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Strength training in older adults: The benefits for osteoarthritis

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Synopsis

The aim of this review was to summarize the findings of randomized controlled trials (RCTs) of progressive resistance strength training (PRT) by older people with osteoarthritis (OA). When data from 8 RCTs were synthesized using meta-analysis, a significant benefit from PRT was found on lower extremity extensor strength (standardized mean difference (SMD) 0.33, 95% confidence interval (CI) 0.12, 0.54), function (SMD 0.33, 95% CI 0.18) and pain reduction −0.35 (95% CI −0.52, −0.18). Across all three outcomes, the estimated effect size was moderate, which contrasted with trials of PRT in non-OA specific groups of older adults where a large effect was found on strength, but a small effect on function. This suggests that strength training has particularly strong functional benefits for older adults with OA. Older adults with osteoarthritis will benefit from a strength training program that provides progressive overload to maintain intensity throughout the exercise program. Clinicians should encourage participation in exercise training programs, even in the oldest old with OA.

Introduction

Muscle weakness is a common impairment in older adults, [1, 2] and osteoarthritis is one of the most frequently occurring chronic conditions in older people. [3] It therefore is not surprising that these conditions frequently co-exist in the elderly. Skeletal muscles produce all voluntary human movement. Changes in properties and performance of muscles can profoundly affect an older person's ability to walk and function independently.[4–6] Loss of muscle strength might be particularly problematic for an older person with OA who has pain, stiffness and mechanical changes to their joint that complicate their ability to mobilize and make them particularly vulnerable to small changes in their physical status.

Strength training has been the focus of a great deal of recent clinical research in many populations, including older adults and people with OA.[7–13] While the benefits of strength training have been well explored in reviews focused on both populations, there has been little attention paid to the benefits and risks of strength training when undertaken by older people who have OA. In addition to being weaker, older people are more likely to have

more advanced OA, including more severe pain and biomechanical changes to the joint which might change their response to exercise training.

Muscle Weakness in Older Adults

Most adults attain their peak muscle strength in their mid-twenties and maintain this level of strength relatively well until the sixth decade.[14] By the age of eighty, strength declines on average to almost half that of a young adult.[15] This decline in strength is consistent across muscle groups and all types of measurements – isometric strength (when the limb does not move), concentric strength (when the muscle shortens), eccentric strength (when a lengthening contraction occurs) and when strength is measured isokinetically (at a fixed speed).[1, 16]

In addition to a reduction in muscle strength, studies have shown enormous declines in muscle mass with age. One study found that the muscle mass of 80 year olds was 40% less than that of people in their twenties.[17] The loss of muscle strength and mass that occurs with age was given the name ‘sarcopenia’ by Rosenberg in 1989, from the Greek “poverty of flesh”.[18]

The New Mexico Elder Health Survey, involving 883 people, is the most comprehensive study to date of the prevalence of sarcopenia in older people.[19] This study defined sarcopenia as a loss of muscle mass of greater than two standard deviations (SD) below the mean appendicular muscle mass for healthy young adults. Among those aged 60 to 70 years, the prevalence of sarcopenia was about 17% for men and about 24% for women. Above the age of eighty, the figure rose to 53 to 58% for men and 43 to 60% for women. Although these findings need to be confirmed in other populations, the high prevalence of sarcopenia in this study suggests that sarcopenia is a common disorder among older people.

Muscle Weakness in OA

Muscle weakness, particularly of the knee extensors, is common in people with OA[7, 20] and has been consistently shown to be associated with an increased risk of functional limitations and disability.[20, 21] The Bristol Knee OA study found lower limb strength to be a stronger predictor of functional limitations than radiographic severity or knee pain.[21]

The nature of the cause –effect relationship between muscle weakness and OA is complex, and has been widely debated. While strength probably declines in people with OA as a secondary result of reduced activity, there is also evidence that muscle weakness directly contributes to the development and progression of OA.[20] Muscle strength appears to have a protective effect against the disability associated with progressing OA. In a longitudinal study that monitored a cohort of women with for 6 years who had no functional limitations at baseline, knee extensor strength was protective against the development of functional limitations associated with OA.[22]

Benefits of Strength Training

In older adults, there is now strong evidence from randomized controlled clinical trials (RCTs) that even in the oldest old, muscle strength can be increased with a strength training program that uses a progressive overload.[12, 13] There is also evidence that strength training improves mobility (i.e. increased gait speed), simple functional tasks (i.e. standing up from a chair) and self-rated daily function in older adults.[13] However, while the effects of strength training are large, the impact on function and disability is much more modest.

There are also a large number of RCTs that support the benefits of exercise in general, and strength training in particular, in people with OA. Recent systematic reviews and guidelines have summarized the evidence for the effectiveness of strength training in people with osteoarthritis, and have found that strength training has a significant benefit in improving strength and function and in reducing pain.[9–11] However, these reviews have also found that the reductions in pain and improvements in function are modest.

Strength Training by Older Adults with OA

While the positive benefits of strength training in the general population of older adults would suggest that it would be beneficial for older people with OA, there are reasons to think that this might not be the case. Because OA is a painful musculoskeletal condition, it is possible that strength training might cause stress on the joints which could exacerbate pain and result in decreased function and mobility. The biomechanical changes to the joint that occur with OA also have the potential to contribute to different responses to and risk factors from strength training.

No systematic review has focused specifically on strength training in older adults with OA. This review will explore the evidence from all identified randomized controlled trials (RCTs) of people with OA undertaking strength training to determine the strength of the evidence to answer several questions. These questions are:

- Does strength training improve strength, function and reduce pain in older people with OA?
- Are there differences in the effect of strength training in older adults with OA compared to the general population of older people?

There are other important questions about the benefits of strength training for older people with OA. Although there is inadequate data to allow a meta-analysis, the current evidence from randomized controlled trials will be explored to determine whether the design of the strength training program influences their response to strength training.

A. Systematic Review Methods

Criteria for Including Studies

This review includes only randomized controlled clinical trials (RCTs), which provide the highest level of evidence of treatment efficacy. Because the focus of this review is on older adults, only studies where the participants had a mean age of 65 or above in the overall group, or in the progressive resistance training (PRT) group, were included. This review did not include exercise programs in which there was not a treatment arm where the subjects received only PRT. Because of this criteria, all studies where the intervention group received exercise programs that combined different types of exercise training (e.g. aerobic and strength training) were excluded. This review also only included strength training programs that used progressive resistance strength training (PRT), because strength training programs that do not use this approach might be less effective. For this review, PRT was defined as strength training in which the overload increases during the training program to maintain or increase the intensity of the program.

Identifying Studies

To identify studies, we searched the Cochrane Bone, Joint and Muscle Trauma Group Specialised Register, the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, CINAHL, SPORTDiscus, PEDro - The Physiotherapy Evidence Database and Digital Dissertations for all randomized controlled trials of strength training in older adults.

Specific searches for osteoarthritis exercise trials were conducted. Reference lists from other reviews and guidelines that summarized the evidence for strength training by people with osteoarthritis were also reviewed. No language restrictions were applied.

The authors reviewed the titles, descriptors or abstracts identified from all literature searches to identify potentially relevant trials for full review. A copy of the full text of all trials that appeared to be potentially suitable for the review was obtained. The authors used previously defined inclusion criteria to select the trials. Data were extracted for lower extremity leg strength, pain and self-rated function outcomes. Information about the study methods, subject characteristics, exercise program, adverse events and exercise adherence were also recorded.

Data synthesis

When adequate data were provided for the outcomes of lower limb extensor strength, pain or function, the results from each study were entered into the database and combined. Data synthesis was carried out using MetaView in Review Manager version 5.0. Standardized units (i.e. standardized mean differences (SMD)) were created to allow the pooling of outcomes using different units and 95% confidence intervals (CI) were calculated. Random effects models were used for all analyses.

Meta-analysis Results

Summary of Included Studies

A total of 8 studies were included in this review (Table 1).[23–30] Most studies that were not included in this review were excluded because the mean age was below 65 and/or the study included participants younger than 50; the exercise program included more types of exercises than PRT or the program was not a true progressive resistance training program.

All of the studies focused on people with knee OA, with one study including people with both hip and knee OA.[25] The size of the studies ranged from 20 to 295 people.

The number of exercises that were included in the program varied from 1 exercise to 9. Most of the exercise programs were conducted at a moderate to high intensity. All of the programs had participants exercise 3 times per week, except in the study by Lim *et al*,[26] where people exercised 5 times per week. The duration of the programs ranged from 6 to 72 weeks. In 3 studies participants exercised only in a gym setting, 1 study used only home-based training and 4 studies used a combination of home-based and gym-based training. A wide variety of equipment was used, including therabands, cuff weights and isokinetic dynamometers.

In the study by Lim *et al,* [26] the subjects were divided the subjects into two groups prior to randomization, people with neutral knee alignment and people with more varus malalignment. Because these groups were separately randomized, they were treated as two different studies for the purpose of the meta-analysis.

Effect of Strength Training on Strength and Function in Older People with OA

Progressive resistance strength training improves strength in older adults with OA. The effect size for the impact that strength training has on leg extensor muscle strength of older adults with OA was moderate and the effect was statistically significant (Figure 1), with a SMD of 0.33 (95% Confidence Interval (CI) 0.12, 0.54).

This review also found that strength training significantly improves function in older people with OA (Figure 2). The effect of strength training on function was almost identical to the

effect size found for strength, with a SMD 0.33 (95% CI 0.18, 0.49), which is statistically significant.

Pain decreased in people who participated in PRT. This effect was negative, indicating a reduction in pain, with a SMD of −0.35 (95% CI −0.52, −0.18).

Comparison of Outcomes between Older People with and Without OA

To compare the effects of strength training on older people with and without OA, newly identified trials were added to a database that included all previously identified trials of PRT in older people. As described elsewhere, this database includes trials of healthy older adults, as well as older people with a variety of medical conditions.[13]

These analyses found that the studies of older adults that were not specifically focused on older people with OA had a much larger effect on strength than the OA-specific studies. (Table 2) When the studies OA-specific studies were excluded, the effect size for strength was 0.88 (95% CI 0.7, 1.05), which is significantly lower than the strength estimate for older people with OA.

In contrast, the studies of strength training in the general population of older people had only a small effect on function (Table 2). In fact, when the OA-specific studies were removed from the analysis, the effect of strength training on function was no longer statistically significant with an effect size of 0.07 (−0.02, 0.17)). In contrast, the OA-specific studies had a moderate effect on function, which was significantly different from the small functional effect in the non-OA specific studies.

B. Design of Training Programs

From a clinical perspective, questions about the optimal design of a strength training program are important. There are fewer studies that have randomized comparisons of different strength training approaches in older adults with OA, so meta-analytic comparisons are not possible. Two studies with randomized comparisons of different strength training approaches are summarized below. Because so few studies exist in this area, the search was broadened to include studies where the mean age of participants was 60 or above.

High versus low-moderate intensity Strength Training

There has been debate about the most appropriate exercise intensity for strength training programs for people with OA. Larger training effects are usually seen when people participate in high-intensity strength training, but there is concern that a large overload might increase pain and joint stress in people with OA. Jan *et al*,[31] conducted an RCT that compared high intensity and low intensity training in people with knee OA. The authors stated in the text that their original intent had been to have people exercising at an intensity of 80% of 1repetition maximum (1RM), but they found in pilot testing that 7/10 subjects were unable to complete the exercises at this intensity because of pain. Therefore, high intensity training was conducted at 60% of 1RM with 3 sets of 8 repetitions and low intensity training was set at 10% 1RM with 10 sets of 15 repetitions. After 8 weeks of training, both exercise groups had significantly reduced pain and improved function compared to the control group, but there were no significant differences in these outcomes between the high and low intensity training groups. No adverse events were reported.

Dynamic versus Isometric Resistance Training

Topp *et al.*[30] compared a dynamic resistance training program where the exercises were performed through the range of motion using theraband to an isometric training program

where the joint did not move as the subjects generated muscle tension against the maximum-resistance theraband while the joint angle did not change. After 16 weeks of training, both groups had improvements in function and pain compared to the control group, but the improvements were not significantly different between the two treatment groups.

Discussion

This review found that strength training is beneficial to older people with OA. Older adults in the strength training group had significant improvements in strength and function, and reductions in pain in the older adults. All of these outcomes had a moderate effect size.

These findings are consistent with what is known about the effect of strength training in the general older adult population and in the general population of people with OA, where strength training has been found to improve muscle strength and function.[11, 13, 23] The effect on strength was smaller than that found by Fransen in the Cochrane review of knee OA which found an effect size of 0.53 (95% CI 0.79, 0.27), although the confidence intervals overlap.[9] It is not clear why the results were different in this review. It is possible that the studies that included younger people with OA were more likely to use the highest intensity of training or had other differences in the program, but such differences in the training programs are not apparent in the study descriptions. It is also possible that the older people's muscles were slightly less responsive overall or slower to respond to the training stimulus. Finally, it is possible that adherence to the exercise program was lower in older people with OA, but this can not be confirmed because adherence was poorly recorded or not recorded at all in many of these trials.

An interesting finding from this review was the difference in the magnitude of the effect on strength and function between studies with a general older adult population and OA-specific studies of older people. In the general older adult population, strength training has a very large effect on strength, and a much smaller, barely significant, effect on function. This is perhaps not surprising, since the intervention is targeting muscle and so the direct impact is on strength, while many factors can contribute to late-life functional problems. In OA, the effect on strength, function and pain was a moderate size, and almost an identical effect size across the three outcomes. These findings suggest that while strength training is beneficial for all older adults, it has a much larger functional impact on people with OA, and all of the improvements in muscle strength are directly translated into improvements in function. One reason for this could be that the impairments that limit function in older people with OA are more narrowly focused, and muscle weakness is a primary contributor to pain and functional problems in OA. When older people with OA participate in strength training the training directly targets one of the main barriers to their functional performance.

It is not clear why the strength gains in people with OA were smaller than those in the general older adult population. Given the larger strength gains observed in the general older adults studies, it would appear that larger strength gains are possible to achieve in older adults exercisers. It is possible that if strength gains could be increased in older people with OA, perhaps by changes to the type, intensity or duration of training, or by ensuring maximal adherence to the training, there might also be additional improvements in function and reductions in pain beyond the moderate effects currently seen.

A major limitation of this review is the fact that no appropriate RCTs were identified that explored the effects of strength training on older adults with hip or upper limb OA. Any studies that were identified could not be included because they focused on a younger population, did not use an RCT design or used either combined exercise training or a non-PRT approach. Studies in these groups of OA patients are clearly needed.

There is also very limited randomized data available about the comparative effectiveness of different strength programs or even the relative effectiveness of different training approaches. The existing evidence suggests that there are few differences in outcomes when different training approaches are used. In particular, Jan et al found no significant differences in strength and functional outcomes between high and low intensity training groups. However, caution is needed in interpreting these findings because the studies comparing training intensity or approaches have all had a short duration of follow-up so true training effects might not have occurred. They also have small sample sizes, and therefore might have failed to detect real differences that exist between the treatment groups because of a lack of statistical power.

The positive message from this review that should be clearly communicated to older people with OA is that no matter how old they are, they will probably benefit in clinically important ways from participating in a strength training program, as long as it provides some consistent overload to their muscles as they exercise. The biggest challenge with any exercise program is to maintain long-term adherence, because the benefits of exercise will diminish if people stop exercising. There is currently no evidence that one type of strength training program is superior to another as long as the program provides progressive overload, so older people should exercise at the intensity, location and using the equipment that they most prefer. Although not the focus of this review, aerobic training programs have been found to have a similar benefit to strength training in an RCT that had one of the largest sample sizes and longest follow-up of any trials in this area.[24] If people prefer aerobic exercise, this mode of exercise should also be utilized by older people with OA.

Summary and Recommendations

Older adults with osteoarthritis will benefit from a strength training program that provides progressive overload to maintain intensity throughout the exercise program. Significant improvements in strength and function and pain reduction were seen when the data from 8 RCTs were synthesized, and there was a moderate effect size for all three outcomes.

Clinicians should encourage participation in exercise training programs, even in the oldest old with OA. There is no evidence that there is significantly decreased efficacy or increased risk of adverse events when older adults with OA participate in exercise programs compared to younger adults. People with OA should be reassured that it is unlikely to exacerbate their pain if performed using the appropriate methods and at the appropriate dose. In fact, the evidence suggests that it will decrease pain in most older people.

More information is needed about the comparative effectiveness of different training approaches. Specifically, trials with adequate sample size and duration of follow up are needed to comparing the effectiveness of different training intensities and types of strength training approaches. However, the current evidence suggests people can benefit from a wide variety of exercise programs, as long as the strength training program provides a progressive overload. Older people with OA should therefore select the type and style of strength training that best fits into their lifestyle. Long-term adherence is required in order to maintain the benefits of strength training, and studies to increase our understanding of the best way to achieve long-term compliance with exercise programs in this population would be very useful.

Finally, more evidence is needed about the benefits of strength training for older people with OA of the hip and upper limb. The current findings are almost completely based on studies of people with knee OA.

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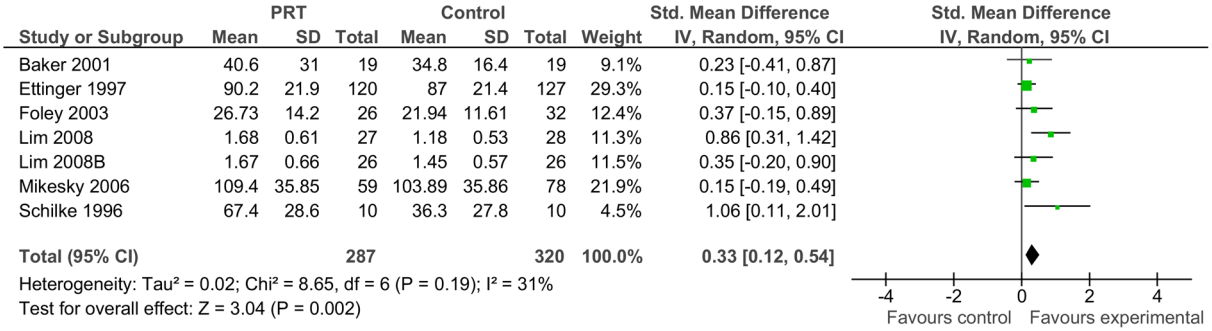

Figure 1. Forest plot of leg extensor strength in trials of strength training by older adults with OA

Note: PRT= progressive resistance training, sd=standard deviation, CI= confidence interval Mean and SD are based on the final scores for each outcome measure in the PRT and control groups. Total refers to the sample size in each group for each outcome. The sample size is used to weight the contribution of each study to the overall estimate of treatment effect. The total standardized mean difference indicates what the overall effect size and the associated confidence interval is for this estimate. The test of statistical significance is provided by the test for overall effect and the associated P-value which is shown to the far left of the figure.

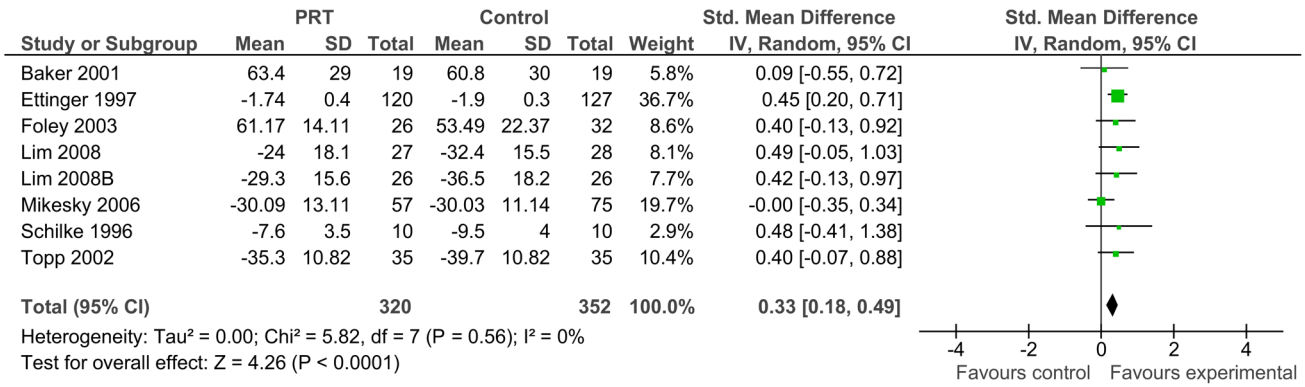

Figure 2. Forest plot of function in trials of strength training by older adults with OA

Note: PRT= progressive resistance training, sd=standard deviation, CI= confidence interval

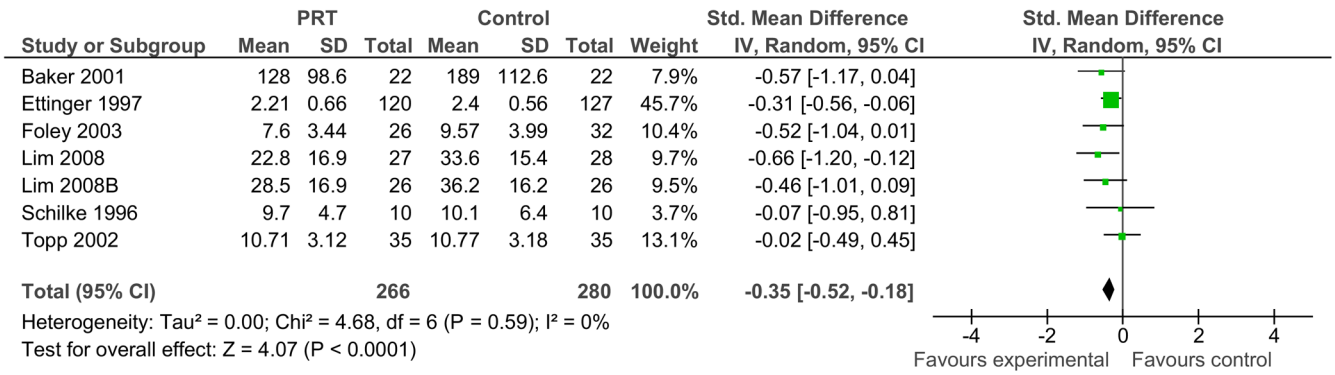

Figure 3. Forest plot of pain in trials of strength training by older adults with OA

Note: PRT= progressive resistance training, sd=standard deviation, CI= confidence interval

Table 1

Characteristics of included studies

Study ID	Sample Size	Mean Age	Intervention	Control	Exercise Adheren ce	OA Group
Schilke 1996[29]	20	65	Type of Ex:1LL Equipment: isokinetic dynamometer Intensity: high Frequency: 3x pw Reps/Sets: 5/6 Duration: 8 weeks Setting: gym	usual activities	Not reported(NR)	Knee OA
Ettinger 1997[24]	295 (in PRT vs control)	68	Type of Ex: 4UL, 4LL, 1Tr Equipment: cuff-weights, dumb bells Intensity: moderate to high Frequency: 3x pw Reps/Sets: 12/2 Duration: 78 weeks Setting: facility-based group for 3 months, then home- based for 15 months	health education program	70% at 18 months	Knee OA
Maurer 1999[27]	113	66.3	Type of Ex: 1 LL Equipment: isokinetic dynamometer Intensity: high Frequency: 3x pw Reps/Sets: 3 reps at 3 speeds (total 9 reps) in 3 sets Duration: 8 weeks Setting: gym	four classes on OA education and self-management	NR	Knee OA
Baker 2001[23]	46	68	Type of Ex: 2 functional exercises (squats and step-ups), 5 LL isotonic exercises Equipment: velcro ankle weights Intensity: initially low, progressed to hard Frequency: 3x pw Reps/ sets: 12/2 Duration: 16 weeks Setting: home-based	given nutrition info, 7 home visits over 16 weeks, kept food logs 3/14 days	84%	Knee OA
Topp 2002[30]	35	65.6	Type of Ex: 6 LL for 30 minutes Equipment: Theraband Intensity: mild fatigue after 8RM Frequency: 3x pw (2 at home 1 at gym) Reps/Sets: increasing reps and sets every week and then reached 12 reps/3sets at week 9 Duration: 16 weeks Setting: home and gym	No intervention	NR	Knee OA
Foley 2003[25]	70	69.8	Type of Ex: 1UE/4 LL Equipment: weighted gaiters Intensity: 10 RM Frequency: 3x pw Reps/Sets: not reported Duration: 6 weeks Setting: gym	telephone calls to record any changes in their condition	75%	Hip or Knee OA

Study ID	Sample Size	Mean Age	Intervention	Control	Exercise Adheren ce	OA Group
Mikesky 2006[28]	221	69.4	Type of Ex: 2UL/2LL Equipment: CYBEX machines at gym; Elastic bands at home, Intensity: 8–10 RM Frequency: 3x pw Duration: 1 year Setting: gym and home	Flexibility exercise group: flexibility ex, 3x pw	59% Gym 56% Home	Knee OA
Lim 2008[26] – malaligned	52	67.2	Type of Ex: 5LL Equipment: theraband and cuff weights Intensity: 10 RM Frequency: 5x pw Reps/Sets: Initially 2 sets of 10 reps, progressed to 3 sets of 10 reps Duration: 12 weeks Setting: gym and home	No intervention	89%	Medial knee OA
Lim 2008[26] - neutral	55	64.1	Same program as above	No intervention	86%	Medial knee OA

Note: Ex=exercise, LL= lower limb, UL=upper limb, Tr=trunk, x pw= times per week, reps=repetitions, PRT= progressive resistance training

Table 2

Comparison of strength and functional outcomes between older adults with and without OA

Outcome	Comparison	N	Effect Size (95% CI
Strength			
	All older adults	3166	0.83 (0.67,0.98)
	Excluding OA-specific studies	2559	0.88 (0.7, 1.05)
	Including only OA-specific studies	607	0.33 (0.12, 0.54)
Function			
	All older adults	2279	0.15 (0.07, 0.23)
	Excluding OA-specific studies	1607	0.07 (−0.02, 0.17)
	Including only OA-specific studies	672	0.33 (0.18, 0.49)