Exercise & Sports Science Australia (ESSA) updated Position Statement on exercise and physical activity for people with hip/knee osteoarthritis.

Rana S Hinman[1] (BPhysio(Hons), PhD), Michelle Hall[1] (BSc (Hons), MSc, PhD), Sarah Comensoli[2] (BExScRehab, MBA), Kim L Bennell[1] (BAppSc(physio), PhD)

[1]Department of Physiotherapy, The University of Melbourne, Melbourne, VIC, Australia

[2]BJC Health, Sydney, NSW, Australia

Financial disclosures: RSH is supported by a NHMRC Senior Research Fellowship (#1154217). MH is supported by a NHMRC Investigator Grant Emerging Leadership Level 1 (#1172928). KLB is supported by a NHMRC Investigator Grant Leadership Level 2 (#1174431).

Correspondence and reprints:

Prof Rana Hinman ranash@unimelb.edu.au

Twitter handle: @HinmanRana

Word Count: 4244

Key words: osteoarthritis; exercise; rehabilitation; resistance; aerobic; strength; knee; hip; pain; function; physical activity.

Abstract

This Position Statement is an update to the existing statement. It is intended for all health practitioners who manage people with hip/knee osteoarthritis (OA). It synthesises the most recent evidence (with a focus on clinical guidelines and systematic reviews) for exercise in people with hip/knee OA, and provides guidance to practitioners about how best to implement exercise in clinical practice. Clinical practice guidelines for hip/knee OA advocate physical activity and exercise as fundamental core components of evidence-based management. Research evidence indicates that exercise can reduce joint pain, increase physical function, and improve quality of life in hip/knee OA, and that a range of exercise types (both supervised and unsupervised) may be beneficial. Exercise dosage should be guided by the principles of the American College of Sports Medicine. As people with OA experience many barriers to exercise, practitioners should take an active role in monitoring and promoting adherence to exercise in order to optimise therapeutic benefits.

Background

Osteoarthritis (OA) is considered a disease of the whole joint organ, arising from complex biological processes that involve cartilage, bone, muscles, ligaments, synovium, and the meniscus. There is currently no cure for OA. Thus, clinical guidelines from Australia and around the world emphasise non-invasive strategies as core treatments, with the aim of reducing symptoms, improving function and quality of life, and delaying the need for joint replacement surgery.[1] Exercise is strongly advocated for all people with hip/knee OA because of proven benefits with respect to pain, physical function, and quality of life.[1] This Position Statement is an update to the existing statement,[2] given the increasing burden of hip/knee OA and the large expansion of research evidence that has occurred over the past 10 years. It is intended for all health practitioners who manage people with hip/knee OA, including exercise practitioners, general practitioners, physiotherapists and lifestyle coaches.

Over the past 30 years, the number of people with OA has increased by 113%, with 528 million people across the world affected by OA in 2019 compared to 248 million in 1990.[3] Knee OA accounts for 61% of prevalent cases whilst hip OA accounts for 6%, and the remaining proportion occurs at the hand or other sites.[3] In Australia, around 2.2 million people (1 in 11) had OA at any joint in 2017-18.[4] Although OA can affect people at any age, its prevalence increases dramatically from middle age, such that 1 in 5 Australians aged over 45 years have OA.[4] In 2015–16, OA cost the Australian health system around $3.5 billion,[4] representing 28% of disease expenditure on musculoskeletal conditions. Much of this OA expenditure is driven by costly joint replacement surgeries. Alarmingly, the incidence of total knee replacement and total hip replacement for OA is estimated to rise by 276% (from 42,920 procedures in 2013) and 208% (from 25,945 procedures in 2013), respectively, by 2030.[5]

Osteoarthritis disproportionately affects women,[3] with 3 in 5 people with OA in Australia being female.[4] The cardinal sign is joint pain, which is often accompanied by swelling and stiffness.

Together these problems can limit activity, restrict participation, impair sleep, contribute to fatigue and/or depressed or anxious mood, and ultimately result in loss of independence and reduced quality of life. More than 1 in 2 Australians with OA suffer from moderate to very severe pain and Australians with OA are 2.1 times more likely to describe their health as 'poor' compared to those without OA.[4] Clinical presentation may differ somewhat between hip and knee OA. At time of presentation, people with hip OA tend to be younger and have experienced a shorter duration of symptoms compared to knee OA.[6] People with hip OA tend to have more problems with restricted range of joint motion, whilst knee joint instability (buckling and giving way) occurs more freqently with knee OA.[6] Compared to knee OA, people with hip OA often describe pain as intense or rapidly progressing from mild to severe.[6]

The aim of this updated Position Statement is to provide practitioners with contemporary evidence-based guidance for prescribing safe and effective exercise for adults with hip/knee OA. The evolving evidence base continues to support exercise recommendations in the prior Position Statement, but new clinical trials, systematic reviews and meta-analyses allow recommendations to be refined. In addition, emerging evidence about the importance of physical activity warrants the inclusion of recommendations specific to physical activity. Increased research into the barriers to exercise also justifies the inclusion of recommendations about how best to maximise exercise adherence.

Boundaries of evidence

Relative to knee OA, there have been fewer clinical trials evaluating exercise for hip OA. Findings from studies in people with knee OA cannot necessarily be generalised to those with hip OA given differences in prevalence, prognosis, epigenetics, pathophysiology, anatomical and biomechanical factors, clinical presentation, pain, and current practice.[6] Thus, recommendations for exercise for hip OA are typically based on a smaller evidence base and uncertainty around the magnitude of benefits (relative to knee OA). Additionally, there are some types of exercise (such as flexibility, balance and

yoga) that have a smaller evidence base compared to others (such as resistance training) and often the trials are of lower quality. There is also currently limited evidence about which subgroups of people with hip/knee OA respond best to exercise. Finally, incomplete descriptions of exercise interventions upon which current clinical guideline recommendations are based[7] can make it challenging for replication in clinical practice.

Role of exercise in hip/knee OA

Physical activity and exercise are considered core components of evidence-based management for all people with hip/knee OA.[1] Physical activity may be considered to be "any bodily movement produced by skeletal muscles that results in energy expenditure".[8] Thus, physical activity refers to all planned and incidental movement, including that occurring during daily living, leisure, sport, transport, and occupational tasks. Exercise is "a subset of physical activity that is planned, structured, and repetitive" with the goal of improving or maintaining physical fitness.[8]

Like most adults, people with hip/knee OA are not sufficiently physically active. A systematic review showed that only 48% of people with knee and hip OA achieve ≥7,000 steps per day,[9] and data from the Osteoarthritis Initiative (USA) has revealed that over 50% of men and nearly 80% of women with or at risk of knee OA do not perform at least 150 minutes of moderate-vigorous physical activity each week.[10] Insufficient physical activity may lead to loss of muscle strength, which may exacerbate OA symptoms, reduce functional capacity, and may increase risk of structural changes within the joint. It is also possible that loss of muscle strength contributes to declines in physical activity in the first instance. Low quality evidence suggests that lower knee extensor muscle strength is associated with incident symptomatic and radiographic knee OA,[11] leading to speculation that increasing knee extensor muscle strength in adults may help to prevent knee OA. In people with established knee OA, lower knee extensor strength is associated with an increased risk of worsening pain and declining physical function (e.g. walking ability) but not necessarily structural changes.[12]

Insufficient physical activity can contribute to co-morbidities in people with hip/knee OA. Two out of three people with OA (at any joint) suffer from at least one other chronic comorbid medical condition,[13] with the most common including hypertension, dyslipidaemia, back pain, thyroid conditions, and depression. Multimorbidity is common, with around a quarter of people with OA having three or more comorbidities.[13] In addition, overweight and obesity are well-established risk factors for both incidence and progression of knee OA.[14] People with OA (at any joint) are at increased risk of death due to cardiovascular disease,[15] and there is increasing evidence that symptomatic or radiographic knee OA increases risk of death from any cause.[16] In the USA, if even 20% of the inactive knee OA population were instead active, modelling suggests that 95,920 cases of cancer, 222,413 of cardiovascular disease, and 214,725 of diabetes mellitus could potentially be averted.[17]

Sedentary behaviour and insufficient physical activity can lead to an increased risk of falls and falls-related injuries, particularly for people with knee OA.[18] The odds of falling increases with an increasing number of hip/knee joints affected by symptomatic OA. Compared to people without knee or hip OA, people with 1 symptomatic OA hip/knee joint have 53% higher odds of falling, those with 2 OA hip/knee joints have 74% higher odds, and those with 3–4 OA hip/knee joints have 85% higher odds.[19] Impaired balance, muscle weakness, presence of comorbidities, and increasing number of symptomatic joints, are all risk factors for falls in people with knee OA.[20]

Types of exercise

Many different types of exercise can help people with hip/knee OA, with typical benefits including improvements in joint pain, physical function, and health-related quality of life,[21] lasting up to 6 months following cessation of a defined program.[22] Whilst there are far fewer clinical trials of exercise in hip OA (relative to knee OA), a Cochrane review in hip OA reported immediate

improvements in pain and physical function with land-based exercise which were still evident 3-6 months later.[23] Limited but emerging evidence suggests that an exercise intervention can reduce the need for arthroplasty by 44% 6 years later in people with hip OA[24] and by 68% at 2 years in knee OA.[25] Exercise may be supervised (either individually part of a group), performed unsupervised, or via a combination of methods, however clinical benefits appear to be greater when exercise is supervised by a clinician.[26] Land-based and water-based exercise are both effective,[22] noting that water-based exercise can harness the benefits of buoyancy, thereby reducing joint impact and presenting a viable exercise option for those who find land-based exercise too difficult or painful. Whilst meta-analyses show that exercise effect sizes on pain and physical function are generally only small to moderate in magnitude, the benefits achieved with exercise appear to be similar to those observed with common analgesic drugs.[27] It is also important to note the many other health benefits of exercise over and above analgesics, many of which will be reviewed below.

Aerobic (cardiovascular) exercise

Aerobic exercise (typically involving walking, running, cycling, and/or swimming) is aimed at increasing cardiovascular fitness. Low-impact aerobic exercise that is gentle and places less stress on the joint (such as walking, cycling, or swimming) may be best for people with hip/knee OA rather than high-impact activities that involve running and/or jumping. Walking is a popular choice of aerobic exercise, given it is readily implemented by most people with hip/knee OA, can be done on a variety of surfaces, settings, or environments (treadmill, indoors, outdoors, in the water) and may be undertaken independently or in a group. For people with knee OA, practitioners should aim for a daily walking goal of at least >6,000 steps/day, as research shows this may prevent declines in walking speed and physical functioning during daily tasks in the future.[28] Aerobic exercise improves cardiovascular fitness in people with hip/knee OA and inflammatory arthritis,[29] and improves both pain and physical function in people with knee OA.[26] Aerobic walking combined with resistance training over 18 months can lead to modest amounts of weight loss (approximately 1.8 kgs or 2% of

body weight) in people with knee OA and overweight/obesity.[30] Weight loss of 5-10% of body weight is required for pain reduction[31] and dietary interventions should be combined with exercise to maximise weight loss.[30] Of all types of exercise for hip/knee OA, aerobic exercise may be the best for improving objective physical performance (e.g., gait and walking parameters) and is one of the most effective for reducing joint pain, at least in the short-term.[21] For people with hip/knee OA who have overweight or obesity, aerobic exercise may be particularly appropriate to assist with weight loss.

Resistance (strength) training

For hip/knee OA, resistance training should target the lower limb muscle groups appropriate for the affected joint(s) (e.g., hip flexors, extensors, abductors, adductors, and rotators, knee flexors and extensors, calf muscles) and based on individual impairments.[32] In people with hip/knee OA, meta-analyses confirm that resistance training increases muscle strength[29] and improves pain, physical function, objective measures of performance, and quality of life.[21, 26] For people with knee OA, resistance training of both hip and quadriceps muscles improves walking function more than quadriceps training alone.[33] Current evidence also suggests that resistance training is the most beneficial type of exercise for improving mental health and depressive symptoms in people with knee OA,[34] compared to aerobic, mind-body and stretching exercise. A recent high-quality RCT suggests that high-intensity strength training (75-90% of 1 repetition maximum) does not reduce knee pain or compressive forces compared to low-intensity strength training (30-40% of 1 repetition maximum) or attention control over 18 months in people with knee OA.[35]

Flexibility (stretching) exercise

The goal of flexibility exercises is to improve joint range of motion and muscle pliability. In people with knee OA, two low quality clinical trials with small sample sizes suggest stretching exercises in isolation may relieve pain compared to no exercise.[36] Limited evidence suggests that stretching, when

combined with resistance training or aerobic exercises, does not change flexibility in people with hip/knee OA.[29] Given the more robust evidence base and broader beneficial effects of aerobic and resistance exercise, practitioners should prioritise these forms of exercise in preference to stretching for hip/knee OA.

Neuromotor (neuromuscular) exercise

Neuromotor exercise, typically performed in functional weightbearing positions, incorporates motor skills such as balance, coordination, agility, and proprioception. Research evaluating effects of neuromotor exercise in hip/knee OA is scarce and it is not clear if neuromotor performance can be improved with neuromotor exercise.[29] Given that balance exercises can reduce the rate of falls in older adults by 23%,[37] inclusion of balance exercises in an exercise program may be warranted in people with hip/knee OA who have a history of falls or where increased falls risk is identified. It should also be noted that yoga and Tai Chi (below) incorporate elements of neuromotor exercise.

Mind-body exercise

Mind-body exercise, such as yoga and Tai Chi, combines body movement, mental focus, and controlled breathing with the goals of increasing strength, balance, flexibility, and overall health. Research evidence, often from trials of low quality, suggests that mind-body exercise may be one of the most effective exercise types for improving self-reported physical function and for reducing joint pain in hip/knee OA.[21] Specifically, Tai Chi has been shown to have moderate benefits on pain, physical function, and stiffness in people with OA (any joint).[38] The evidence around yoga is somewhat conflicting, with a systematic review suggesting there is only very low quality evidence it improves pain, physical function, and stiffness (compared to exercise and non-exercise controls)[39] and a new RCT in 212 people with knee OA[40] showing an unsupervised online yoga program improved physical function but not knee pain (compared to online education).

Recommendations for physical activity

For adults and older adults, the World Health Organization[41] recommends at least 150-300 minutes of moderate intensity aerobic physical activity per week, or at least 75-150 minutes of vigorous intensity activity, along with muscle strengthening (on at least two days) for additional health benefits. In people with knee/hip OA, doing some physical activity is better than none and health benefits can be gained even if recommendations are not met. People with hip/knee OA should be advised to start with small amounts of physical activity, and gradually increase the frequency, intensity, and duration over time.[41] For people with hip/knee OA who find it difficult to achieve World Health Organization recommendations, practitioners should, at a minimum, aim for at least 45 minutes of moderate-vigorous physical activity each week, as research in adults with lower extremity symptoms (pain, aching or stiffness) shows this amount predicts improved or sustained high physical function over two years.[42]

The European League Against Rheumatism has recognised that public health physical activity recommendations may be challenging for people with hip/knee OA to achieve, and developed ten recommendations (Table 1).[43] These emphasise that all healthcare providers have a responsibility to promote general physical activity (consistent with public health recommendations) as an integral component of care throughout the OA disease course. When clinicians advise people with arthritis to be more physically active, patients are more likely to increase physical activity levels.[29] In partnership with the patient, practitioners should develop a patient-centred plan to increase weekly participation in moderate-vigorous physical activity. Increased sedentariness is related to poorer physical function in adults with knee OA,[44] independent of the amount time spent participating in moderate-vigorous physical activity. Thus, practitioners should encourage adults with knee OA to reduce time spent in sedentary activities and postures as much as possible.

Recommendations for prescription of exercise

Exercise for hip/knee OA should follow American College of Sports Medicine (ACSM) 'FITT-VP' exercise prescription principles.[45] In people with knee OA, strength gains are maximised when exercise is prescribed according to ACSM recommendations for resistance training.[46] In people with hip OA, exercise only reduced pain when exercise dose meets the ACSM recommendations for cardiorespiratory fitness, muscular strength, and flexibility.[47] The FITT-VP principles incorporate: Frequency (how often to exercise), Intensity (how hard to exercise), Time (how long to exercise for), Type (mode of exercise), Volume (total amount of exercise), and Progression (how to progress the exercise program). Table 2 summarises these principles for cardiovascular, resistance, flexibility, and neuromotor exercise in healthy adults. These principles also apply to all people with hip/knee OA (any age or disease severity).

Any exercise program prescribed (including the dosage) should be within the capability of the individual to perform. It is quite normal for people with hip/knee OA to experience some joint discomfort with exercise, particularly with exercise in weight-bearing postures. Exercise practitioners may be afraid of aggravating pain, with data suggesting that 83% of accredited exercise physiologists always or most of the time prescribe 'nonpainful' exercise for knee OA.[48] There is no evidence that exercising with tolerable levels of joint pain is harmful, and in fact, exercise programs where pain is allowed/encouraged may be more beneficial for reducing pain in the short-term in chronic musculoskeletal disorders compared to pain-free exercises.[49] It is possible that exercising with some pain or discomfort may help reduce fear avoidance, kinesiophobia and catastrophising, and/or increase self-efficacy. Whilst exercising, joint pain should remain within a range that is considered tolerable by the individual and practitioners may wish to advise their patients to consider exercising at a time of day when pain levels are typically at their lowest. Monitoring pain during exercise with simple numerical rating or visual analog scales can be helpful.[50] Although each individual should determine an "acceptable" level for themselves, pain scores up to 5 out of 10 are tolerable with exercise in hip/knee OA.[50] An increase in joint pain immediately after exercise is also not uncommon,

however research shows that there is a decrease in the magnitude of acute exercise-induced pain flares with increasing numbers of exercise sessions.[51] A simple method to judge whether a person with hip/knee OA has 'overdone' it with exercise is that any increase in joint pain (from normal pain levels) should return to normal levels within 24 hours after exercise.[50] If pain remains elevated beyond this timeframe, the practitioner should review the exercise program and modify it accordingly.

It is important practitioners are aware of the potential for exercise to aggravate pain at other sites, such as the lower back or foot. Hip OA is often accompanied by low back pain, and it is important to ensure that any exercise program for the hip does not flare up problems in the lower back. Thus, practitioners should always be cognisant of the potential for aggravating joint pain (at the site of OA or other body areas) when choosing exercise postures/positions, amount of resistance and the dosage of exercise programs. Programs should always be individualised and tailored to the unique needs and presentation of the individual.

It is also important for practitioners to recognise and consider the heterogeneity of the hip/knee OA population when selecting an exercise program/modality. Individuals typically present with their own unique OA-related problems (e.g. while one person may experience knee instability, another may have problems getting in and out of the car) and personal goals of exercise therapy (e.g. one person may want to get stronger whilst another may want to be able to walk for longer distances). Thus, an exercise program/modality that is appropriate for a 75 year old retired woman with knee OA and obesity may not be suitable for a 50 year old active man with hip OA who is employed as a carpenter (for example).

Maximising exercise adherence

Clinical benefits of exercise in hip/knee OA may decrease over time if exercise adherence declines and promoting exercise adherence is a clinical challenge frequently encountered by exercise

practitioners.[52] A complex variety of factors can influence exercise participation,[53] including physical, personal, social, and environmental. Barriers to exercise in people with hip/knee OA can include joint pain and physical disability, negative exercise experiences, inaccurate beliefs and misinformation, lack of motivation, and inadequate professional support. In particular, barriers related to environmental context and resources (e.g. financial costs of exercise, accessibility, weather, equipment),[53] beliefs about the consequences of exercise, and beliefs about capability to exercise are all important for the practitioner to understand and consider (Table 3). Table 4 outlines a checklist of factors that practitioners should consider with an individual with hip/knee OA when prescribing an exercise program, to assist identifying those at increased risk of poor exercise adherence. It is important that practitioners monitor adherence at each consultation. Although there is no gold standard method for monitoring adherence, practitioners may use verbal questioning or ask the person to record participation/adherence in a calendar, log-book, mobile app, diary, or via a wearable device (e.g., steps per day).

Table 3 outlines suggested strategies that practitioners may consider if they encounter problems with exercise adherence. Practitioner support is important to assist people to participate in, and adhere, to exercise.[53] Some evidence suggests "booster sessions" with a practitioner, or a behavioural graded approach (where activity is gradually increased in a time-contingent manner) may help.[54] A strong and positive therapeutic alliance can improve pain outcomes from treatments, including exercise, for chronic musculoskeletal pain.[55] Agreeing on exercise goals, provision of clear communication and positive feedback, showing genuine interest, trust in the practitioner, and a feeling of self-empowerment, along with developing individualised care plans, may all help promote adherence. It is also important that clinicians carefully consider the language they use when describing OA and the role of exercise in its management to their patients,[56] as terms such as 'wear and tear' and 'bone on bone' can reinforce misconceptions about OA, perpetuate beliefs that individuals have little control

over symptoms, and discourage individuals from engaging in effective self-management strategies such as exercise.

Special considerations: safety of exercise in hip/knee OA

People with hip/knee OA (and sometimes, healthcare providers) may fear that exercise is not safe for their joint. However, research suggests that low-impact (e.g., cycling, swimming, walking) exercise (lasting 3 to 30 months) is safe for most older adults with knee pain and/or OA.[57] Mild adverse events do occur, in up to a quarter of exercise participants, which usually involve muscle soreness and/or temporary or mild increases in joint pain.[57] Whilst the current evidence base is uncertain regarding the safety of high-impact exercise,[22] a cohort study suggested that running was associated with improvements in knee pain without increasing structural progression in people over 50 years with knee OA.[58]

Based on the current limited (often low-quality) research available, it appears that exercise is safe for articular cartilage. Magnetic resonance imaging studies suggests that knee joint loading exercise is not harmful for articular cartilage in people at risk of, or with, established knee OA, although the quality of evidence is low.[59] These findings are supported by research showing that exercise does not increase the concentration of molecular biomarkers related to cartilage turnover and inflammation, suggesting exercise is not harmful.[60] Data suggest that up to 10,000 steps/day of physical activity does not increase the risk of progression on magnetic resonance imaging in people with knee OA,[22] although there may be an increased risk with ≥10,000 steps/day. Whilst running has some immediate effects on knee cartilage, the effects appear to be only transient (possibly due to natural fluid dynamics) and moderate evidence suggests that running does not lead to new cartilage lesions.[61] Collectively, the current evidence does not show that exercise increases the risk of structural progression in people with established knee OA.

Given the high rates of comorbidity observed in people with hip/knee OA,[13] exercise practitioners are encouraged to screen individuals before prescribing an exercise program to identify those at risk for exercise-related cardiovascular events. People at risk should receive medical clearance before undertaking moderate-vigorous intensity exercise or increasing exercise program intensity. Some individuals may not be able to safely participate in exercise until the relevant medical condition has been managed adequately by an appropriate healthcare professional. Practitioners may wish to use the Exercise & Sports Science Australia Adult Pre-Exercise Screening System (https://www.essa.org.au/Public/ABOUT_ESSA/Pre-Exercise_Screening_Systems.aspx) and/or the ACSM Preparticipation Screening Algorithm for exercise screening purposes.[46]

Using technology to assist exercise management

Digital health technologies provide opportunities to enhance care of people with knee OA. Consumer-based wearable devices[62] and smart phone-based interventions including apps and text messaging[63] can be effective at increasing amounts of physical activity in adults. Wearable devices offer exercise practitioners and people with hip/knee OA an accessible and inexpensive method for monitoring markers of physical activity. In particular, steps per day can be readily measured and may be used by practitioners to establish a baseline level of activity and/or determine agreed physical activity goals with an individual. Access to exercise practitioners can be an issue for many people with hip/knee OA and digital/telehealth models of care[64-67] may help overcome barriers. A recent systematic review evaluated the efficacy of remotely-delivered exercise interventions for knee OA including via online, telephone, SMS, or app-based methods.[68] Although the evidence is limited, studies that used an active comparator suggested that magnitude of pain relief with remote exercise programs is similar to in-person care. Thus, practitioners may wish to consider telehealth models of service delivery for people who find it difficult to attend for in-person care. Research in people with musculoskeletal problems also suggests that web- and app-based systems for exercise programming/prescription can improve adherence to unsupervised home-based exercise, compared with providing paper-based exercise

instructions.[69, 70] Digital interventions (SMS, telephone, web or apps) also appear to be effective for improving exercise adherence in people with musculoskeletal conditions at 1-6 months follow-up.[71]

Assessment and monitoring outcomes of exercise

The Osteoarthritis Research Society International recommends that exercise interventions be monitored using outcomes that assess domains of pain, physical function, and patient global assessment. Practitioners may select from a variety of patient-reported outcomes and/or physical performance measures to choose a measure that is suitable to the context of their practice and is feasible for administration (e.g., time/space/resources required) (Table 5). Pain may be readily measured via self-report using simple patient-reported outcome measures such as a numerical rating scale or a visual analogue scale. Although physical function may also be measured via self-report using disease-specific questionnaires, the Osteoarthritis Research Society International has recommended a set of performance-based tests of physical function for people with hip/knee OA that are suited for clinical purposes (https://oarsi.org/research/physical-performance-measures), including the 30 second chair test, 40 m fast-paced walk, stair climb test, timed up and go test, and/or the 6 minute walk.

Summary

Hip and knee OA are a leading cause of global disability burden and exercise is a core component of recommended care for people with OA. Many people with hip/knee OA are insufficiently physically active to meet public health physical activity recommendations for good health. Exercise can improve joint pain, physical function, and quality of life and may delay the need for joint replacement surgery. People with hip/knee OA should be encouraged to be as physically active as possible in order to minimise the risk of functional decline over time. There are many barriers to exercise for people with hip/knee OA. Exercise practitioners have a responsibility to monitor and discuss exercise adherence

403 with their clients, as well as suggest strategies to overcome obstacles to adherence in order to optimise
404 outcomes from exercise.
405
406
407

Table 1: Physical activity recommendations from the European League Against Rheumatism[43] for people with hip/knee osteoarthritis (OA).

Recommendations
1. Promoting physical activity, consistent with general physical activity recommendations, should be an integral part of standard care throughout the disease course.
2. All healthcare providers should take responsibility for promoting physical activity and should cooperate, including making necessary referrals, to ensure that people receive appropriate physical activity interventions.
3. Physical activity interventions should be delivered by healthcare providers competent in their delivery.
4. Healthcare providers should evaluate the type, intensity, frequency, and duration of an individual's actual physical activity via standardised methods to identify which can be targeted for improvement.
5. General and disease-specific contraindications for physical activity should be identified and taken into account.
6. Physical activity interventions should have clear personalised aims, which should be evaluated over time, preferably via both subjective and objective measures (including self-monitoring when appropriate).
7. General and disease-specific barriers and facilitators related to performing physical activity, including knowledge, social support, symptom control, and self-regulation should be identified and addressed.
8. Where individual adaptations to general physical activity recommendations are needed, these should be based on a comprehensive assessment of physical, social, and psychological factors including fatigue, pain, depression, and disease activity.
9. Healthcare providers should plan and deliver physical activity interventions that include behaviour change techniques of self-monitoring, goal setting, action planning, feedback, and problem solving.
10. Healthcare providers should consider different modes of delivery of physical activity in line with people's preferences.

Table 2: American College of Sports Medicine[45] FITT-VP principles for exercise prescription applicable to people with hip/knee osteoarthritis.

	Aerobic (cardiovascular) exercise	Resistance (strengthening) exercise	Flexibility (stretching) exercise	Neuromotor (neuromuscular) exercise
Frequency	≥3 days/week Spreading exercise sessions across 3-5 days/week may be optimal.	Beginner: at least 2 days/week Experienced: frequency is secondary to training volume; choose frequency according to personal preference	≥2-3 days/week (daily may be optimal)	≥2–3 days/week
Intensity	Moderate (40-59% HRR) and/or vigorous (60-89% HRR).	Beginner: 60-70% of 1-RM (moderate to hard) for strength Older &/or sedentary beginners: beginners: 40-50% of 1-RM (very light to light) for strength Experienced: ≥80% of 1-RM (hard to very hard) for strength ≤50% of 1-RM (light to moderate) for muscular endurance 20-50% of 1-RM in older people to improve power	Stretch to point of feeling tightness or slight discomfort.	Not yet determined.
Time	30-60 mins/day (≥150 mins/week) of moderate intensity or 20-60 min/day (≥75 mins/week) of vigorous intensity or combination	No specific duration	Hold static stretch for 10-30 secs. Older people: holding for 30-60 secs may confer greater benefit.	≥20–30 mins/day

	Performed in one continuous session/day or in multiple bouts of ≥10 mins.			
Type	Regular, purposeful exercise involving major muscles and performed in a continuous or intermittent in nature. Activities with low joint stress (e.g., walking, cycling, swimming, aquatic exercise) may be most appropriate in people with osteoarthritis.	Multi-joint exercises affecting more than one muscle group and targeting agonist and antagonist muscle groups. Single-joint and core exercises may be included. Exercise equipment and/or body weight can be used.	Flexibility exercises for each of the major muscle–tendon units. Static flexibility, dynamic flexibility, ballistic flexibility and, proprioceptive neuromuscular facilitation may be appropriate.	Exercises involving motor skills (e.g., balance, agility, coordination and gait), proprioceptive training and multifaceted activities (eg, Tai Chi and yoga) are recommended for older people.
Volume	≥500–1000 MET/min/week. Increasing step counts by ≥2000 steps/day to reach a daily step count ≥7000 steps per day is beneficial.	1-3 sets (of 8-12 repetitions) to improve strength and power. Single set of 10-15 repetitions in older, beginners may be effective for strength. ≤2 sets of 15-20 repetitions for muscular endurance.	Total of 90 secs of discontinuous flexibility exercise per joint.	Not yet determined.
Progression	Gradual progression by adjusting duration, frequency, and/or intensity until the desired exercise goal (maintenance) is attained.	Gradual progression of greater resistance and/or more repetitions/set and/or increasing frequency.	Not yet determined.	Not yet determined.

HRR=heart rate reserve; MET= metabolic equivalents; 1-RM= one-repetition max

Table 3 Common barriers to exercise in hip/knee osteoarthritis (OA) informed by behaviour change theory[53] and suggested strategies to improve exercise adherence.

Barrier to adherence	Potential solutions
Knowledge: insufficient or incorrect knowledge about OA and its prognosis; inadequate instruction about how to perform exercise or dosage; inadequate understanding about safety of exercise in OA and its benefits.	Education & information: may include information about OA, its prognosis, causes and role of exercise relative to other management strategies. Open discussion: provide opportunity for patient to ask questions and express doubts regarding the benefits of exercise for OA and have any misconceptions adressed. Ask the patient what their understanding of OA is and correct any misinformation. Exercise instruction: provide clear demonstrations and instructions about correct execution of exercises along with the presecribed dosage. Verbal and written instructions should be provided (consider diagrams, photos or videos).
Capability: belief that not capable of exercise because of OA symptoms (e.g., pain, stiffness, fatigue) or because of comorbidities or excess body weight.	Education and information: reassurance that all people with hip/knee OA are capable of exercise, that exercise can benefit many comorbidities along with OA symptoms and that radiographic OA severity does not dictate exercise capability. Individualise exercise: offer exercise options using a shared decision-making process. Individualise physical activity advice and prescribe tailored exercise programs according to the capability of the patient. Use a graded approach, gradually building up the exercise program and dosage slowly as the patient gains confidence in their capability to exercise. Consider aquatic exercise for people with overweight/obesity to reduce load on joints whilst exercising. Monitor: check patient is confident to safely and independently undertake the exercise program unsupervised. Consider supervised individual or group sessions if confidence with unsupervised exercise is low.
Consequences: belief that exercise will not be effective for managing OA symptoms; belief that exercise and physical activity will be harmful for the hip/knee joint.	Education and information: discuss benefits of exercise, including for pain, physical function, strength and ability to participate in meaningful activities. Discuss safety of exercise for OA, including that exercise is not harmful for the joint or articular cartilage. Monitor: pain during exercise and reassure patient that tolerable levels of joint pain are OK. Teach patient how to recognize pain flares from exercise and what

	to do should this occur. Review and revise the exercise program if joint pain is being aggravated to unacceptable levels. Monitor the impact of the exercise program on any other comorbid health conditions and particularly, any other other pain sites. Adjust the program if pain at other sites is being aggravated.
Environmental context/resources: circumstances that discourage exercise and physical activity such as weather conditions, access to exercise facilities/equipment, financial costs of exercise, physical environment, transport and parking.	Open discussion: proactively ask patients about their potential environmental barriers to exercise adherence and brainstorm potential solutions should these be encountered. Discuss what exercise equipment is readily available to the patient or is feasible for purchase and devise a suitable exercise program. Consider costs and willingness to attend exercise facilities/classes etc when devising an exercise program and ensure there are no transport or financial barriers to access. Consider home-based or local exercise options that are free of charge or low cost whenever possible. Monitor: when reviewing patient progress, ask specifically about any barriers to adherence encountered and offer solutions.
Intentions: lacks motivation to exercise or belief that already sufficiently physically active.	Plan: encourage patients to plan when to undertake exercise. Consider using a calender or diary to schedule time for exercise and physical activity. Realistic: ensure the exercise program is feasible for the patient, considering time-constraints, lifestyle, occupation and other demands. Accountability and monitoring: regular review by the clinician to monitor exercise progress and adherence. Encourage self-monitoring of exercise adherence and physical activity (e.g., log books, exercise diaries, using wearables to monitor daily steps). Encourage exercise with a friend or as part of a group class. Preferences: ask about patient pereferences for exercise and choose exercises and physical activities that the person is most likely to enjoy.
Memory: forgets to exercise.	Cueing and reminders: encourage patient to pair exercise performance with an established behaviour, such as undertaking exercise after eating breakfast. Use visual reminders (such as exercise instructions pinned to the wall) or digital tools to prompt exercise (e.g., email reminders, SMS alerts, mobile apps). Monitoring: encourage using a calendar, diary, log book, wearables, or mobile apps to track exercise adherence.

Reinforcement: fails to see any benefits from exercise or frustrated with slow progress.	Positive reinforcement: encourage patient to reward self for exercise adherence. Review exercise adherence and praise patient for adhering to the exercise program. Goal-setting: with the patient, set realistic and meaningful short-term and long-term goals related to physical function or a meaningful task/activity. Encourage patient to focus on these, rather than just joint pain. Education and information: about the likely time-frames for benefits of exercise, noting these may be different depending on the goal. Monitoring and feedback: measure changes in pain, physical function, strength and physical activity as appropriate and feedback to patient positive improvements as they occur. Monitor progress against individual goals and be sure to set new goals as goals are achieved. Encourage self-awareness and self-monitoring of improvements in symptoms and other meaningful outcomes.

Table 4: Adapted checklist[72] for exercise practitioners to screen for individual factors that might indicate potential for reduced adherence with exercise in people with hip/knee osteoarthritis.

Any unchecked item may require intervention:
□ Does the person have accurate knowledge about osteoarthritis and the importance of exercise, including its benefits?
□ Does the person have realistic expectations about when to anticipate experiencing benefits from exercise?
□ Does the person show signs of forgetfulness?
□ Does the person have any comorbidities that may make exercising difficult?
□ Does the person understand how to perform the exercises, including how often and at what dosage?
□ Does the person have equipment (if required), clothing, and footwear suitable for exercise?
□ Does the person understand that some joint pain is normal with exercise, and possibly for a short time after?
□ Does the person have concerns about their ability to exercise or how exercise will affect their joint?
□ Will the person find it difficult to accommodate the exercise routine into their regular life (e.g considering work and/or caring responsibilities)?
□ Will the person find it financially challenging to participate in the prescribed program?
□ Has the person had a bad experience with exercise before or previously found it aggravated their problems?

Table 5: Selected exercise assessment and monitoring strategies for people with hip/knee osteoarthritis (OA).

	Measure	Description	Clinical interpretation
Self-reported pain			
	Visual analogue scale	A mark is placed on a 100 mm line with terminal anchors of 'none' to 'extreme' to indicate the severity of joint pain felt	Minimal clinically important difference in people with OA estimated at 18mm.[73] Cut points have been recommended:[74] 0-4mm: no pain 5-44mm: mild pain 45-74mm: moderate pain 75-100mm: severe pain
	Numeric rating scale	A number from 0 to 10 along a scale is ticked to indicate the severity of joint pain felt	Minimal clinically important difference for people with OA estimated at 1.8 units.[73]
Self-reported composite measures (including pain and physical function)			
	Knee Injury and Osteoarthritis Outcome Score (KOOS)	Knee-specific questionnaire that assesses five outcomes: pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life	Minimal clinically important differences have not been calculated for patients with knee OA undergoing non surgical, non-drug treatment but the scale developers consider a score of 8-10 to be appropriate.[75] Minimal detectable change for each subscale has been reported as:[76] -pain=15.1 -symptoms=10.5 -activities of daily living=9.6 -sports/recreation=15.5 -quality of life=16.2 An online score calculator can be found at https://orthotoolkit.com/koos/
	Hip disability and osteoarthritis outcome score (HOOS)	Hip-specific questionnaire that assesses five outcomes: pain, symptoms, activities of daily living, sport and recreation function, and hip-related quality of life	Minimal clinically important differences have not been calculated for patients with hip OA. An online score calculator can be found at https://orthotoolkit.com/hoos/

	Western Ontario and McMaster Universities (WOMAC) OA index	A questionnaire with subscales assessing pain, stiffness and difficulties with activities of daily living (physical function)	The minimal clinically important difference for the physical function subscale is 6 non-normalized units in people with knee OA undergoing non-surgical treatment.[77]
Self-reported global assessment			
	Global rating of change	A 5-point Likert scale with response options of much worse, slightly worse, no change, slightly better, much better since beginning exercise.	Can be used to quickly evaluate patient's perceived change in status from one category to the next
Self-reported exercise adherence			
	Number of exercise sessions	Use a diary or log book to tick which days exercise were performed over the prior week, fortnight or month	No threshold level of optimal exercise adherence has been determined
Muscle strength			
	30-second chair stand test*	Maximum number of chair stand repetitions possible in 30 seconds	Based on 3 different methods to assess the minimal clinically important difference in patients with hip OA undergoing physical therapy, an increase of greater than or equal to 2.0, 2.6, and 2.1 repetitions were associated with a major improvement on a global rating scale.[78]
	One-repetition maximum	Using hand-held or isokinetic dynamometry to assess maximal muscle strength of lower limb muscles particularly quadriceps, hamstrings and hip abductors	No consensus in the literature and dependent on equipment used, patient set up, patient age, muscle group, force value reported.[79]
Gait and walking performance			

	40m fast-paced walk test*	A fast-paced walking test that is timed over 4 x 10m for a total of 40m	Change scores of 0.2 to 0.3 m/s were associated with a minimum clinically important improvement in patients with hip OA undergoing manual therapy and exercise.[78] A score less than 1.0 m/s is a well-established risk factor for poor future health outcomes in older people.[80]
	Timed up and go*	Time to rise from a standard armchair, walk as quickly but as safely as possible for a distance of 3m, turn, walk back to the chair and sit down	Change scores of 0.8 to 1.4 seconds were associated with a minimally clinically important improvement in patients with hip OA undergoing physical therapy.[78] A score more than 14 seconds is associated with poor health outcomes including falls in older adults.[81]
	6-minute walk test*	The maximum distance that can be walked over a 6-min interval	'Slight' or 'more' improvement at 26-weeks post knee joint replacement surgery was associated with a minimal clinically important change between 26-55 m.[82] A score less than 350 m is associated with future poor health outcomes in older adults.[83]
	Stair climb test*	Time in seconds it takes to ascend and descend a flight of stairs.	There are no normative data for the nine-step stair climb test. Normative values for the 12-step stair test in a healthy population over the age of 60 are 8.72 (standard deviation 2.58) seconds for men and 10.22 (SD 2.61) seconds for women.* Minimal clinically important differences are not available for OA populations.
Balance performance			
	Step test	One foot is repeatedly placed on top of a 7.5cm step and returned back down to the ground as many times as able in 15 sec.	Normative value for those aged 60-79 years = 16 repetitions.[84]
	Single or tandem leg stance test	Performed with eyes open or closed, the test times how	If unable to stand for more than 5 seconds with eyes open, then at greater risk of injury from a fall.

		long the person can stand on one leg or in tandem leg stance with the hands on the hips	Normative values by age group and gender are found at: https://www.sralab.org/rehabilitation-measures/single-leg-stance-or-one-legged-stance-test
	Functional reach	Measures the maximum distance an individual can reach forward without losing balance while standing in a fixed position	In elderly male adults:[85] 25cm or more – low risk of falls 15-25cm – falls risk 2x greater than normal 15cm or less – falls risk 4x greater than normal Unable to reach- falls risk 8x greater than normal

*These tests make up the set of physical performance measures for hip and knee osteoarthritis recommended by the Osteoarthritis Research Society International (https://oarsi.org/sites/default/files/docs/2013/manual.pdf)

References

1. Overton C, Nelson AE, Neogi T. Osteoarthritis Treatment Guidelines from Six Professional Societies: Similarities and Differences. *Rheum. Dis. Clin. North Am.* 2022; 48(3):637-657.
2. Bennell KL, Hinman RS. A review of the clinical evidence for exercise in osteoarthritis of the hip and knee. *J. Sci. Med. Sport.* 2011; 14(1):4-9.
3. Long H, Liu Q, Yin H, et al. Prevalence Trends of Site-Specific Osteoarthritis From 1990 to 2019: Findings From the Global Burden of Disease Study 2019. *Arthritis Rheumatol.* 2022; 74(7): 1172-1183.
4. Australian Institute of Health & Welfare. Osteoarthritis. Cat. no. PHE 232. Canberra 2020.
5. Ackerman IN, Pratt C, Gorelik A, Liew D. Projected Burden of Osteoarthritis and Rheumatoid Arthritis in Australia: A Population-Level Analysis. *Arthritis Care Res (Hoboken).* 2018; 70(6):877-883.
6. Hall M, van der Esch M, Hinman RS, et al. How does hip osteoarthritis differ from knee osteoarthritis? *Osteoarthritis Cartilage.* 2022; 30(1):32-41.
7. Bartholdy C, Nielsen SM, Warming S, Hunter DJ, Christensen R, Henriksen M. Poor replicability of recommended exercise interventions for knee osteoarthritis: a descriptive analysis of evidence informing current guidelines and recommendations. *Osteoarthritis Cartilage.* 2019; 27(1):3-22.
8. 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):126-131.
9. Wallis JA, Webster KE, Levinger P, Taylor NF. What proportion of people with hip and knee osteoarthritis meet physical activity guidelines? A systematic review and meta-analysis. *Osteoarthritis Cartilage.* 2013; 21(11):1648-1659.
10. Chang AH, Song J, Lee J, Chang RW, Semanik PA, Dunlop DD. Proportion and associated factors of meeting the 2018 Physical Activity Guidelines for Americans in adults with or at risk for knee osteoarthritis. *Osteoarthritis Cartilage.* 2020; 28(6):774-781.
11. Oiestad BE, Juhl CB, Culvenor AG, Berg B, Thorlund JB. Knee extensor muscle weakness is a risk factor for the development of knee osteoarthritis: an updated systematic review and meta-analysis including 46 819 men and women. *Br. J. Sports Med.* 2022; 56(6):349-355.
12. Culvenor AG, Ruhdorfer A, Juhl C, Eckstein F, Oiestad BE. Knee Extensor Strength and Risk of Structural, Symptomatic, and Functional Decline in Knee Osteoarthritis: A Systematic Review and Meta-Analysis. *Arthritis Care Res (Hoboken).* 2017; 69(5):649-658.
13. Swain S, Sarmanova A, Coupland C, Doherty M, Zhang W. Comorbidities in Osteoarthritis: A Systematic Review and Meta-Analysis of Observational Studies. *Arthritis Care Res (Hoboken).* 2020; 72(7):991-1000.
14. King LK, March L, Anandacoomarasamy A. Obesity & osteoarthritis. *Indian J. Med. Res.* 2013; 138:185-193.
15. Veronese N, Cereda E, Maggi S, et al. Osteoarthritis and mortality: A prospective cohort study and systematic review with meta-analysis. *Semin. Arthritis Rheum.* 2016; 46(2):160-167.
16. Wang Y, Nguyen UDT, Lane NE, et al. Knee Osteoarthritis, Potential Mediators, and Risk of All-Cause Mortality: Data From the Osteoarthritis Initiative. *Arthritis Care Res (Hoboken).* 2021; 73(4):566-573.
17. Losina E, Silva GS, Smith KC, et al. Quality-Adjusted Life-Years Lost Due to Physical Inactivity in a US Population With Osteoarthritis. *Arthritis Care Res (Hoboken).* 2020; 72(10):1349-1357.
18. Deng Z, Xu J, Long L, et al. Association between hip and knee osteoarthritis with falls: A systematic review and meta-analysis. *Int. J. Clin. Pract.* 2021; Jun 15;e14537. doi: 10.1111/ijcp.14537. Online ahead of print.

19. Dore AL, Golightly YM, Mercer VS, et al. Lower-extremity osteoarthritis and the risk of falls in a community-based longitudinal study of adults with and without osteoarthritis. *Arthritis Care Res (Hoboken).* 2015; 67(5):633-639.
20. Manlapaz DG, Sole G, Jayakaran P, Chapple CM. Risk Factors for Falls in Adults with Knee Osteoarthritis: A Systematic Review. *PMR.* 2019; 11(7):745-757.
21. Goh SL, Persson MSM, Stocks J, et al. Relative Efficacy of Different Exercises for Pain, Function, Performance and Quality of Life in Knee and Hip Osteoarthritis: Systematic Review and Network Meta-Analysis. *Sports Med.* 2019; 49(5):743-761.
22. Kraus VB, Sprow K, Powell KE, et al. Effects of Physical Activity in Knee and Hip Osteoarthritis: A Systematic Umbrella Review. *Med. Sci. Sports Exerc.* 2019; 51(6):1324-1339.
23. Fransen M, McConnell S, Hernandez-Molina G, Reichenbach S. Exercise for osteoarthritis of the hip. *Cochrane Database Syst Rev.* 2014(4):CD007912.
24. Svege I, Nordsletten L, Fernandes L, Risberg MA. Exercise therapy may postpone total hip replacement surgery in patients with hip osteoarthritis: a long-term follow-up of a randomised trial. *Ann Rheum Dis.* 2015; 74(1):164-169.
25. Skou ST, Roos EM, Laursen MB, et al. Total knee replacement and non-surgical treatment of knee osteoarthritis: 2-year outcome from two parallel randomized controlled trials. *Osteoarthritis Cartilage.* 2018; 26(9):1170-1180.
26. Juhl C, Christensen R, Roos EM, Zhang W, Lund H. Impact of exercise type and dose on pain and disability in knee osteoarthritis: a systematic review and meta-regression analysis of randomized controlled trials. *Arthritis Rheumatol.* 2014; 66(3):622-636.
27. Henriksen M, Hansen JB, Klokker L, Bliddal H, Christensen R. Comparable effects of exercise and analgesics for pain secondary to knee osteoarthritis: a meta-analysis of trials included in Cochrane systematic reviews. *J Comp Eff Res.* 2016; 5(4):417-431.
28. White DK, Tudor-Locke C, Zhang Y, et al. Daily walking and the risk of incident functional limitation in knee osteoarthritis: an observational study. *Arthritis Care Res (Hoboken).* 2014; 66(9):1328-1336.
29. Rausch Osthoff AK, Juhl CB, Knittle K, et al. Effects of exercise and physical activity promotion: meta-analysis informing the 2018 EULAR recommendations for physical activity in people with rheumatoid arthritis, spondyloarthritis and hip/knee osteoarthritis. *RMD Open.* 2018; 4(2):e000713.
30. Messier SP, Mihalko SL, Legault C, et al. Effects of intensive diet and exercise on knee joint loads, inflammation, and clinical outcomes among overweight and obese adults with knee osteoarthritis: the IDEA randomized clinical trial. *JAMA.* 2013; 310(12):1263-1273.
31. Chu IJH, Lim AYT, Ng CLW. Effects of meaningful weight loss beyond symptomatic relief in adults with knee osteoarthritis and obesity: a systematic review and meta-analysis. *Obes. Rev.* 2018; 19(11):1597-1607.
32. Holden MA, Button K, Collins NJ, et al. Guidance for implementing best practice therapeutic exercise for people with knee and hip osteoarthritis: what does the current evidence base tell us? *Arthritis Care Res (Hoboken).* 2021; 73(12): 1746-1753.
33. Hislop AC, Collins NJ, Tucker K, Deasy M, Semciw AI. Does adding hip exercises to quadriceps exercises result in superior outcomes in pain, function and quality of life for people with knee osteoarthritis? A systematic review and meta-analysis. *Br. J. Sports Med.* 2020; 54(5):263-271.
34. Hall M, Dobson F, Van Ginckel A, et al. Comparative effectiveness of exercise programs for psychological well-being in knee osteoarthritis: A systematic review and network meta-analysis. *Semin. Arthritis Rheum.* 2021; 51(5):1023-1032.
35. Messier SP, Mihalko SL, Beavers DP, et al. Effect of High-Intensity Strength Training on Knee Pain and Knee Joint Compressive Forces Among Adults With Knee Osteoarthritis: The START Randomized Clinical Trial. *JAMA.* 2021; 325(7):646-657.

36. Luan L, El-Ansary D, Adams R, Wu S, Han J. Knee osteoarthritis pain and stretching exercises: a systematic review and meta-analysis. *Physiotherapy.* 2022; 114:16-29.
37. Sherrington C, Fairhall N, Wallbank G, et al. Exercise for preventing falls in older people living in the community: an abridged Cochrane systematic review. *Br. J. Sports Med.* 2020; 54(15):885-891.
38. Chen YW, Hunt MA, Campbell KL, Peill K, Reid WD. The effect of Tai Chi on four chronic conditions-cancer, osteoarthritis, heart failure and chronic obstructive pulmonary disease: a systematic review and meta-analyses. *Br. J. Sports Med.* 2016; 50(7):397-407.
39. Lauche R, Hunter DJ, Adams J, Cramer H. Yoga for Osteoarthritis: a Systematic Review and Meta-analysis. *Curr Rheumatol Rep.* 2019; 21(9):47.
40. Bennell KL, Schwartz S, Teo PL, et al. Effectiveness of an Unsupervised Online Yoga Program on Pain and Function in People With Knee Osteoarthritis : A Randomized Clinical Trial. *Ann. Intern. Med.* 2022; 175(10):1345-1355.
41. World Health Organization. WHO guidelines on physical activity and sedentary behaviour. Geneva: World Health Organization; 2020. Licence: CC BY-NC-SA 3.0 IGO.2020.
42. Dunlop DD, Song J, Lee J, et al. Physical Activity Minimum Threshold Predicting Improved Function in Adults With Lower-Extremity Symptoms. *Arthritis Care Res (Hoboken).* 2017; 69(4):475-483.
43. Rausch Osthoff AK, Niedermann K, Braun J, et al. 2018 EULAR recommendations for physical activity in people with inflammatory arthritis and osteoarthritis. *Ann Rheum Dis.* 2018; 77(9):1251-1260.
44. Lee J, Chang RW, Ehrlich-Jones L, et al. Sedentary behavior and physical function: objective evidence from the Osteoarthritis Initiative. *Arthritis Care Res (Hoboken).* 2015; 67(3):366-373.
45. American College of Sports Medicine. *ACSM's Guidelines for Exercise Testing and Prescription. Eleventh Edition.,* 11th Edition ed, Wolters Kluwer; 2021.
46. Bartholdy C, Juhl C, Christensen R, Lund H, Zhang W, Henriksen M. The role of muscle strengthening in exercise therapy for knee osteoarthritis: A systematic review and meta-regression analysis of randomized trials. *Semin. Arthritis Rheum.* 2017; 47(1):9-21.
47. Moseng T, Dagfinrud H, Smedslund G, Osteras N. The importance of dose in land-based supervised exercise for people with hip osteoarthritis. A systematic review and meta-analysis. *Osteoarthritis Cartilage.* 2017; 25(10):1563-1576.
48. Ram A, Booth J, Thom J, Jones MD. Exercise and education for knee osteoarthritis-What are accredited exercise physiologists providing? *Musculoskeletal Care.* 2020; 18(4):425-433.
49. Smith BE, Hendrick P, Smith TO, et al. Should exercises be painful in the management of chronic musculoskeletal pain? A systematic review and meta-analysis. *Br. J. Sports Med.* 2017; 51(23):1679-1687.
50. Skou ST, Pedersen BK, Abbott JH, Patterson B, Barton C. Physical Activity and Exercise Therapy Benefit More Than Just Symptoms and Impairments in People With Hip and Knee Osteoarthritis. *J. Orthop. Sports Phys. Ther.* 2018; 48(6):439-447.
51. Sandal LF, Roos EM, Bogesvang SJ, Thorlund JB. Pain trajectory and exercise-induced pain flares during 8 weeks of neuromuscular exercise in individuals with knee and hip pain. *Osteoarthritis Cartilage.* 2016; 24(4):589-592.
52. Teo PL, Bennell KL, Lawford BJ, Egerton T, Dziedzic KS, Hinman RS. Physiotherapists may improve management of knee osteoarthritis through greater psychosocial focus, being proactive with advice, and offering longer-term reviews: a qualitative study. *J Physiother.* 2020; 66(4):256-265.
53. Dobson F, Bennell KL, French SD, et al. Barriers and Facilitators to Exercise Participation in People with Hip and/or Knee Osteoarthritis: Synthesis of the Literature Using Behavior Change Theory. *Am. J. Phys. Med. Rehabil.* 2016; 95(5):372-389.

54. Nicolson PJA, Bennell KL, Dobson FL, Van Ginckel A, Holden MA, Hinman RS. Interventions to increase adherence to therapeutic exercise in older adults with low back pain and/or hip/knee osteoarthritis: a systematic review and meta-analysis. *Br. J. Sports Med.* 2017; 51(10):791-799.
55. Kinney M, Seider J, Beaty AF, Coughlin K, Dyal M, Clewley D. The impact of therapeutic alliance in physical therapy for chronic musculoskeletal pain: A systematic review of the literature. *Physiother Theory Pract.* 2020; 36(8): 886-898.
56. Behera NS, Bunzli S. Towards a Communication Framework for Empowerment in Osteoarthritis Care. *Clin. Geriatr. Med.* 2022; 38(2):323-343.
57. Quicke JG, Foster NE, Thomas MJ, Holden MA. Is long-term physical activity safe for older adults with knee pain?: a systematic review. *Osteoarthritis Cartilage.* 2015; 23(9):1445-1456.
58. Lo GH, Musa SM, Driban JB, et al. Running does not increase symptoms or structural progression in people with knee osteoarthritis: data from the osteoarthritis initiative. *Clin. Rheumatol.* 2018; 37(9):2497-2504.
59. Bricca A, Juhl CB, Steultjens M, Wirth W, Roos EM. Impact of exercise on articular cartilage in people at risk of, or with established, knee osteoarthritis: a systematic review of randomised controlled trials. *Br. J. Sports Med.* 2019; 53(15):940-947.
60. Bricca A, Struglics A, Larsson S, Steultjens M, Juhl CB, Roos EM. Impact of Exercise Therapy on Molecular Biomarkers Related to Cartilage and Inflammation in Individuals at Risk of, or With Established, Knee Osteoarthritis: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Arthritis Care Res (Hoboken).* 2019; 71(11):1504-1515.
61. Khan MCM, O'Donovan J, Charlton JM, Roy JS, Hunt MA, Esculier JF. The Influence of Running on Lower Limb Cartilage: A Systematic Review and Meta-analysis. *Sports Med.* 2022; 52(1):55-74.
62. Brickwood KJ, Watson G, O'Brien J, Williams AD. Consumer-Based Wearable Activity Trackers Increase Physical Activity Participation: Systematic Review and Meta-Analysis. *JMIR Mhealth Uhealth.* 2019; 7(4):e11819.
63. Feter N, Dos Santos TS, Caputo EL, da Silva MC. What is the role of smartphones on physical activity promotion? A systematic review and meta-analysis. *Int J Public Health.* 2019; 64(5):679-690.
64. Bennell KL, Lawford BJ, Keating C, et al. Comparing Video-Based, Telehealth-Delivered Exercise and Weight Loss Programs With Online Education on Outcomes of Knee Osteoarthritis : A Randomized Trial. *Ann. Intern. Med.* 2022; 175(2):198-209.
65. Hinman RS, Campbell PK, Lawford BJ, et al. Does telephone-delivered exercise advice and support by physiotherapists improve pain and/or function in people with knee osteoarthritis? Telecare randomised controlled trial. *Br. J. Sports Med.* 2020; 54(13):790-797.
66. Bennell KL, Nelligan R, Dobson F, et al. Effectiveness of an Internet-Delivered Exercise and Pain-Coping Skills Training Intervention for Persons With Chronic Knee Pain: A Randomized Trial. *Ann. Intern. Med.* 2017; 166(7):453-462.
67. Nelligan RK, Hinman RS, Kasza J, Crofts SJC, Bennell KL. Effects of a Self-directed Web-Based Strengthening Exercise and Physical Activity Program Supported by Automated Text Messages for People With Knee Osteoarthritis: A Randomized Clinical Trial. *JAMA Intern Med.* 2021; 181(6):776-785.
68. McHugh C, Kostic A, Katz J, Losina E. Effectiveness of remote exercise programs in reducing pain for patients with knee osteoarthritis: A systematic review of randomized trials. *Osteoarthritis and Cartilage Open.* 2022; 4(3):100264.
69. Bennell KL, Marshall CJ, Dobson F, Kasza J, Lonsdale C, Hinman RS. Does a web-based exercise programming system improve home exercise adherence for people with musculoskeletal conditions? Randomized controlled trial. *Am J Phys Med Rehabil.* 2019; 98(10): 850-858.

70. Lambert TE, Harvey LA, Avdalis C, et al. An app with remote support achieves better adherence to home exercise programs than paper handouts in people with musculoskeletal conditions: a randomised trial. *J Physiother.* 2017; 63(3):161-167.
71. Zhang ZY, Tian L, He K, et al. Digital rehabilitation programs improve therapeutic exercise adherence for patients with musculoskeletal conditions: a systematic review with meta-analysis. *J. Orthop. Sports Phys. Ther.* 2022:1-36.
72. Ritschl V, Stamm TA, Aletaha D, et al. 2020 EULAR points to consider for the prevention, screening, assessment and management of non-adherence to treatment in people with rheumatic and musculoskeletal diseases for use in clinical practice. *Ann Rheum Dis.* 2021; 80: 707-713.
73. Bellamy N, Carette S, Ford P, et al. Osteoarthritis antirheumatic drug trials. III. Setting the delta for clinical trials- results of a consensus development (Delphi) exercise. *J. Rheumatol.* 1992; 19(3):451-457.
74. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). *Arthritis Care Res (Hoboken).* 2011; 63 Suppl 11:S240-252.
75. Roos EM, Lohmander LS. The Knee injury and Osteoarthritis Outcome Score (KOOS): from joint injury to osteoarthritis. *Health Qual Life Outcomes.* 2003; 1:64.
76. Ornetti P, Parratte S, Gossec L, et al. Cross-cultural adaptation and validation of the French version of the Knee injury and Osteoarthritis Outcome Score (KOOS) in knee osteoarthritis patients. *Osteoarthritis Cartilage.* 2008; 16(4):423-428.
77. Tubach F, Ravaud P, Baron G, et al. Evaluation of clinically relevant changes in patient reported outcomes in knee and hip osteoarthritis: the minimal clinically important improvement. *Annals of the Rheumatic Diseases.* 2005; 64(1):29-33.
78. Wright AA, Cook CE, Baxter GD, Dockerty JD, Abbott JH. A comparison of 3 methodological approaches to defining major clinically important improvement of 4 performance measures in patients with hip osteoarthritis. *J. Orthop. Sports Phys. Ther.* 2011; 41(5):319-327.
79. Morin M, Duchesne E, Bernier J, Blanchette P, Langlois D, Hebert LJ. What is Known About Muscle Strength Reference Values for Adults Measured by Hand-Held Dynamometry: A Scoping Review. *Arch Rehabil Res Clin Transl.* 2022; 4(1):100172.
80. Cesari M, Kritchevsky SB, Penninx BW, et al. Prognostic value of usual gait speed in well-functioning older people--results from the Health, Aging and Body Composition Study. *J. Am. Geriatr. Soc.* 2005; 53(10):1675-1680.
81. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. *Phys. Ther.* 2000; 80(9):896-903.
82. Naylor JM, Mills K, Buhagiar M, Fortunato R, Wright R. Minimal important improvement thresholds for the six-minute walk test in a knee arthroplasty cohort: triangulation of anchor- and distribution-based methods. *BMC Musculoskelet Disord.* 2016; 17(1):390.
83. Agarwala P, Salzman SH. Six-Minute Walk Test: Clinical Role, Technique, Coding, and Reimbursement. *Chest.* 2020; 157(3):603-611.
84. Isles RC, Choy NL, Steer M, Nitz JC. Normal values of balance tests in women aged 20-80. *J. Am. Geriatr. Soc.* 2004; 52(8):1367-1372.
85. Duncan PW, Studenski S, Chandler J, Prescott B. Functional reach: predictive validity in a sample of elderly male veterans. *J. Gerontol.* 1992; 47(3):M93-98.