Published in final edited form as:

Arch Phys Med Rehabil. 2016 November ; 97(11): 1945–1952. doi:10.1016/j.apmr.2016.05.011.

Predictors of Exercise Adherence in Patients with Meniscal Tear and Osteoarthritis

Yetsa A. Tuakli-Wosornu, M.D., M.P.H., Faith Selzer, Ph.D., Elena Losina, Ph.D., M.S., and Jeffrey N. Katz, M.D., M.S.

Orthopaedic and Arthritis Center for Outcomes Research, Department of Orthopedic Surgery (YAT-W, FS, EL, JNK) and Department of Physical Medicine and Rehabilitation (YAT-W), Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA

Abstract

Objective—To identify predictors of poor exercise adherence in patients with osteoarthritis (OA) and meniscal tear.

Design—Secondary analysis of data gathered over the first 12 weeks in the Meniscal Tear in Osteoarthritis Research (MeTeOR) Trial, a multicenter, randomized controlled trial.

Setting—Seven referral centers in the US.

Participants—This analysis was conducted in 325 of the 351 MeTeOR patients, each of whom was 45 years old and had meniscal tear and osteoarthritic changes on imaging studies; 26 were excluded due to missing data from which to derive the primary outcome variable.

Interventions—All patients received a structured supervised exercise program focused on strengthening, along with prescribed home exercises; half were randomized to also receive arthroscopic partial meniscectomy.

Main Outcome Measure—Poor exercise adherence through 12 weeks, defined as performing <50% of prescribed exercise.

Results—38% of the MeTeOR cohort showed poor exercise adherence. In the multivariate model, adjusting for treatment group, those who earned \$29,000/year had 1.64 times the risk of non-adherence (95% CI: 1.10, 2.43) than those who earned >\$100,000 /year; and, those without baseline pain with pivoting and twisting had 1.60 times greater risk of non-adherence than those with these symptoms (95% CI: 1.14, 2.25).

Conclusion—Low income was associated with poor exercise adherence among patients 45 with osteoarthritis and meniscal tear, as was absence of pain with pivoting and twisting. Our

Correspondence: Jeffrey N. Katz, M.D., M.S., Director, Orthopaedic and Arthritis Center for Outcomes Research, Division of Rheumatology, Immunology and Allergy, Brigham and Women's Hospital, 75 Francis Street, PBB-B3, Boston, MA 02115, Telephone: 617-732-5338, Fax: 617-525-7900, jnkatz@partners.org.

Publisher's Disclaimer: 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 citable 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.

findings highlight the need for further research into exercise adherence and for interventions to enhance adherence among those with low incomes.

Keywords

adherence; exercise; meniscal tear; randomized trial

Introduction

Osteoarthritis (OA) compromises the mobility and quality of life of over 250 million people around the world [1–3] and knee OA is the most frequent cause of musculoskeletal disability in industrialized nations [4–9]. Degenerative meniscal tear is a common cause of morbidity in adults, and arthroscopic partial meniscectomy (APM) is among the most commonly performed orthopedic surgeries [10]. Exercise is a subset of physical activity that is planned, structured and purposeful [11]. Aerobic and strengthening exercises have been shown to be effective treatments for reducing pain and improving function in patients with knee OA [12–20]. Postoperative exercises are associated with improvements in self-reported measures of knee function and range of motion among patients who have undergone arthroscopic partial meniscectomy (APM) for degenerative meniscal tear [21]. In patients with OA and symptomatic meniscal tear, the treatment effect of exercise is comparable to that of APM [15–17].

Increasingly, scientists are moving beyond the known benefits of exercise among adults with degenerative knee disease and are studying risk factors that influence patient adherence to exercise [13, 14, 18]. In this clinical population, it has been shown that the benefits of exercise cannot be realized unless patients adhere to their programs [12, 20]. Furthermore, as a 2005 multidisciplinary expert panel suggested, long-term adherence to a recommended exercise program is the key predictor of the long-term clinical success of that program [22].

Although a positive dose-response relationship between exercise adherence and health benefits among adults with OA has been described [14, 18], adults with knee OA often become non-adherent to their exercise program just weeks after exercise is prescribed [13, 19, 20]. No exercise adherence study has been conducted among patients with knee OA and concomitant meniscal tear.

Literature on exercise adherence often describes two broad categories of factors that motivate exercise: intrinsic (i.e. patient-level clinical and psycho-social factors) and extrinsic (i.e. physical and environmental factors outside of the patient) [23–26]. Intrinsic factors include mood/affect, pain, attitude towards exercise, and expectation of outcome, among others, while extrinsic factors include social support, socioeconomic status, accessibility of exercise facility and transportation, among others [13, 27–33]. A recent review noted the factors that most significantly influence exercise adherence in the OA population are extrinsic, and fall into the category of ‘Environmental Context and Resources’ [34]. The factors associated with poor exercise adherence in patients with OA and concomitant symptomatic meniscal tear have not been examined explicitly. The aim of the study was to help fill this research gap.

Methods

Design and Setting

We performed a prospective, observational secondary analysis of data from the Meniscal Tear in Osteoarthritis Research Trial (MeTeOR; ClinicalTrials.gov NCT00597012), a multicenter randomized controlled trial (RCT) involving adult patients with symptomatic mild-to-moderate osteoarthritic changes and concomitant meniscal tear [17, 35]. Between June 2008 and July 2011, eligible patients were randomized to receive APM followed by physical therapy or a physical therapy regimen alone. Inclusion criteria for the MeTeOR trial included clinical symptoms consistent with a torn meniscus, availability of knee radiograph and MRI, evidence of cartilage defects on knee MRI or evidence of osteophytes or joint space narrowing on plain radiograph, and evidence of meniscal tear on knee MRI. MRI readings were standardized by using the Boston Leeds Osteoarthritis Knee Score [36] and a quantitative 3D assessment of articular cartilage volume.

Before randomization, all MeTeOR patients received a baseline questionnaire examining clinical data such as perceived pain and demographic data such as socioeconomic status. After randomization, all MeTeOR patients were called every other week to assess adherence to the prescribed exercise program. Both operative and non-operative study arms received an exercise program consisting of supervised physical therapy sessions and an unsupervised home exercise program. The operative arm commenced exercise after surgery and the non-operative arm commenced exercise within two weeks of randomization. This analysis used MeTeOR data from the baseline questionnaires and the biweekly phone interviews conducted through the first 12 weeks of follow-up.

Exercise Program

The MeTeOR physical therapy program was a standardized, land-based protocol administered to patients in both arms. The research coordinator distributed the protocol to each patient at the randomization visit, along with a set of 2.5-pound therapy weights. All patients progressed through three stages addressing range of motion, proprioception, balance, eccentric strength, concentric strength, and aerobic conditioning. Patients worked with physical therapists up to twice weekly and undertook a written home exercise program in addition to their outpatient therapy sessions. Readiness to advance through stages of the exercise program was determined by the physical therapist using a protocol that included self-reported pain, observed strength, knee range of motion, functional mobility, and knee effusion. Over-the-counter pain medications were allowed as needed during the trial period, as were prescribed pain medications and intra-articular corticosteroid injections as determined by patient and physician.

Underlying Theoretical Model

Our framework was informed by elements of an exercise behavior model described by Bennell, *et al.* [33]. We anchored our analysis by first distinguishing intrinsic and extrinsic factors. Intrinsic factors are clinical and psycho-social factors *within* a patient such as pain, disease severity (i.e. Kellgren-Lawrence OA grade), attitude towards health, and health expectations. Extrinsic factors are physical and environmental factors *outside* of a patient

such as socioeconomic status and social support. We present the intrinsic and extrinsic factors considered in this analysis in Table 1. The variables we used to represent these intrinsic and extrinsic factors included validated measures such as the SF-36 [37], Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) function scale [38], Knee injury and Osteoarthritis Outcome Scale (KOOS) [39], and the five-item mental health index (MHI-5) contained within the SF-36 [40].

Outcome

The primary outcome was poor exercise adherence over the course of 12 weeks. Based on prior literature, we defined those who adhered to < 50% of their program elements over the course of 12 weeks as non-adherent [41].

Research staff called patients bi-weekly during first 12 weeks post-randomization and asked about the number of PT sessions patients were scheduled to attend in the prior 2 weeks and the number they actually attended. Similarly, the researcher asked patients the number of days on which they did all, part, or none of their prescribed home exercise program.

Thus, exercise adherence for each study participant was calculated as:

$$\frac{[(\# \text{ attended physical therapy days}) + [1 * (\# \text{ Days Full Home Exercise Program Completed}) + 0.5 * (\# \text{ Days Partial Home Exercise Program Completed})]}{84 \text{ days}}$$

Since a variety of exercises under varying conditions have been shown to improve clinical outcomes among patients with degenerative knee disease, our outcome of interest was total adherence to exercise, rather than adherence to home exercise or adherence to physical therapy alone. Thus the numerator, bi-weekly adherence data from each individual participant, was summed. We assumed that study patients would not perform home exercises on the days they had physical therapy. However, to account for potential redundancy arising from reporting home exercise and PT attendance on the same day, the outcome variable was capped at 1 for each patient. We developed conservative algorithms for augmenting data in instances of partially missing data on physical therapy sessions and home exercises (Appendix 1 provides the algorithms). Study patients not providing any data on physical therapy or home exercise data were excluded because the outcome variable could not be calculated (n=26, 7%).

Statistical Analysis

We assessed each of the potential predictors of exercise non-adherence (listed in Table 1) individually, in bivariate analyses using the chi-squared test for categorical predictors and the t-test for continuous variables. We advanced to multivariate analyses those variables that had relative risks of over 1.5 or under 0.67, or p-values less than or equal to 0.25. We identified independent predictors of non-adherence with multivariable models. In order to provide risk ratios rather than odds ratios, we utilized a modified Poisson regression approach with robust error variance [42]. We conducted sensitivity analyses at both 4- and 8-weeks post-randomization by examining the association between the same predictors

identified at 12-weeks and exercise non-adherence using the same modeling approach used for the 12-week analyses. SAS v9.4 was used to perform all statistical analyses.

Results

Cohort Demographics

The study was conducted in 325 of the 351 patients in the MeTeOR study. Twenty-six patients from the MeTeOR cohort were excluded from the analysis due to completely missing data from which to derive an outcome variable.

Of the patients included in this analysis, 57% were female and 86% were white (Table 2). Sixteen of patients reported living alone. In general, the cohort was well educated with 84% having attended college. Most patients were employed, with 10% of the group reporting earning less than \$30,000 annually.

Clinical Characteristics and Self-Reported Symptoms

Knee OA severity varied: 24% had Kellgren-Lawrence grade 0 (normal plain radiographs), 19% had grade 1 (questionable osteophyte), 30% had grade 2 (definite osteophyte), and 26% had grade 3 (define joint space narrowing, < 50%) [43]. Thirty-three percent of the cohort was overweight (BMI 25–30) and 42% was obese (BMI > 30). At baseline, 21% of patients reported being anxious or depressed currently. Twenty-nine percent expected a moderate or great improvement in symptoms as a result of the intervention to which they were assigned while 71% anticipated only a little improvement in symptoms. At baseline, 83% reported their current level of pain or discomfort as moderate and 13% as extreme. Twenty-eight percent reported having an intra-articular injection in the past 3 months and half of patients reported daily or near daily use of Tylenol, anti-inflammatory medications or stronger pain medicine for their knee pain.

Functional Characteristics

The baseline functional characteristics of the cohort were as follows: on the physical activity subscale of the SF-36 (possible range 0–100 with 100 best), 14 (4%) reported a score of 0–39, 253 (78%) reported a score of 40–79 and 57 (18%) reported a score of 80. Thirty-nine patients (12%) endorsed a score of 0–39 on the KOOS activities of daily living subscale (possible score 0–100, 100 best), 227 (70%) endorsed a score of 40–79 and 57 (18%) endorsed a score of 80.

Total Cohort Adherence

Finally, with respect to the primary outcome, 124 patients (38%) were less than 50% adherent to exercise (non-adherers) over 12 weeks.

Bivariate Analysis

In the bivariate analysis, 3 intrinsic patient factors – male sex, non-white race and less pain with pivoting and twisting, reached or approached statistical significance as predictors of non-adherence. Men had 1.2 times the risk of non-adherence compared to women (95% CI 0.92, 1.60). Non-white study participants had 1.3 times the risk of non-adherence compared

to white study participants (95% CI 0.96, 1.88). Patients without pain with pivoting and twisting had 1.7 times the risk of non-adherence compared to those with painful meniscal symptoms (95% CI 1.17, 2.41). One extrinsic factor (lower annual income; Table 3) was also associated with non-adherence. Compared to those who earned greater than \$100,000 annually, those who earned \$29,000 annually had 1.5 times the risk of non-adherence (95% CI 1.01, 2.19), while those who earned between \$30,000 and \$99,000 annually had 15% lower risk (95% CI 0.61, 1.19) and those who did not report income data had 1.4 times greater risk of non-adherence to exercise over 12 weeks (95% CI 0.89, 2.12). In addition, compared to patients randomized to the physical therapy arm of the study, patients randomized to the surgical arm of the study had 1.6 times the risk of non-adherence (95% CI 1.17, 2.06).

Multivariate Analysis

The final model (Figure 1) included both intrinsic (pain, age) and extrinsic (socioeconomic status) factors as predictors of non-adherence after adjusting for study arm and age. Compared to those who earned \$100,000 per annum or more, those who earned less than or equal to \$29,000 per annum had 1.6 times the risk of non-adherence (95% CI 1.10, 2.43). Those not experiencing pain with pivoting or twisting had 1.6 times the risk of non-adherence (95% CI 1.14, 2.25) as compared to those who endorsed such pain.

Sensitivity Analysis

To test the strength of select variables to predict non-adherence at various time points following enrollment, we examined predictors of non-adherence at shorter time intervals (4 and 8 weeks post-randomization; Table 4). The models comprised the same variables from the 12-week analysis including annual income, pain with pivoting and twisting and age and were further adjusted for study arm. Lower annual income and no pain with pivoting or twisting became more strongly associated with non-adherence over longer duration of follow-up. Compared to those who earned \$100,000 annually, those who earned \$29,000 annually had 1.3 times the risk of non-adherence at 4 weeks but 1.6 times the risk at 12 weeks (95% CI 0.88, 1.96 and 1.10, 2.43, respectively). Compared to those who experienced pain with pivoting and twisting, those who did not experience painful meniscal symptoms had the same risk of non-adherence at 4 weeks (95% CI 0.70, 1.52) but 1.6 times the risk of non-adherence at 12 weeks (95% CI 1.14, 2.25; Table 4). The APM group had greater risk of non-adherence at all 3 time points (data not shown).

Discussion

We examined the relationship between intrinsic and extrinsic individual-level factors and non-adherence to prescribed exercise over 12 weeks in a cohort of patients with knee OA and concomitant meniscal tear (the MeTeOR trial patients). Of the factors studied, lower socioeconomic status (extrinsic) and no pain with pivoting and twisting (intrinsic) were associated with higher risk of exercise non-adherence.

One key finding of this research is that patients with lower income were significantly less likely to be adherent. These patients may have had more difficulty attending outpatient

physical therapy (e.g. because of difficulty finding transportation, affording co-payments, etc.). This finding conforms to published data among similar cohorts (e.g. well-educated adults or adults with lower extremity osteoarthritis), where decreasing socioeconomic status was negatively associated with physical activity level [44, 45]. The same association has been described among older adults [46].

Another key finding is that patients with less baseline pain with pivoting and twisting had worse adherence. Considering the types of activities that require pivoting and twisting of the knee such as golf and basketball, participants who reported pain with pivoting and twisting may have been more active at baseline than those who did not report this symptom. These patients may have had greater desire to get back to usual activities, leading them to be more adherent than those who were less active at baseline. The finding that patients with more severe pain with twisting and pivoting may have been more adherent is also consistent with prior OA literature showing that patients with more severe symptoms were more likely to adhere to their exercise programs [31]. We did not observe a relationship between overall lower extremity pain as measured by WOMAC and adherence, suggesting this relationship may depend on the type of pain.

In multivariate and sensitivity analyses, study arm was associated with adherence status. Patients randomized to surgery were most likely to be non-adherent. This finding may simply reflect the longer duration of time after randomization required for patients to undergo surgery, get scheduled for PT, and receive PT. Post-surgical pain may have played a role. In addition, patients randomized to surgery may have unwittingly assumed that a high-intensity intervention such as surgery could more swiftly and completely improve their symptoms, obviating their need to participate in a low-intensity intervention like exercise. Thus, if the surgical patients assumed that surgery would be curative and they did not need to exercise, they may have exercised less compared to patients randomized to PT.

The observation that many of the intrinsic and extrinsic factors that we examined were not associated with exercise adherence is consistent with prior literature. Studies of exercise adherence that have focused on healthy adults [25], and musculoskeletal patients [47] have documented few predictors of adherence.

Limitations

Our study was limited by only using data available in the secondary analysis of an RCT. For example, due to the a priori study design of the MeTeOR trial, during bi-weekly telephone calls, research staff did not ask patients to provide reasons why they did not adhere to their exercise programs. Similarly, while the original MeTeOR study allowed patients to use additional medications as needed, data on medication use during the trial was not available for this secondary analysis. If use of medications influenced patient motivation to exercise, this may have confounded our results. Finally, Focht and colleagues demonstrated that osteoarthritic patients randomized to a cognitive behavioral therapy-based exercise program featuring intrinsic factors like self-regulation and goal-setting and extrinsic factors like group identity and social support had increased adherence compared to those randomized to a traditional, center-based exercise program [48]. In the same way that we were not able to

examine self-reported reasons for non-adherence, we were not able to measure factors such as self-regulation and goal-setting.

Conclusion

The number of high-quality studies examining exercise adherence in patients with lower extremity musculoskeletal disease is increasing [34], reflecting the key role exercise adherence plays in clinical outcomes within this group. Our findings suggest that socioeconomic status may be an important predictor of non-adherence. Strategies to understand the specific barriers to adherence associated with low income are merited, as are studies of interventions to overcome these barriers. Finally, as our study and other studies emphasize, the intrinsic and extrinsic factors that lead patients with degenerative knee disease to initiate, maintain and progress in an exercise program may be difficult to measure. To optimize clinical outcomes, clinicians need a better understanding of measurable and modifiable predictors of exercise adherence. Focht and colleagues' have suggested that future interventions should include elements of behavioral psychology, such as exercise stage of change as candidate predictors of adherence [48].

Acknowledgments

We thank Ellen Gurary, M.S. for support with the study's statistical analyses and Amelia Winter, B.A. for editorial assistance.

Support: The work was supported by NIAMS grants R01AR05557, T32AR055885, K24AR057827, P60AR47782. The authors have no potential conflicts of interest relevant to this manuscript and have not received support or benefits from commercial sources for the work reported.

References

1. Cross M, et al. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. *Ann Rheum Dis.* 2014; 73(7):1323–30. [PubMed: 24553908]
2. Glyn-Jones S, et al. Osteoarthritis. *Lancet.* 2015 Mar 3. pii: S0140-6736(14)60802-3. doi: 10.1016/S0140-6736(14)60802-3
3. March L, et al. Burden of disability due to musculoskeletal (MSK) disorders. *Best Pract Res Clin Rheumatol.* 2014; 28(3):353–66. [PubMed: 25481420]
4. Jevsevar DS, et al. The American Academy of Orthopaedic Surgeons evidence-based guideline on: treatment of osteoarthritis of the knee, 2nd edition. *J Bone Joint Surg Am.* 2013; 95(20):1885–6. [PubMed: 24288804]
5. Fernandes L, et al. EULAR recommendations for the non-pharmacological core management of hip and knee osteoarthritis. *Ann Rheum Dis.* 2013; 72(7):1125–35. [PubMed: 23595142]
6. Hochberg MC, et al. American College of Rheumatology 2012 recommendations for the use of nonpharmacologic and pharmacologic therapies in osteoarthritis of the hand, hip, and knee. *Arthritis Care Res.* 2012; 64(4):465–74.
7. McAlindon TE, et al. OARSI guidelines for the non-surgical management of knee osteoarthritis. *Osteoarthritis Cartilage.* 2014; 22(3):363–88. [PubMed: 24462672]
8. Musumeci G, et al. Osteoarthritis in the XXIst century: risk factors and behaviours that influence disease onset and progression. *Int J Mol Sci.* 2015; 16(3):6093–112. [PubMed: 25785564]
9. Prieto-Alhambra D, et al. Incidence and risk factors for clinically diagnosed knee, hip and hand osteoarthritis: influences of age, gender and osteoarthritis affecting other joints. *Ann Rheum Dis.* 2014; 73(9):1659–64. [PubMed: 23744977]

10. Kim S, et al. Increase in outpatient knee arthroscopy in the United States: a comparison of National Surveys of Ambulatory Surgery, 1996 and 2006. *J Bone Joint Surg Am.* 2011; 93(11):994–1000. [PubMed: 21531866]
11. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* 1985; 100(2):126–31. [PubMed: 3920711]
12. Bennell K, et al. Exercise and osteoarthritis: cause and effects. *Compr Physiol.* 2011; 1(4):1943–2008. [PubMed: 23733694]
13. Campbell R, et al. Why don't patients do their exercises? Understanding non-compliance with physiotherapy in patients with osteoarthritis of the knee. *J Epidemiol Community Health.* 2001; 55(2):132–8. [PubMed: 11154253]
14. Ettinger WH Jr, 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(1):25–31. [PubMed: 8980206]
15. Herrlin S, et al. Arthroscopic or conservative treatment of degenerative medial meniscal tears: a prospective randomised trial. *Knee Surg Sports Traumatol Arthrosc.* 2007; 15(4):393–401. [PubMed: 17216272]
16. Herrlin SV, et al. Is arthroscopic surgery beneficial in treating non-traumatic, degenerative medial meniscal tears? A five year follow-up. *Knee Surg Sports Traumatol Arthrosc.* 2013; 21(2):358–64. [PubMed: 22437659]
17. Katz JN, et al. Surgery versus physical therapy for a meniscal tear and osteoarthritis. *N Engl J Med.* 2013; 368(18):1675–84. [PubMed: 23506518]
18. Pisters MF, et al. Exercise adherence improving long-term patient outcome in patients with osteoarthritis of the hip and/or knee. *Arthritis Care Res.* 2010; 62(8):1087–94.
19. Pisters MF, et al. Long-term effectiveness of exercise therapy in patients with osteoarthritis of the hip or knee: a systematic review. *Arthritis Rheum.* 2007; 57(7):1245–53. [PubMed: 17907210]
20. van Baar ME, et al. Effectiveness of exercise in patients with osteoarthritis of hip or knee: nine months' follow up. *Ann Rheum Dis.* 2001; 60(12):1123–30. [PubMed: 11709454]
21. Dias JM, et al. The effectiveness of postoperative physical therapy treatment in patients who have undergone arthroscopic partial meniscectomy: systematic review with meta-analysis. *J Orthop Sports Phys Ther.* 2013; 43(8):560–76. [PubMed: 23756350]
22. Roddy E, et al. Evidence-based recommendations for the role of exercise in the management of osteoarthritis of the hip or knee--the MOVE consensus. *Rheumatology (Oxford).* 2005; 44(1):67–73. [PubMed: 15353613]
23. Dacey M, Baltzell A, Zaichkowsky L. Older adults' intrinsic and extrinsic motivation toward physical activity. *Am J Health Behav.* 2008; 32(6):570–82. [PubMed: 18442337]
24. Martin JE, Dubbert PM. Exercise applications and promotion in behavioral medicine: current status and future directions. *J Consult Clin Psychol.* 1982; 50(6):1004–17. [PubMed: 7174968]
25. Dubbert PM. Exercise in behavioral medicine. *J Consult Clin Psychol.* 1992; 60(4):613–8. [PubMed: 1506509]
26. Marcus BH, et al. Physical activity behavior change: issues in adoption and maintenance. *Health Psychol.* 2000; 19(1 Suppl):32–41. [PubMed: 10709946]
27. Damush TM, et al. Motivational factors influencing older adults diagnosed with knee osteoarthritis to join and maintain an exercise program. *J Aging Phys Act.* 2005; 13(1):45–60. [PubMed: 15677835]
28. Petursdottir U, Arnadottir SA, Halldorsdottir S. Facilitators and barriers to exercising among people with osteoarthritis: a phenomenological study. *Phys Ther.* 2010; 90(7):1014–25. [PubMed: 20466741]
29. Holden MA, et al. Role of exercise for knee pain: what do older adults in the community think? *Arthritis Care Res.* 2012; 64(10):1554–64.
30. Marks R. Knee osteoarthritis and exercise adherence: a review. *Curr Aging Sci.* 2012; 5(1):72–83. [PubMed: 21762086]

31. Hurley MV, et al. Health beliefs before and after participation on an exercised-based rehabilitation programme for chronic knee pain: doing is believing. *BMC Musculoskelet Disord.* 2010; 11(31): 1471–2474.
32. Pisters MF, et al. Behavioural graded activity results in better exercise adherence and more physical activity than usual care in people with osteoarthritis: a cluster-randomised trial. *J Physiother.* 2010; 56(1):41–7. [PubMed: 20500136]
33. Bennell KL, Dobson F, Hinman RS. Exercise in osteoarthritis: moving from prescription to adherence. *Best Pract Res Clin Rheumatol.* 2014; 28(1):93–117. [PubMed: 24792947]
34. Dobson F, et al. Barriers and Facilitators to Exercise Participation in People with Hip and/or Knee Osteoarthritis: Synthesis of the Literature Using Behavior Change Theory. *American journal of physical medicine & rehabilitation/Association of Academic Physiatrists.* 2016
35. Katz JN, et al. The MeTeOR trial (Meniscal Tear in Osteoarthritis Research): rationale and design features. *Contemp Clin Trials.* 2012; 33(6):1189–96. [PubMed: 22968127]
36. Hunter DJ, et al. The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston Leeds Osteoarthritis Knee Score). *Ann Rheum Dis.* 2008; 67(2):206–11. [PubMed: 17472995]
37. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Med Care.* 1992; 30(6):473–83. [PubMed: 1593914]
38. Bellamy N, et al. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol.* 1988; 15(12):1833–40. [PubMed: 3068365]
39. Roos EM, et al. Knee Injury and Osteoarthritis Outcome Score (KOOS)--development of a self-administered outcome measure. *J Orthop Sports Phys Ther.* 1998; 28(2):88–96. [PubMed: 9699158]
40. Berwick DM, et al. Performance of a five-item mental health screening test. *Med Care.* 1991; 29(2):169–76. [PubMed: 1994148]
41. van Gool CH, et al. Effects of exercise adherence on physical function among overweight older adults with knee osteoarthritis. *Arthritis care & research.* 2005; 53(1):24–32. [PubMed: 15696558]
42. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol.* 2004; 159(7):702–6. [PubMed: 15033648]
43. EuroQol--a new facility for the measurement of health-related quality of life. *Health Policy.* 1990; 16(3):199–208. [PubMed: 10109801]
44. Cassetta JA, et al. Association of education and race/ethnicity with physical activity in insured urban women. *J Womens Health (Larchmt).* 2007; 16(6):902–8. [PubMed: 17678461]
45. Stubbs B, Hurley M, Smith T. What are the factors that influence physical activity participation in adults with knee and hip osteoarthritis? A systematic review of physical activity correlates. *Clin Rehabil.* 2015; 29(1):80–94. [PubMed: 24917590]
46. Tucker-Seeley RD, et al. Neighborhood safety, socioeconomic status, and physical activity in older adults. *Am J Prev Med.* 2009; 37(3):207–13. [PubMed: 19595554]
47. Beinart NA, et al. Individual and intervention-related factors associated with adherence to home exercise in chronic low back pain: a systematic review. *Spine J.* 2013; 13(12):1940–50. [PubMed: 24169445]
48. Focht BC, et al. Improving maintenance of physical activity in older, knee osteoarthritis patients trial-pilot (IMPACT-P): design and methods. *Contemp Clin Trials.* 2012; 33(5):976–82. [PubMed: 22575796]
49. Kellgren JH, Lawrence JS. Radiological assessment of osteoarthrosis. *Ann Rheum Dis.* 1957; 16(4):494–502. [PubMed: 13498604]
50. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc.* 1991; 39(2):142–8. [PubMed: 1991946]
51. Williams M. Manual muscle testing, development and current use. *Phys Ther Rev.* 1956; 36(12): 797–805. [PubMed: 13378993]

Appendix 1. Algorithms for imputing missing data on physical therapy sessions and home exercise

If a patient had missing data on the number of physical therapy (PT) sessions attended over a specific 2-week period, we imputed the number of PT sessions attended with the average number of PT sessions attended for that patient over the entire study period, calculated based on non-missing data for that person. If the average number of PT sessions attended over 12 weeks was missing (i.e. there was no data available across the entire 12 week span), we assumed the average number of PT sessions attended for that patient over the entire study period was 0. If a patient had missing data on the number of PT sessions assigned over a specific 2-week period, this was imputed by either the average PT sessions attended for that patient or the average PT sessions assigned for that time interval (across all patients) whichever value was smaller. If a patient had missing data on number of PT sessions assigned over 14 days, this was imputed by either the average number of PT sessions attended for that patient over the entire 12-week period or by the average assigned PT session data for that time interval across all study participants, whichever was larger.

Figure 1.
Multivariate Correlates of Non-Adherence at 12 Weeks
Model also includes randomization assignment

Table 1**Intrinsic and Extrinsic Factors Examined**

Intrinsic factors	Source	Scoring system
Demographic Data		
Age, race, gender, height, weight	Self-reported	
Living status	<i>Who do you currently live with?</i>	Alone versus Not alone
Subjective Clinical Data		
General affect	MHI-5 [46] (a subscale within SF- 36[43])	Index score: 5–25 (5 items each score 1–5)
Symptoms of anxiety/depression	Anxiety/Depression items in EQ- 5D[46]	Item score: 0–2
Expectations of intervention	<i>How much do you expect your treatment (surgery or physical therapy) to improve your quality of life over the NEXT COUPLE YEARS?</i>	Item score: 0–4
Perception of personal health	Current health status subscale of EQ-5D [55]	Item score: 0–100
Clinical symptoms of knee OA	KOOS symptoms subscale[45]	Index score: 0–20
Clinical symptoms of meniscal tear	<i>In the LAST WEEK, have you had any of the following symptoms in your [INDEX] KNEE? Clicking, catching, popping, giving way, locking, swelling, pain with pivoting/ twisting?</i>	Yes versus No for each item
Knee pain with specific activities	KOOS pain subscale[45]	Index score: 0–36
General pain	Pain/Discomfort subscale of EQ- 5D[55]	Item score: 0–2
Index knee-related function during athletic activities or specific postures and activities of daily living	SF-36 activities subscale[43]	Index score: 9–27 (9 items scores 1–3)
General function during ADLs and mild physical activity	KOOS function/daily living subscale[45]	Index score: 0–68 (17 items scores 014)
Objective Clinical Data		
Need to take oral medication for knee pain	<i>How often do you take each of the following medications for your knee?</i>	Index score: 0–6
Need for intra-articular knee injection(s)	<i>Have you had injections in your knee in the LAST THREE MONTHS?</i>	Yes versus No
Kellgren and Lawrence OA grade on plain films[47]	AP standing plain radiograph reviewed and scored during pre-trial screening by participating physician	Grade 0 – 4
Score on Timed Up and Go test	Timed Up and Go test supervised by physical therapist during pre- trial musculoskeletal exam[48]	Seconds
Score on Quadriceps and Hamstrings manual muscle testing	Manual muscle testing[49] performed and recorded by physical therapist during pre-trial musculoskeletal exam	Average of 3 trials using the manual muscle test hand held dynamometer, pounds
Extrinsic Factors		
Annual income	<i>What is your annual household income from all sources before taxes?</i>	Item score: 1–5
Randomization arm	Randomization arm assigned during pre-trial screening by research coordinator (Surgical / Non- Surgical)	Surgery versus Physical Therapy
Highest level of education achieved	<i>What is the highest level of education you have achieved?</i>	Item score: 1–5

Table 2

Baseline Demographic and Clinical Characteristics of Cohort (N=325)

Variable	Frequency	Percent
Study Arm		
Physical Therapy	172	52.9
APM surgery	153	47.1
Demographics		
Age (years)		
45–54	120	36.9
55–64	146	44.9
65–74	54	16.6
75	5	1.5
Female		
No	139	42.8
Yes	186	57.2
White Race		
No	45	13.8
Yes	280	86.1
Education Level		
High School Graduate or Less	51	16.0
Some College	51	16.0
Graduated from Technical/Professional School	36	11.3
College Graduate	181	56.7
Annual Income		
\$29,000	32	9.8
\$30,000–\$99,999	152	46.8
\$100,000	114	35.1
Missing	27	8.3
Living Situation		
Alone	51	15.9
With Spouse or Partner	238	74.1
With other Family Members or Friends	32	10.0
BMI (kg/m ²)		
Missing	17	5.2
25.0	62	19.1
25.1–30.0	109	33.5
30.1	137	42.1
KL Score		
0	68	24.4
1	53	19.0

Variable	Frequency	Percent
2	84	30.1
3	74	26.5
Knee Symptoms		
Catching		
No	156	49.2
Yes	161	50.8
Clicking		
No	107	33.6
Yes	211	66.3
Giving Away		
No	156	49.5
Yes	159	50.5
Pain with pivoting/twisting		
No	23	7.2
Yes	298	92.8
Popping		
No	166	52.4
Yes	151	47.6
Episodic Swelling		
No	80	25.2
Yes	238	74.8
Quality of Life		
SF-36 Physical Activity Subscale		
0–39	14	4.3
40–59	136	42.0
60–79	117	36.1
80	57	17.6
KOOS Activities of Daily Living Subscale		
0–39	39	12.1
40–59	96	29.7
60–79	131	40.6
80	57	17.6

APM = arthroscopic partial meniscectomy

Table 3
Bivariate Associations between Candidate Predictors of Non-Adherence at 12 Weeks

Variable	Adherence Level				Parameter Estimates		
	<50% (n=124)		50% (n=201)		Relative Risk	95% CI	P-value
	N	% or Mean (SD)	N	% or Mean (SD)			
Sex							0.17
Female	65	34.9	121	65.0	1.00	Reference	
Male	59	42.4	80	57.5	1.21	0.92–1.60	
White Race							0.09
Yes	102	36.4	178	63.6	1.00	Reference	
No	22	48.9	23	51.1	1.34	0.96–1.88	
Study Arm							0.002
PT	52	41.9	120	59.7	1.00	Reference	
APM	72	58.1	81	40.3	1.56	1.17–2.06	
Annual Income							0.046
\$100,000	43	37.7	71	62.3	1.00	Reference	--
\$30,000–\$99,999	49	32.2	103	67.8	0.85	0.61–1.19	
\$29,000	18	56.2	14	43.7	1.49	1.01–2.19	
Missing	14	51.8	13	48.1	1.37	0.89–2.12	
Pain with pivot							0.005
Yes	108	39.1	190	63.8	1.00	Reference	
No	14	60.9	9	36.2	1.68	1.17–2.41	
Age (years)							0.84
45–54	48	40.0	72	60.0	1.12	0.75–1.69	
55–64	55	37.7	91	62.3	1.06	0.71–1.58	
65	21	35.6	38	64.4	1.00	Reference	

Additional factors included in Table 1 were not associated with exercise non-adherence at OR < 0.67 or > 1.5 and are therefore not shown

Table 4
Risk Ratios for Select Variables at 4, 8, and 12 Weeks to Test the Effects of these Variables on Exercise Non-Adherence over Time

Risk Factors	4-Weeks				8-Weeks				12-Weeks			
	RR	95% CI	P-value		RR	95% CI	P-value		RR	95% CI	P-value	
Age, per 5 years ↓	1.01	0.94–1.08	0.82		1.05	0.95–1.15	0.32		1.08	0.98–1.19	0.10	
Annual income (versus \$100,000)			0.52				0.34				0.016	
\$29,000	1.31	0.88–1.96	0.19		1.25	0.76–2.07	0.37		1.64	1.10–2.43	0.015	
\$30,000–\$99,999	0.96	0.75–1.23	0.74		0.88	0.64–1.21	0.43		0.82	0.59–1.14	0.24	
Missing	1.09	0.75–1.58	0.66		1.26	0.81–1.95	0.31		1.33	0.88–2.02	0.18	
No pain with pivoting/twisting	1.03	0.70–1.52	0.86		1.25	0.81–1.93	0.32		1.60	1.14–2.25	0.006	
C-statistic		0.72				0.66				0.66		