI) -8.06 to -2.56) and medium-term follow-up (MD -7.92, 95% CI -12.37 to -3.48). No effect on pain was observed for long-term data (MD -2.22, 95% CI -6.03 to 1.59) (Figure 2). For self-reported function, improvements were found at short-term (MD -6.47, 95% CI -12.00 to -0.95), medium (MD -9.31, 95% CI -14.00 to -4.61) and long-term follow-up (MD -5.22, 95% CI -7.21 to -3.23) (Figure 3). Sensitivity analyses excluding studies which combined walking with a co-intervention did not alter overall results.

DISCUSSION

Overall findings indicated that walking interventions were associated with significant improvements in both pain and self-reported function in individuals with CMP. While effects appeared to be maintained beyond the immediate post-intervention period, only differences in function were observed at long-term follow-up. This was based primarily on data derived from interventions lasting for between six and 12 months. It is therefore unlikely that improvements in outcome would be maintained following the shorter intervention periods included in the majority of other interventions. This is supported by additional sub-sample data from one included study which indicated that

Walking for Musculoskeletal Pain: Review

significant improvements in outcome following an eight week intervention were absent at 12 months.(53)

While it has been suggested that supervised interventions may be required to maintain adherence with exercise,(7) other techniques, including those encouraging self-management, may be of benefit.(54) Walking did appear to have a slightly greater effect on function than pain outcomes. Inclusion of educational and behavioral components alongside walking in many studies may have contributed to this apparent effect; lending support to treatment approaches which place greater emphasis on improving function despite continued pain.(55) These interventions are often based on psychological theories such as operant conditioning which use positive reinforcement to reduce negative pain behaviors; for example through graded activity or pacing.(56) The underlying mechanisms contributing to these effects are uncertain but could be related to reduced fear of movement or increased self-efficacy.(55) Although co-interventions varied, there were commonalities: including that they frequently consisted of hospital or clinic-based group discussions (supplemented with written information), with condition-specific and general information on pain management strategies and advice on maintaining exercise. Some studies included additional strategies including goal setting and self-monitoring. Use of self-monitoring techniques including pedometer feedback represents a potentially useful method to increase walking in individuals with CMP disorders.(43,51) However, these methods have not been widely tested. This is reflected in the fact that only three of the included studies used pedometers. A recent study examining a remote, web-delivered pedometer intervention (excluded from this review as it compared two forms of walking) found no

Walking for Musculoskeletal Pain: Review

long-term effects on functional outcomes.(57) Further work is required examining pedometer interventions in this population which are delivered within a clinical setting.

To our knowledge, this is one of the first systematic reviews to examine the effects of walking in a range of CMP disorders. A previous review (58) examining walking for LBP (both acute and chronic) found limited evidence to support its use as a primary intervention. Roddy and co-authors (59) found aerobic walking to be equally as effective as strengthening at reducing pain and disability in knee OA. Other reviews examining the effects of general aerobic exercise interventions in CMP (7,8,60,61) have provided conflicting results, with limited evidence to support the use of any one type or intensity of exercise. While aerobic exercise may lead to improved overall well-being and physical function it is often associated with little or no difference in pain.(60,62) In contrast, others have shown slight to moderate intensity aerobic exercise to be effective at reducing pain;(8) however this latter review did not look directly at effects on functional data.

Study strengths and limitations

This review has a number of strengths, including an extensive search of the available evidence, rather than limiting inclusion to studies selected on the basis of experimental design. We also included studies which involved only walking-based interventions, allowing for examination of a more homogenous intervention type than has previously been examined. Studies were considered to be similar on the basis of clinical characteristics and intervention methods. The majority involved supervised treadmill or land-based interventions (commonly within a hospital or clinic gymnasium setting), of between six to eight weeks duration. A number of these studies included more

Walking for Musculoskeletal Pain: Review

independent home-based walking as an additional exercise element and we were therefore unable to determine the influence of treatment setting on outcomes.

We were unable to use sensitivity analysis to examine studies separately on the basis of quality as only one study included in the meta-analysis contained a potential serious methodological flaw which could have compromised its validity. Use of the USPSTF system allowed a qualitative assessment of the overall evidence to be made, and the findings and conclusions were broadly similar between this assessment method and the results of the meta-analysis.

There are some limitations which should be taken into account when considering these findings. A small number of studies had methodological limitations, including inadequate allocation concealment in randomized controlled trials or lack of an appropriate method for dealing with missing data. In six studies there was insufficient information on masking of outcome assessments and with additional information it is possible that some studies rated as “fair” may have been rated as “poor” which would influence the recommendation made on the basis of the evidence included in the review. Many studies lacked sufficient detail to assess adequacy of the exercise interventions. The overall effects of the interventions may also have been attenuated by the small number of non-intervention control groups. Furthermore, few studies reported whether there were any associated adverse events. Even among the more supervised interventions, there was limited detail regarding participant adherence. Further research is required examining interventions which use objective measurement of overall physical activity as both an important outcome and a method for increasing motivation and use of self-monitoring. Objective monitors are more accurate than

Walking for Musculoskeletal Pain: Review

subjective assessment methods, due to recall and social-desirability biases of subjective reports (63). Objective monitors such as pedometers can give immediate feedback on performance (prompting adherence), however, one limitation is that they require the user to remember to put them on. Other solutions, such as wrist worn, waterproof devices, that don't need to be removed for sleep or water based activities may offer a solution, but may not provide the same quality of visual feedback that a pedometer does. Such issues should be considered in the design of future research.

Conclusions

Meta-analysis of data from studies of at least fair methodological quality demonstrated that walking may lead to improvements in outcome, comparable to other forms of exercise. Using the USPSTF system to summarize the existing evidence, walking-based exercise can be recommended for individuals with CMP. However, robustly designed research is required examining longer-term maintenance of walking programs and their effects on important health related outcomes in this population.

AUTHOR CONTRIBUTIONS

All authors contributed to the conception and design of this review. SOC, BR, CB and SMcD were responsible for conducting the search strategies and extracting study data. SOC, MT, GDB, JB and SMcD were responsible for assessment of study quality and rating the overall strength of evidence. SOC drafted the manuscript and all authors contributed to and approved the finalised version.

Walking for Musculoskeletal Pain: Review**References**

1. Vos T, Flaxman AD, Naghavi M, et al. Years lived with disability (YLDs) for 1160 sequelae of 289 diseases and injuries 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380(9859):2163-96.
2. Reid KJ, Harker J, Bala MM, et al. Epidemiology of chronic non-cancer pain in Europe: narrative review of prevalence, pain treatments and pain impact. *Curr Med Res Opin* 2011;27:449-62.
3. Landmark T, Romundstad P, Borchgrevink PC, et al. Associations between recreational exercise and chronic pain in the general population: evidence from the HUNT 3 study. *Pain* 2011;152:2241-7.
4. Zhang W, Nuki G, Moskowitz RW, et al. OARSI recommendations for the management of hip and knee osteoarthritis Part III: changes in evidence following systematic cumulative update of research published through January 2009. *Osteoarthritis Cartilage* 2010;18:476-99.
5. The Map of Medicine and the British Pain Society. Chronic Widespread Pain including Fibromyalgia. England view, London, 2013.
6. Delitto A, George SZ, Van Dillen L, et al. Low Back Pain: Clinical Practice Guidelines Linked to the International Classification of Functioning, Disability, and

Walking for Musculoskeletal Pain: Review

Health from the Orthopaedic Section of the American Physical Therapy Association. J Orthop Sports Phys Ther 2012;42(4):A1-A57.

7. Fransen M, McConnell S. Land-based exercise for osteoarthritis of the knee: a meta-analysis of randomized controlled trials. J Rheumatol 2009;36:1109-17.

8. Häuser W, Klose P, Langhorst J, et al. Efficacy of different types of aerobic exercise in fibromyalgia syndrome: a systematic review and meta-analysis of randomised controlled trials. Arthritis Res Ther 2010;12:R79.

9. Foster NE. Barriers and progress in the treatment of low back pain. BMC Medicine 2011;27;9:108.

10. Hootman JM, Macera CA, Ainsworth BE, et al. Association among physical activity level, cardiorespiratory fitness, and risk of musculoskeletal injury. Am J Epidemiol 2001;154:251-8.

11. Colbert LH, Hootman JM, Macera CA. Physical activity-related injuries in walkers and runners in the aerobics center longitudinal study. Clin J Sport Med 2000;10:259-63.

12. Ainsworth BE, Haskell WL, Herrmann SD, et al. Compendium of Physical Activities: a second update of codes and MET values. Med Sci Sports Exerc. 2011;43(8):1575-81.

Walking for Musculoskeletal Pain: Review

13. Tully MA, Cupples ME, Hart ND, et al. Randomised controlled trial of home-based walking programmes at and below current recommended levels of exercise in sedentary adults. *J Epidemiol Community Health* 2007;61:778-83.
14. Tschentscher M, Niederseer D, Niebauer J. Health benefits of nordic walking: a systematic review. *Am J Prev Med*. 2013 Jan;44(1):76-84.
15. Eijsvogels T, George K, Shave R, et al. Effect of prolonged walking on cardiac troponin levels. *Am J Cardiol* 2010;105:267-72.
16. Johnson ST, Bell GJ, McCargar LJ, et al. Improved cardiovascular health following a progressive walking and dietary intervention for type 2 diabetes. *Diabetes Obes Metab* 2009;11:836-43.
17. Mody GM, Brooks PM. Improving musculoskeletal health: global issues. *Best Pract Res Clin Rheumatol* 2012;26(2):237-49.
18. Moher D, Liberati A, Tetzlaff J, et al. PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PRISMA Group. Ann Intern Med* 2009;151:264-9.
19. Maxwell L, Santesso N, Tugwell PS, et al. Method guidelines for Cochrane Musculoskeletal Group systematic reviews. *J Rheumatol* 2006;33:2304-11.
20. Zhang W, Doherty M, Peat G, et al. EULAR evidence-based recommendations for the diagnosis of knee osteoarthritis. *Ann Rheum Dis* 2010;69:483-9.

Walking for Musculoskeletal Pain: Review

21. Wolfe F, Clauw DJ, Fitzcharles MA, et al. The American College of Rheumatology preliminary diagnostic criteria for fibromyalgia and measurement of symptom severity. *Arthritis Care Res* 2010;62:600-10.
22. Sawaya GF, Guirguis-Blake J, LeFevre M, et al. U.S. Preventive Services Task Force. Update on the methods of the U.S. Preventive Services Task Force: estimating certainty and magnitude of net benefit. *Ann Intern Med* 2007;147:871-75.
23. Harris RP, Helfand M, Woolf, SH, et al. Methods work group, Third US Preventive Services Task Force, 2001. Current methods of the US Preventive Services Task Force: a review of the process. *Am J Prev Med*, 20(Supplement 3):21-35.
24. American College of Sports Medicine. ACSM's Guidelines for Exercise Testing and Prescription. 9th edn. Philadelphia, USA: Lippincott Williams & Wilkins. 2009.
25. Review Manager (RevMan) [Computer program]. Version 5.0. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2008.
26. Higgins JPT, Thompson SG, Deeks JJ, et al. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557-60.
27. Bautch JC, Clayton MK, Chu Q, et al. Synovial fluid chondroitin sulphate epitopes 3B3 and 7D4, and glycosaminoglycan in human knee osteoarthritis after exercise. *Ann Rheum Dis* 2000;59:887-91.

Walking for Musculoskeletal Pain: Review

28. Hiyama Y, Yamada M, Kitagawa A, et al. A four-week walking exercise programme in patients with knee osteoarthritis improves the ability of dual-task performance: a randomized controlled trial. *Clin Rehabil* 2012; 26(5):403-12.
29. Bautch JC, Malone DG, Vailas AC. Effects of exercise on knee joints with osteoarthritis: a pilot study of biologic markers. *Arthritis Care Res* 1997;10:48-55.
30. Meyer BB, Lemley KJ. Utilizing exercise to affect the symptomology of fibromyalgia: a pilot study. *Med Sci Sports Exerc* 2000;32:1691-7.
31. Dias RC, Dias JM, Ramos LR. Impact of an exercise and walking protocol on quality of life for elderly people with OA of the knee. *Physiother Res Int* 2003;8:121-130.
32. Rasmussen-Barr E, Ang B, Arvidsson I, et al. Graded Exercise for Recurrent Low-Back Pain. A Randomized, Controlled Trial With 6-, 12-, and 36-Month Follow-ups. *Spine* 2009;34:221-228.
33. Lemstra M, Olszynski WP. The effectiveness of multidisciplinary rehabilitation in the treatment of fibromyalgia: a randomized controlled trial. *Clin J Pain* 2005;21:166-74.
34. Holtgreffe K, McCloy C, Rome L. Changes associated with a quota-based approach on a walking program for individuals with fibromyalgia. *J Orthop Sports Phys Ther* 2007;37:717-24.

Walking for Musculoskeletal Pain: Review

35. Martin L, Nutting A, MacIntosh BR, et al. An exercise program in the treatment of fibromyalgia. *J Rheumatol* 1996;23:1050-3.

36. Brosseau L, Wells GA, Kenny GP, et al. The implementation of a community-based aerobic walking program for mild to moderate knee osteoarthritis: A knowledge translation randomized controlled trial: Part II: Clinical outcomes. *BMC Public Health*. 2012 Dec 12;12(1):1073.

37. Ettinger WH, Burns R, Messier SP, et al. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis and Seniors Trial (FAST). *JAMA* 1997;277:25-31.

38. Evcik D, Sonel B. Effectiveness of a home-based exercise therapy and walking program on osteoarthritis of the knee. *Rheumatol Int* 2002;22:103-6.

39. Kovar PA, Allegrante JP, MacKenzie CR, et al. Supervised fitness walking in patients with osteoarthritis of the knee. A randomized, controlled trial. *Ann Intern Med* 1992;116:529-534.

40. Messier SP, Loeser RF, Miller GD, et al. Exercise and Dietary Weight Loss in Overweight and Obese Older Adults With Knee Osteoarthritis: The Arthritis, Diet, and Activity Promotion Trial. *Arthritis Rheum* 2004;50:1501-10.

Walking for Musculoskeletal Pain: Review

491 41. Miller GD, Nicklas BJ, Davis C, et al. Intensive Weight Loss Program Improves
492 Physical Function in Older Obese Adults with Knee Osteoarthritis. *Obesity*
493 2006;14:1219-30.

495 42. Schlenk EA, Lias JL, Sereika SM, et al. Improving physical activity and function in
496 overweight and obese older adults with osteoarthritis of the knee: a feasibility study.
497 *Rehabil Nurs* 2011;36(1):32-42.

499 43. Talbot LA, Gaines JM, Huynh TN, et al. A Home-Based Pedometer-Driven Walking
500 Program to Increase Physical Activity in Older Adults with Osteoarthritis of the Knee: A
501 Preliminary Study. *J Am Geriatr Soc* 2003;51:387-92.

503 44. Bircan C, Karasel SA, Akgün B, et al. Effects of muscle strengthening versus
504 aerobic exercise program in fibromyalgia. *Rheumatol Int* 2008;28:527-32.

506 45. Nichols DS, Glenn TM. Effects of aerobic exercise on pain perception, affect, and
507 level of disability in individuals with fibromyalgia. *Phys Ther* 1994;74:327-32.

509 46. Valim V, Oliveira L, Suda A, et al. Aerobic fitness effects in fibromyalgia. *J Rheum*
510 2003;30:1060-9.

512 47. Rooks DS, Gautam S, Romeling M, et al. Group exercise, education, and
513 combination self-management in women with fibromyalgia: a randomized trial. *Arch*
514 *Intern Med* 2007;167:2192-200.

Walking for Musculoskeletal Pain: Review

48. Hartvigsen J, Morsø L, Bendix T, et al. Supervised and non-supervised Nordic walking in the treatment of chronic low back pain: a single blind randomized clinical trial. *BMC Musculoskelet Disord.* 2010;10:30.

49. Koldaş Doğan S, Sonel Tur B, Kurtaiş Y et al. Comparison of three different approaches in the treatment of chronic low back pain. *Clin Rheumatol* 2008;27:873-81.

50. Shnayderman I, Katz-Leurer M. An aerobic walking programme versus muscle strengthening programme for chronic low back pain: a randomized controlled trial. *Clin Rehabil.* 2012 Jul 31. [Epub ahead of print]

51. McDonough SM, Tully MA, Boyd A, O'Connor SR, Kerr DP, O'Neill SM, Delitto A, Bradbury I, Tudor-Locke C, Baxter GD, Hurley DA. Pedometer-driven walking for chronic low back pain: a feasibility randomized controlled trial. *Clin J Pain.* 2013;29(11):972-81.

52. Ferrell BA, Josephson KR, Pollan AM, et al. A randomized trial of walking versus physical methods for chronic pain management. *Aging* 1997;9:99-105.

53. Sullivan T, Allegrante JP, Peterson MG et al. One-year follow up of patients with osteoarthritis of the knee who participated in a program of supervised fitness walking and supportive patient education. *Arthritis Care Res* 1998;11:228-33.

Walking for Musculoskeletal Pain: Review

54. Jordan JL, Holden MA, Mason EE, et al. Interventions to improve adherence to exercise for chronic musculoskeletal pain in adults. *Cochrane Database Syst Rev* 2010;1:CD005956.
55. Greaves CJ, Sheppard KE, Abraham C, et al. IMAGE Study Group. Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. *BMC Public Health* 2011;11:119.
56. Vincent HK, Seay AN, Montero C, et al. Kinesiophobia and fear-avoidance beliefs in overweight older adults with chronic low-back pain: relationship to walking endurance--part II. *Am J Phys Med Rehabil*. 2013;92(5):439-45.
57. Krein SL, Kadri R, Hughes M et al. Pedometer-based internet-mediated intervention for adults with chronic low back pain: randomised controlled trial. *J Med Internet Res* 2013;15(8)e181.
58. Hendrick P, Te Wake AM, Tikkisetty AS, et al. The effectiveness of walking as an intervention for low back pain: a systematic review. *Eur Spine J* 2010;19(10)1613-20.
59. Roddy E, Zhang W, Doherty M. Aerobic walking or strengthening exercise for osteoarthritis of the knee? A systematic review. *Ann Rheum Dis* 2005;64:544-48.
60. Busch AJ, Barber KA, Overend TJ, et al. Exercise for treating fibromyalgia syndrome. *Cochrane Database Syst Rev* 2007; 4: CD003786.
61. Brosseau L, MacLeay L, Robinson V, et al. Intensity of exercise for the treatment of osteoarthritis. *Cochrane Database Syst Rev* 2003;2:CD004259.

Walking for Musculoskeletal Pain: Review

562

563 62. Ribaud A, Tavares I, Viollet E, Julia M, Hérisson C, Dupeyron A. Which physical
564 activities and sports can be recommended to chronic low back pain patients after
565 rehabilitation? Ann Phys Rehabil Med. 2013;56(7-8):576-94.

566

567 63. Westerterp KR. Assessment of physical activity: a critical appraisal. Eur J Appl
568 Physiol. 2009;105:823-828

569

570

571

572

573

574

575

576

577

578

579

580

581

582

583

584

585

586

Walking for Musculoskeletal Pain: Review

- 587 Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses
588 (PRISMA) flow diagram showing process of selection for systematic review (16)
589
- 590 Figure 2. Effect of walking on pain (/100) compared to control interventions
591
- 592 Figure 3. Effect of walking on self-reported function (/100) compared to control
593 interventions

Walking for Musculoskeletal Pain: Review

594

ACCEPTED MANUSCRIPT

Walking for Musculoskeletal Pain: Review

595

ACCEPTED MANUSCRIPT

Table 1. Summary of demographic information from individual studies (studies included in the meta-analysis are highlighted in bold)

Study	Condition	Diagnostic Criteria	Duration of Symptoms (years) Mean (SD)	Age (years) Mean (SD)	Gender (% Female)	Mass (kg) / BMI (Kg/m ²) Mean (SD)
Bautch et al, 2000 (27)	OA knee	Clinical diagnosis according to ACR criteria *	-	69.7 (1.9)	66.7	- / 28.6 (1.0)
Bautch et al, 1997 (29)	OA knee	Clinical diagnosis according to ACR criteria *	-	69.0 (2.3) ‡	72.7 ‡	- / 28.7 (1.2)
Bircan et al, 2008 (44)	FM	Clinical diagnosis according to ACR criteria †	4.2 (4.3)	47.2 (9.5)	100	- / -
Brosseau et al, 2012 (36)	OA knee	Clinical diagnosis according to ACR criteria †	10.3 (9.3)	63.4 (8.6)	68.9	82.2 (16.6) / 29.8 (5.4)
Dias et al, 2003 (31)	OA knee	-	-	75 § (65-89 #)	86.4	- / -
Ettinger et al, 1997 (37)	OA knee	Radiographic evidence	-	68.6 (6.1)	70.4	- / -
Evcik et al, 2002 (38)	OA knee	Clinical and radiographic assessment using Kellgren & Lawrence criteria	8.1 (3.3)	56.3 (6.5)	68.9	- / -
Ferrell et al, 1997 (52)	cMSK pain **	Clinical diagnosis of 'stable' lower extremity / mechanical LBP (>3 months)	-	73.2 (3.7)	21.1	- / -
Hartvigsen et al, 2010 (48)	cLBP	Clinical diagnosis	-	46.7 (10.9)	71.6	- / -
Hiyama et al, 2012 (28)	OA knee	Clinical diagnosis	-	72.8 (5.4)	100	59.4 (6.9) / 23.7 (2.1)
Holtgrafe et al, 2007 (34)	FM	Clinical diagnosis according to ACR criteria †	4.3 (4.7)	52.3 (18.1)	100	- / 27.9 (5.7)
Koldas Dogan	cLBP	-	4.5 (5.5)	42.1 (9.5)	78.2	- / -

et al, 2008 (49)						
Kovar et al, 1992 (39)	OA knee	Clinical and Radiographic evidence	-	69.4 (10.2)	83.4	- / -
Lemstra et al, 2005 (33)	FM	Clinical diagnosis	10.1 (15.6)	49.4 (16.3)	84.6	-
Martin et al, 1996 (35)	FM	Clinical diagnosis according to ACR criteria †	14.1 (7.2)	44.8 (9.8)	97.4	- / -
McDonough et al, 2013 (51)	cLBP	Clinical diagnosis	10.7 (7.7)	49.5 (20.1)	55.3	28.5 (6.9)
Messier et al, 2004 (40)	OA knee	Clinical and radiographic assessment using Kellgren & Lawrence criteria	-	68.6 (0.4)	72.8	95.1 (1.2) / 34.6 (0.3)
Meyer et al, 2000 (30)	FM	Clinical diagnosis according to ACR criteria †	13.1 (15.5)	49.5 (6.3)	100	- / -
Miller et al, 2006 (41)	OA knee	Self-report + clinical diagnosis	-	69.5 (0.9) 	62.1	97.8 (16.6) / 34.6 (4.4)
Nichols et al, 1994 (45)	FM	Clinical diagnosis according to ACR criteria †	-	53.1 (11.5)	91.6	- / -
Rasmussen-Barr et al, 2009 (30)	cLBP	Clinical diagnosis	14.5 (1-38) #	57 (11.0)	2.8	76 (15) / 24.8 ¶
Rooks et al, 2007 (47)	FM	Clinical diagnosis according to ACR criteria †	5.7 (4.7)	49.7 (11.3) ‡	100	76 (16.5) / 29.3 (6.2)
Schlenk et al, 2011 (42)	OA knee	Physician-confirmed diagnosis	11.3 (12.0)	63.2 (9.8)	96.0	- / 33.3 (6.0)
Shnayderman et al, 2012 (50)	cLBP	Clinical diagnosis (≥ 12 weeks)	-	45.3 (11.7)	78.8	73.9 (14.5) / 28.3(4.9)
Talbot et al, 2003 (43)	OA knee	Radiographic assessment using Kellgren & Lawrence criteria	-	70.2 (5.5)	76.5	- / 31.8 (6.4)
Valim et al, 2003 (46)	FM	Clinical diagnosis	-	45.5 (10.5)	100	- / -

- = Not reported. OA = Osteoarthritis. FM = Fibromyalgia. cLBP = chronic Low Back Pain. * = American College of Rheumatology criteria for diagnosis of osteoarthritis. † = American College of Rheumatology criteria for diagnosis of fibromyalgia. ‡ = presents only demographic data from subjects who completed

study not total sample. § = median value. || = Standard error of mean (SEM). ¶ = Where not stated in paper value calculated based on mean mass and therefore unable to calculate SD. # = only range reported. ** = chronic musculoskeletal pain (hip, lower back and knee pain).

Table 2. Summary of methodological characteristics of individual studies (studies included in the meta-analysis are highlighted in bold)

Study design & blinding	Total sample	Walking group	Control group	Duration of intervention (months)	Reported adherence (%) †	Time point of follow-up assessment(s) (post-randomization): Drop out; N (%)
Bautch et al, 2000 (27) RCT/B	30	Education + treadmill walking	Education	3 m	-	3 m: 9 (30)
Bautch et al, 1997 (29) RCT/B	34	Education + treadmill walking	Education	3 m	-	3 m: 4 (11.7)
Bircan et al, 2008 (44) RCT/-	30	Treadmill walking	General Strengthening exercise	2 m	-	2 m: 4 (13.3)
Brosseau et al, 2012 (36) RCT/B	222	Supervised walking	Education	12 m	79.0	3 m: 37 (16.6) 6 m: 19 (8.5) 9 m: 17 (7.6) 12 m: 14 (6.3) 15 m: 5 (2.3) 18 m: 8 (3.6)
Dias et al, 2003 (31) RCT/B	50	Education + supervised exercise + home based walking	Education	1.5 m	-	3 m: - 6 m: 3 (6)
Ettinger et al, 1997 (37) RCT/B	439	Facility and home based walking	Education	18 m	68.0	3 m: 47 (10.7) 9 m: 82 (18.6) 18 m: 75 (17.1)
Evcik et al, 2002 (38) NRS/-	90	Home based walking	Instructed to continue with normal daily activities	3 m	-	6 m: 9 (10)

Ferrell et al, 1997 (52) RCT/-	33	Supervised walking on outdoor track or gymnasium	Pain management information	1.5 m	93.0	2 w: - 2 m: 4 (12.2)
Hartvigsen et al, 2010 (48) RCT/B	136	Supervised Nordic walking	Education	2 m	-	2 m: 10 (7.4) 6 m: 0 12 m: 0
Hiyama et al, 2012 (28) RCT/B	40	Home based walking (with pedometer) + ice + general home exercises	Ice + general home exercises	1 m	-	1 m: 0
Holtgrafe et al, 2007 (34) NRS/B	3	Hospital based indoor walking	Pre-intervention, baseline phase	2 m	-	2 m: -
Koldas Dogan et al, 2008 (49) RCT/-	60	Treadmill based exercise	General home exercises	1.5 m	-	1.5 m: 5 (8.3) 2.5 m: 5 (8.3)
Kovar et al, 1992 (39) RCT/B	102	Hospital based supervised walking + education	Contacted by phone to discuss nature of daily activities	2 m	87.5	2 m: 10 (9.8)
Lemstra et al, 2005 (33) RCT/B	79	Supervised aerobic exercise + massage + education	Standard care	1.5 m	90.6	1.5 m: 7 (8.8) 15 m: 8 (10.2)
Martin et al, 1996 (35) RCT/B	60	Supervised walking + strength and flexibility training	Relaxation sessions	1.5 m	-	1.5 m: 20 (33.3)
McDonough et al, 2013 (51) fRCT/B	56	Pedometer based walking + education	Education	2 m	73.0	2 m: 7 (12.5) 6 m: 8 (14.3)
Messier et al, 2004 (40) RCT/B	316	Facility and home based aerobic + lower limb resistance training	Usual Care	18 m	60.0	6 m: 41 (12.9) 18 m: 64 (20.2)
Meyer et al, 2000 (30) RCT/-	21	Home based walking	Instructed to maintain current activity levels	6 m	-	6 m: - 18 m: - (57.2)

Miller et al, 2006 (41) RCT/-	87	Education + facility / home based lower limb strengthening + aerobic training*	Education	6 m	77.5	6 m: 8 (9.1)
Nichols et al, 1994 (45) RCT/-	24	Supervised indoor walking program	Instructed to continue with usual daily activities	2 m	-	2 m: 5 (20.8)
Rasmussen-Barr et al, 2009 (32) RCT/B	71	Instructed to walk each day plus given general home exercises	Specific stabilization exercises with bio-pressure unit	2 m	71.0	6 m: 7 (9.8) 12 m: 10 (14.8) 36m: 15 (21.2)
Rooks et al, 2007 (47) RCT/B	207	Treadmill walking + flexibility training	Education	3 m	73.0	3 m: 72 (20.2)
Schlenk et al, 2011 (42) RCT/B	26	Fitness walking + Education	Usual care + Education	6 m	-	6 m: 5 (19.2) 12 m : 5 (19.2)
Shnayderman et al, 2012 (50) RCT/B	52	Treadmill walking	General strengthening exercise	1.5 m	-	1.5 m: 9 (17.3)
Talbot et al, 2003 (43) RCT/UB	40	Pedometer based walking	Education	3 m	76.0	3 m: - 6 m: 6 (15)
Valim et al, 2003 (46) RCT/B	76	Supervised walking	General stretching exercises	5 m	-	2.5 m: - 5 m: 16 (21.1)

RCT: Randomized Controlled Trial. fRCT: Feasibility Randomized Controlled Trial. URT: Uncontrolled Randomized Trial. NRS: Non Randomized Study. B: Blinded outcome assessment. U: Unblinded. - = Not reported. * Walking primary mode of aerobic exercise. † Percentage adherence reported as total number of classes attended; self-reported completion of home exercise or self-reported adherence to wearing a pedometer. w: weeks. m: months.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram showing process of selection for systematic review (16)

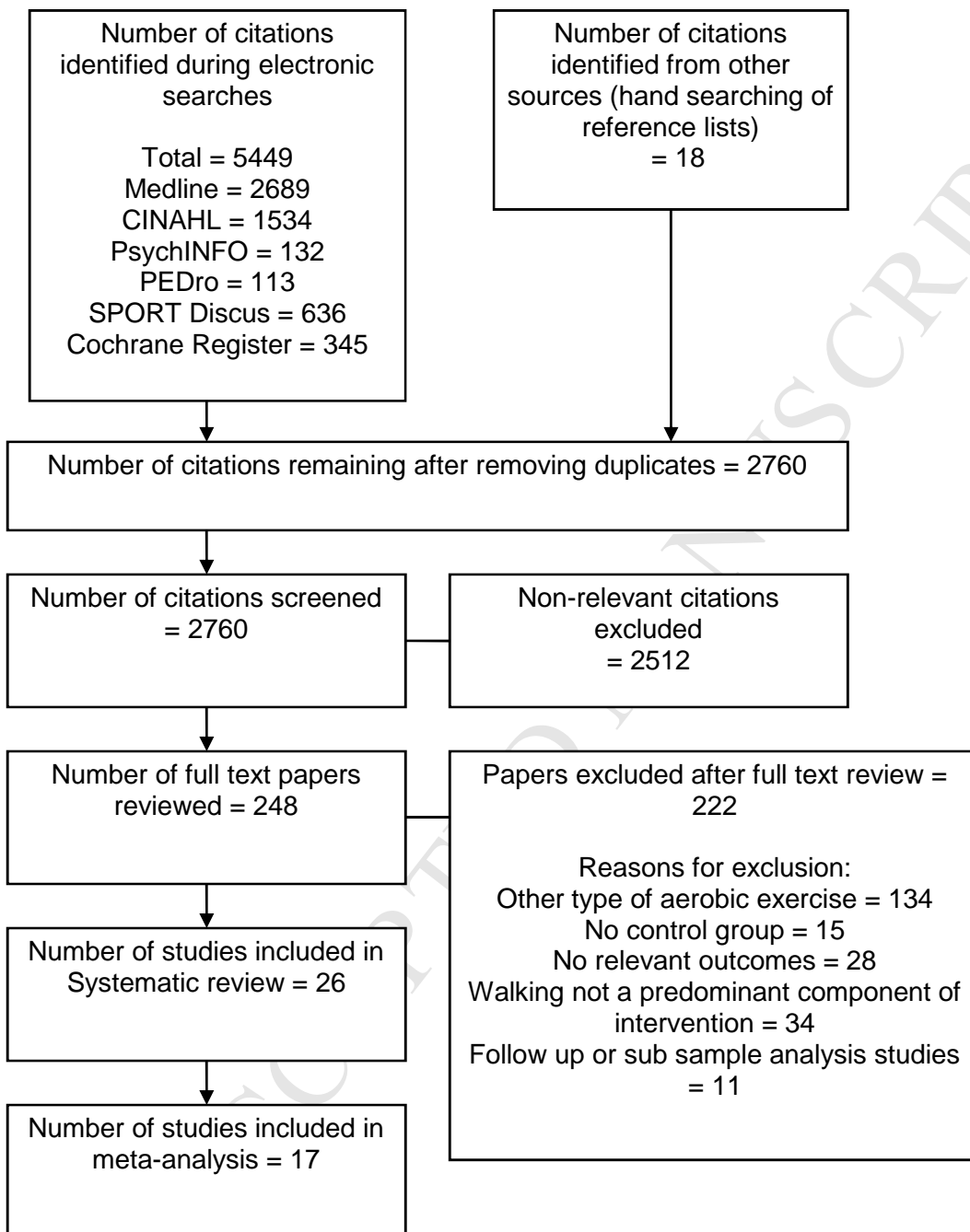


Figure 2. Effect of walking on pain (/100) compared to control interventions

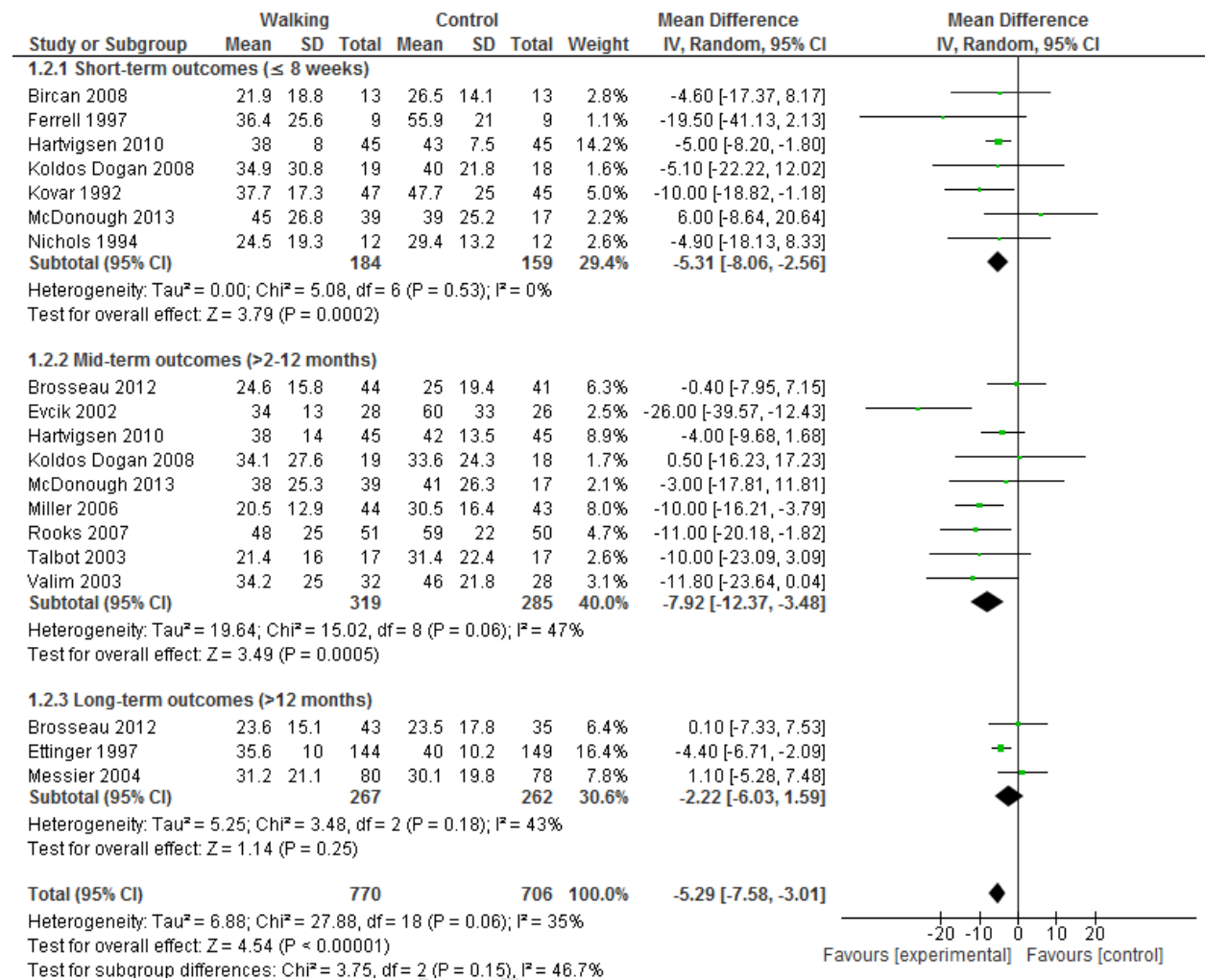
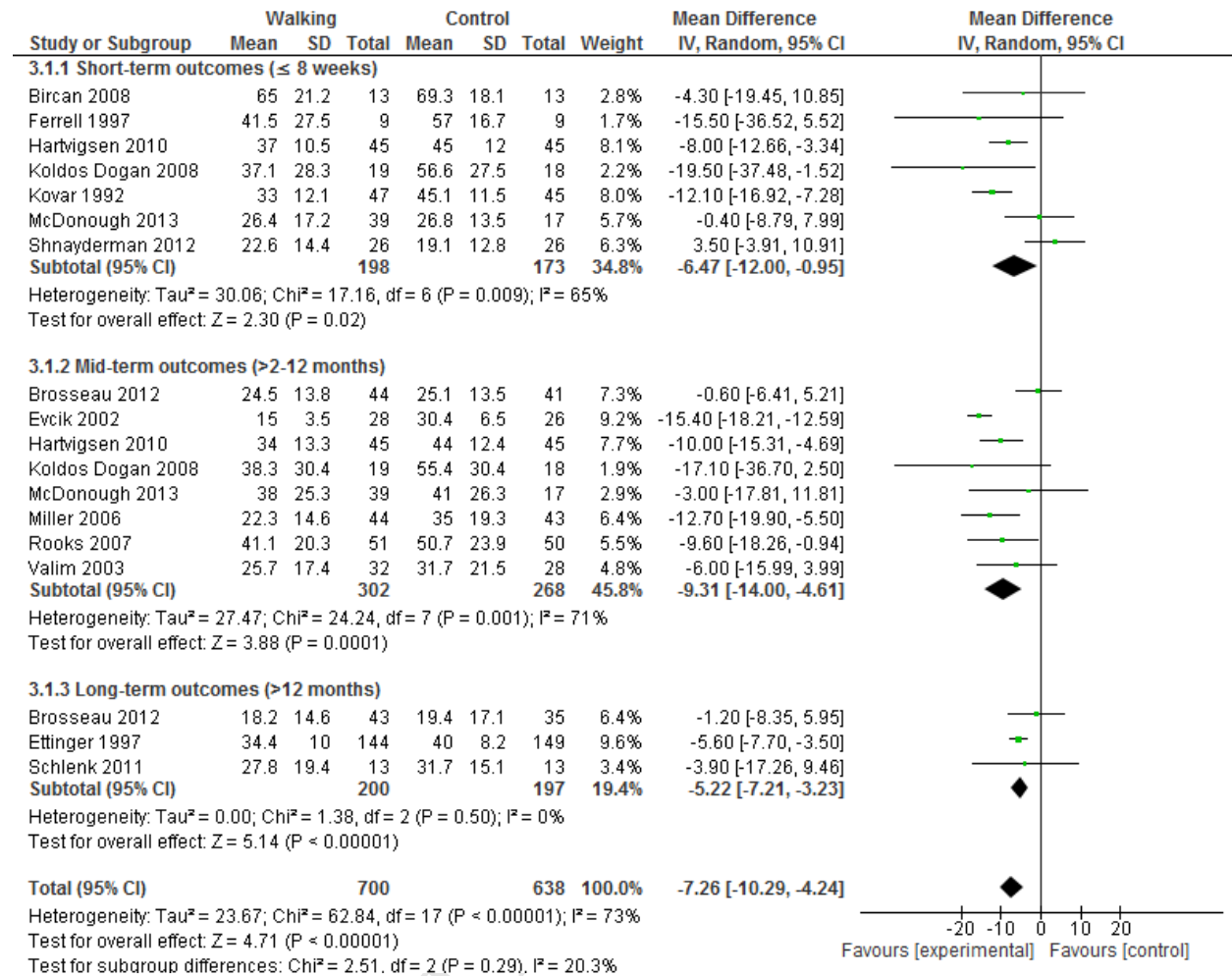


Figure 3. Effect of walking on self-reported function (/100) compared to control interventions

Supplementary data: Appendix A. Medical Subject Heading (MeSH) terms used for identification of relevant studies

Medline (via Ovid) search strategy:

Searches
 1 motor activity.de.
 2 walk\$.de.
 3 lifestyle.mp. [mp=title, abstract, original title, name of substance word,
 4 subject heading word, protocol supplementary concept, rare disease
 5 supplementary concept, unique identifier]
 6 free-living activit\$.mp. [mp=title, abstract, original title, name of substance
 7 word, subject heading word, protocol supplementary concept, rare disease
 8 supplementary concept, unique identifier]
 9 accelerometer\$.mp. [mp=title, abstract, original title, name of substance
 10 word, subject heading word, protocol supplementary concept, rare disease
 11 supplementary concept, unique identifier]
 12 pedometer\$.mp. [mp=title, abstract, original title, name of substance word,
 13 subject heading word, protocol supplementary concept, rare disease
 14 supplementary concept, unique identifier]
 15 activity monitor\$.mp. [mp=title, abstract, original title, name of substance
 16 word, subject heading word, protocol supplementary concept, rare disease
 17 supplementary concept, unique identifier]
 18 physical fitness.de.
 19 exercise therapy.de.
 20 aerobic\$.mp.
 21 exercis\$.mp.
 22 physical exercise.mp.
 23 Musculoskeletal pain.mp.
 24 Musculoskeletal diseases.mp.
 25 dorsalgia.mp.
 26 backache.mp.
 27 back pain.mp.
 28 Low back pain.de.
 29 fibromyalgia.mp.
 30 fibromyalgia syndrome.mp.
 31 arthritis.mp.
 32 osteoarthritis.mp.
 33 rehabilitation.de.
 34 morbidity.de.
 35 mortality.de.
 36 randomised controlled trial.mp.
 37 controlled clinical trial.mp.
 38 double blind method.mp.
 39 single-blind method.mp.
 40 1 or 2 or 3 or 4 or 5 or 6 or 7
 41 8 or 9 or 10 or 11 or 12
 42 13 or 14
 43 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22
 44 23 or 24 or 25
 45 26 or 27 or 28 or 29
 46 30 and 31
 47 32 and 36
 48 33 and 36

39 30 and 34
40 33 and 35 and 36
41 33 or 35 or 36
42 30 or 33
43 limit 42 to yr="1980-Current"
44 30 or 32
45 limit 44 to yr="1980-Current"
46 35 and 43
47 35 and 45
48 33 and 35 and 36
49 limit 44 to yr="1980-Current"
50 31 and 33
51 limit 50 to yr="1980-Current"

Supplementary data: Appendix B. Quality assessment and adequacy of exercise intervention criteria for individual studies (studies included in the meta-analysis are highlighted in bold)

Study	Internal validity	External validity	ACSM criteria met
Bautch et al, 2000 (27)	Poor	Fair	1,3,4,5
Bautch et al, 1997 (29)	Fair	Fair	1,3,4,5
Bircan et al, 2008 (44)	Fair	Fair	1,2,3,4,5
Brosseau et al, 2012 (36)	Fair	Good	1,2,3,4,5
Dias et al, 2003 (31)	Poor	Fair	1,3,4,5
Ettinger et al, 1997 (37)	Good	Fair	1,2,3,4,5
Evcik et al, 2002 (38)	Fair	Good	1,4,5
Ferrell et al, 1997 (52)	Fair	Fair	1,2,4,5
Hartvigsen et al, 2010 (48)	Good	Fair	1,3,4,5
Hiyama et al, 2012 (28)	Poor	Fair	4
Holtgrafe et al, 2007 (34)	Fair	Fair	1,2,4,5
Koldas Dogan et al, 2008 (49)	Fair	Fair	1,2,3,4,5
Kovar et al, 1992 (39)	Fair	Fair	1,3,4,5
Lemstra et al, 2005 (33)	Good	Good	1,2,4,5
Martin et al, 1996 (35)	Fair	Fair	1,2,3,4,5
McDonough et al, 2013 (51)	Good	Good	1,4,5
Messier et al, 2004 (40)	Fair	Fair	1,2,3,4,5
Meyer et al, 2000 (30)	Poor	Fair	1,4,5
Miller et al, 2006 (41)	Fair	Fair	1,2,3,4,5
Nichols et al, 1994 (45)	Fair	Fair	1,2,3,4,5
Rasmussen-Barr et al, 2009 (32)	Good	Good	1,4,5
Rooks et al, 2007 (47)	Good	Good	1,3,4,5
Schlenk et al, 2011 (42)	Fair	Good	4,5
Shnayderman et al, 2012 (50)	Fair	Good	1,2,3,4,5
Talbot et al, 2003 (43)	Poor	Good	1,4,5
Valim et al, 2003 (46)	Fair	Fair	1,2,3,4,5

Using the following guideline criteria, internal and external validity of individual studies were judged as “good” “fair” or “poor” based on the following guideline criteria:

For internal validity: (1) Initial assembly of comparable groups: For RCTs: Adequate randomization including concealment and whether potential confounders were distributed equally among groups. (2) Maintenance of comparable groups (includes attrition, crossovers, adherence, and contamination). (3) Important differential loss to follow-up or overall high loss to follow-up. (4) Measurements: equal, reliable, and valid (includes masking of outcome assessment). (5) Clear definition of interventions. (6) All important outcomes considered. (7) Analysis: Intention-to treat analysis used for RCTs.

For external validity: (1) Biologic plausibility. (2) Similarities of the populations studied and primary care patients (in terms of risk factor profile, demographics, ethnicity, gender, clinical presentation, and similar factors). (3) Similarities of the test or intervention studied to those that would be routinely available or feasible in typical practice. (4) Clinical or social

environmental circumstances in the studies that could modify the results from those expected in a primary care setting.

American College of Sports Medicine (ACSM) criteria for assessment of the adequacy of exercise interventions in individual studies: (1) Frequency of exercise of at least three days per week or twice a week for deconditioned individuals. (2) Intensity of exercise sufficient to achieve equal to or greater than 40% of heart rate reserve (min-max: 40-85%) or 64% of predicted maximum heart rate (min-max: 64-94%). (3) Sessions of at least 20 minutes duration (min-max: 20-60 minutes), either as continuous exercise or spread intermittently throughout the day in blocks of 10 minutes or more. (4) A mode of aerobic exercise involving major muscle groups in rhythmic activities. (5) Intervention should last for a minimum of six weeks.

Supplementary data: Appendix C. List of studies excluded from the systematic review where walking was not considered to be the predominant component of the intervention

Bendix, AF, Bendix T, Lund C, et al. Comparison of three intensive programs for chronic low back pain patients: a prospective, randomized, observer-blinded study with one-year follow-up. *Scandinavian Journal of Rehabilitation Medicine*, 1997;29(2):81-89

Buckelew SP, Conway R, Parker J et al. Biofeedback/relaxation training and exercise interventions for fibromyalgia: a prospective trial. *Arthritis Care and Research*, 11(3):196-209

Burckhardt CS, Mannerkorpi K, Hedenberg L. A randomized, controlled clinical trial of education and physical training for women with fibromyalgia. *Journal of Rheumatology*, 1994;21(4):714-720

Chatzitheodorou D, Kabitsis C, Malliou P. et al. A pilot study of the effects of high-intensity aerobic exercise versus passive interventions on pain, disability, psychological strain, and serum cortisol concentrations in people with chronic low back pain. *Physical Therapy*, 2007;87(3):304-312

Gowans SE, Dehueck A, Voss S et al. A randomized, controlled trial of exercise and education for individuals with fibromyalgia. *Arthritis Care and Research*, 1999;12(2):120-128

Gowans SE, Dehueck A, Voss S et al. Effect of a randomized, controlled trial of exercise on mood and physical function in individuals with fibromyalgia. *Arthritis and Rheumatism*, 2001;45(6):519-529

Martin K, Fontaine KR, Nicklas BJ, et al. Weight loss and exercise walking reduce pain and improve physical functioning in overweight postmenopausal women with knee osteoarthritis. *Journal of Clinical Rheumatology*, 2001;7(4):219-223

McCain GA, BELL DA, MAI FM ET AL. A controlled study of the effects of a supervised cardiovascular fitness training program on the manifestations of primary fibromyalgia. *Arthritis and Rheumatism*, 1988;31(9):1135-1141

- 32 Meiworm I, Jakob E, Walker UA et al. Patients with fibromyalgia benefit from aerobic
33 endurance exercise. *Clinical Rheumatology*, 2000;19(4):253-257
34
- 35 Mengshoel, AM, Komnaes HB, Førre O. The effects of 20 weeks of physical fitness training
36 in female patients with fibromyalgia. *Clinical and Experimental Rheumatology*,
37 1992;10(4):345-349
38
- 39 Mirovsky Y, Grober A, Blankstein A. et al. The effect of ambulatory lumbar traction
40 combined with treadmill on patients with chronic low back pain. *Journal of Back and*
41 *Musculoskeletal Rehabilitation*, 2006;19(2-3):73-78
- 42 Richards SC, Scott DL. Prescribed exercise in people with fibromyalgia: parallel group
43 randomised controlled trial. *British Medical Journal*, 2002;27;325(7357):185
- 44 Saltska E, Jentoft R, Grimstedt AK. et al. Effects of Pool-Based and Land-Based Aerobic
45 Exercise on Women With Fibromyalgia/Chronic Widespread Muscle Pain. *Arthritis Care*
46 *and Research*, 2001;45:42-47
- 47 Sculco AD, Paup DC, Fernhall B. et al. Effects of aerobic exercise on low back pain
48 patients in treatment. *Spine Journal*, 2001;1(2):95-101
- 49 Schachter, CI, Busch AJ, Peloso PM. et al. Effects of short versus long bouts of aerobic
50 exercise in sedentary women with fibromyalgia: a randomized controlled trial. *Physical*
51 *Therapy*, 2003;83(4):340-358
- 52 Sjogren T, Long N, Storay I. et al. Group hydrotherapy versus group land-based treatment
53 for chronic low back pain. *Physiotherapy Research International*, 1997;2(4):212-222
- 54 Thorstensson CA, Roos EM, Petersson IF et al. Six-week high-intensity exercise program
55 for middle-aged patients with knee osteoarthritis: a randomized controlled trial
56 [ISRCTN20244858]. *BMC Musculoskeletal Disorders*, 2005;6:27
- 57 Tritilanunt T, Wajanavisit W. The efficacy of an aerobic exercise and health education
58 program for treatment of chronic low back pain. *Journal of the Medical Association of*
59 *Thailand*, 2001;84:S2:S528-533
- 60 Wigers SH, Stiles TC, Vogel PA. et al. Effects of aerobic exercise versus stress
61 management treatment in fibromyalgia. A 4.5 year prospective study. *Scandinavian*
62 *Journal of Rheumatology*, 1996;25(2):77-86

- Yip YB, Sit JW, Gung KK et al. Effects of a self-management arthritis programme with an added exercise component for osteoarthritic knee: randomized controlled trial. *Journal of Advanced Nursing*, 2007;59(1):20-28
- Chan CW, Mok NW, Yeung EW. Aerobic exercise training in addition to conventional physiotherapy for chronic low back pain: a randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, 2011;92(10):1681-5
- Rantonen J. Luoto S. Vehtari A. et al. The effectiveness of two active interventions compared to self-care advice in employees with non-acute low back symptoms: a randomised, controlled trial with a 4-year follow-up in the occupational health setting. *Occupational & Environmental Medicine*, 2012;69(1):12-20
- Sanudo B. Carrasco L. de Hoyo M. et al. Effects of exercise training and detraining in patients with fibromyalgia syndrome: a 3-yr longitudinal study. *American Journal of Physical Medicine & Rehabilitation*, 2012;91(7):561-9
- Hooten WM. Qu W. Townsend CO. et al. Effects of strength vs aerobic exercise on pain severity in adults with fibromyalgia: a randomized equivalence trial. *Pain*, 2012;153(4):915-23. .
- Jensen RK. Leboeuf-Yde C. Wedderkopp N. et al. Rest versus exercise as treatment for patients with low back pain and Modic changes. A randomized controlled clinical trial. *BMC Medicine*, 2012;10:22
- Hurley MV. Walsh NE. Mitchell H. et al. Long-term outcomes and costs of an integrated rehabilitation program for chronic knee pain: a pragmatic, cluster randomized, controlled trial. *Arthritis care & research*, 2012;64(2):238-47