The Journal of Rheumatology 2023;xx:xxxx
doi:10.3899/jrheum.220728
First Release December 15 2022

Stepping Forward: A Scoping Review of Physical Activity in Osteoarthritis

Daniel K. White[1], Jason Jakiela[1], Tom Bye[1], Jessica Aily[1], and Dana Voinier[1]

ABSTRACT. Physical activity (PA) is recommended to mitigate the symptoms of osteoarthritis (OA); however, this modality remains an unfamiliar construct for many patients and clinicians. Moreover, there can be confusion over the nuanced differences in terminology, such as exercise, sedentary behavior, and moderate intensity. The purpose of this scoping review is to provide a basic overview of PA including terminology, summarize the importance of PA for adults with OA, and discuss current gaps in the literature. Broadly, PA is defined as any energy expenditure from skeletal muscle above a resting level, and exercise is considered a type of PA that is planned, structured, and repetitive. Robust literature shows that PA has a modest protective effect on pain, functional limitation, and disability for OA, in addition to positive effects on a broad range of outcomes from mood and affect to mortality and morbidity in the general population. We provide recommendations for which measurement instruments can be used to record PA, both from a clinical and research perspective, as well as which metrics to employ for summarizing daily activity.

Key Indexing Terms: exercise, osteoarthritis, rehabilitation

An estimated 240 million adults worldwide have painful osteoarthritis (OA), including 10% of men and 18% of women over the age of 60 years.[1] Physical activity (PA), defined as energy expenditure from skeletal muscles above a resting level,[2] plays an important role for OA, namely, as a recommended management strategy. However, PA remains an unfamiliar construct for many patients, clinicians, policymakers, and investigators alike. Moreover, there can be confusion over the nuanced differences in terminology, such as the differences between PA and exercise, sedentary behavior and inactivity, and steps per day and moderate intensity activity.

To clarify these questions, this scoping review will begin with a basic overview of PA, including how it is defined and measured in research. Next, we will summarize the importance of PA to disease, pain, and physical function outcomes for adults with OA. Last, we will discuss current gaps in the literature for PA for adults with OA. We searched the PubMed database (MeSH terms) for publications on "physical activity," "exercise," and "osteoarthritis." We restricted our search to articles, originally published in English, until June 1, 2022. We also added several original studies to provide more detailed support of the findings of the articles, based on the authors' familiarity with the literature. We highlight that this search was performed to inform our scoping review, but we did not employ a systematic approach in identifying key articles.

This study was supported by the National Institutes of Health (NIH; 1R56AR080060-01A1) and the Rheumatology Research Foundation (T32HD007490 Predoctoral Training in Physical Therapy and Rehabilitation Research).

[1]D.K. White, PT, ScD, MSc, J. Jakiela, MSc, T. Bye, PT, J. Aily, PT, D. Voinier, PT, PhD, Department of Physical Therapy, University of Delaware, Newark, Delaware, USA.

The authors declare no conflicts of interest relevant to this article.

Address correspondence to D.K. White, 540 S. College Ave 210L, Newark, DE, 19713, USA. Email: dkw@udel.edu.

Accepted for publication November 10, 2022.

What exactly is PA?

Caspersen and colleagues defined PA as "any bodily movement produced by skeletal muscles that results in energy expenditure."[2] They further distinguish exercise as bodily movement that is planned, structured, and repetitive. Therefore, PA encompasses all energy expenditure, and exercise is a special subtype of PA involving dedicated time to expending energy (ie, working out). Importantly, PA captures how much time is spent in daily activities, such as walking, and gives us an accurate picture about what someone actually does. This is in contrast to performance-based tests (eg, gait speed) that tell us what someone is capable of doing.

How is PA measured?

Wearable monitors and patient-reported questionnaires are the 2 primary means of measuring PA. The advantage of using wearable monitors is access to detailed metrics regarding time spent in different intensities of PA and the number of steps per day taken. While these measures of PA can also be estimated from patient-reported questionnaires, they are less precise than wearable monitors and are subject to recall bias.

Wearable monitors come in research-grade and consumer-grade types, and are worn on specific body sites. For example, a popular research-grade monitor called the Actigraph GT3X is most often worn around the waist with an elastic band (Figure). In contrast, consumer-grade monitors, such as the Fitbit (Google), are often worn around the wrist. Even simple consumer-grade pedometers can be used to measure PA.[3] A major advantage of consumer-grade monitors is that they are less expensive than research-grade monitors. Of note, an increasing number of studies are using consumer-grade monitors to report PA (steps/day) in clinical research studies.[4] A limitation of consumer-grade monitors is that they have limited validity to measure time spent in moderate-to-vigorous intensity PA, which is a common intensity-based PA outcome employed in the literature.[5,6]

The length of time that study participants must wear the monitor is an important consideration when measuring PA. One common and agreed-upon methodology is described by Troiano et al, who used a monitor to measure PA in the National Health and Nutrition Examination Survey.[7] These guidelines recommend 1 week (7 days) of monitoring, with a minimum of 4 valid days to be included in an analytic dataset. A valid day is ≥ 10 hours of monitor wear. Thus, a disadvantage of using wearable monitors is that participants need to wear the monitors for the majority of a day and for several days, which can be burdensome.

As well, consideration should be given to the fact that consumer-grade monitors give users feedback regarding their PA that may positively influence their behaviors. Research-grade monitors do not provide feedback; however, we still observed a Hawthorne effect (ie, when participants began wearing a monitor, they slightly increased their PA).[8] Nevertheless, using steps/day summaries provided in all consumer-grade monitors should suffice for clinicians seeking a snapshot measure of their patient's PA.

What are common metrics of PA?

Steps/day is one of the commonly employed measures of PA. There is a high level of face validity, as taking a step is readily apparent, and both consumer- and research-grade monitors can produce this metric. The most standardized measure of energy expenditure is quantified using a metabolic equivalent (MET). The MET represents the ratio of energy expended for a given activity relative to resting. The resting value of 1.0 MET represents 3.5 mL of oxygen consumed per kilogram of body weight per minute.[9] Another classification of energy expenditure is using the terms *light*, *moderate*, and *vigorous intensity*. Time spent in moderate intensity activity has strong ties to positive health outcomes.[10] Light intensity is defined as METs between 1.5 and < 3.0. Moderate intensity refers to energy expenditure between 3.0 and 6.0 METs, and vigorous intensity is > 6.0 METs. In order to improve the interpretation of energy expenditure corresponding with daily life activities, Ainsworth and colleagues created a compendium of common daily PAs and their associated MET values[11] and made this available online. Examples of activities from the compendium of common daily physical activities and their associated MET values are listed in the Table.

The current PA guidelines from the US Department of Health and Human Services recommends all adults spent at least 150 minutes/week in moderate-to-vigorous intensity PA.[10] The term *inactivity* technically applies to those who do not meet this guideline,[12] and include a wide range of those who participate anywhere from 1 minute/week to 149 minutes/week. Perhaps more important is to consider that inactivity is distinctly different than sedentary behaviors. Sedentary behaviors have received more attention in the past few years, for example, the phrase "sitting is the new smoking," although the literal interpretation

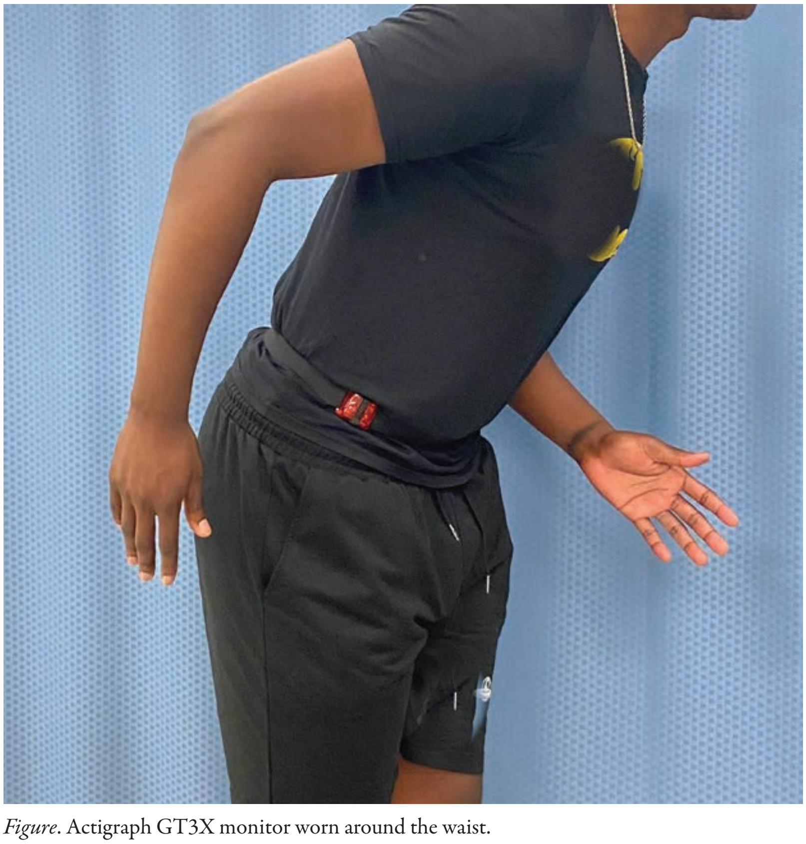

Figure. Actigraph GT3X monitor worn around the waist.

Table. Common daily activities, and associated classifications of energy expenditure.

Daily Activity	MET	Intensity of Physical Activity
Sitting watching TV	1.3	Sedentary
Walking around the house	2.0	Light intensity
Mowing the lawn while walking with a power mower	5.0	Moderate intensity
Shoveling snow by hand	6.0	Vigorous intensity

MET: metabolic equivalent.

of this phrase has been debunked.[13] Sedentary behaviors are defined as < 1.5 METs while sitting or reclining during waking hours.[14]

Why is PA important for OA?

The benefits of PA mitigate many disease-specific symptoms, such as functional limitation, in addition to providing general health benefits relevant to adults with OA, such as improved sleep, mood, muscular strength, and lower risk of mortality. Studies show that supervised strengthening exercises and aerobic walking, especially when combined with weight loss, lessen pain and improve physical function.[15] We previously found from observational studies that greater PA (ie, taking more steps/day) is related to lower risk of developing functional limitation among adults with (or at risk for) knee OA.[16,17] In particular, our group found approximately 6000 steps/day best discriminated between those who did and did not develop functional limitation (eg, difficulty with getting up from a chair or out of bed over 2 years).[16] Even light intensity PA, which includes activities such as gardening and taking a slow walk, prevents the development of functional limitation for adults with knee OA.[17]

These disease-specific findings extend what is already known about the benefits of PA from the general population; that is, there is strong evidence that regular PA has a wide range of health benefits from reduced blood pressure to improved sleep and mood.[10] The benefits of PA increase with age; specifically, older adults who are physically active can mitigate losses in muscular strength,[18] and improve physical function[19] and participation in important daily life activities.[20] They can move better, have lower risk of falls, and are better able to live independently compared with their inactive counterparts.[21] For example, using data from 16,741 women with a mean age of 72 years, Lee and colleagues reported those who took approximately 4400 steps/day had significantly lower risk for all-cause mortality compared with those who took < 2700 steps/day. Moreover, further reductions in mortality were observed up to 7500 steps/day.[22]

Last, current evidence suggests sedentary behaviors have negative effects on all-cause mortality and cardiovascular disease,[10] though it remains unclear if these effects are truly independent of the positive effects of PA, as some literature reports a relationship[23] whereas others do not.[24] One of the first published studies in 2012 showed a relation between sitting and mortality, following 222,497 adults aged > 45 years from Australia with a mean follow-up time of 2.8 years; the authors found a dose-response relationship between sitting time and risk of all-cause mortality within physical activity strata.[23] Namely, within the strata of moderate-to-vigorous intensity PA measured by questionnaire, ranging from 0 to > 300 minutes/week, those with greater time spent sitting had higher mortality compared to those with less sitting.[23] In contrast, a more recent systematic review of over 1,000,000 adults from 16 studies found that daily sitting time was not associated with all-cause mortality for those who were active.[24]

What is the intersection of PA with obesity in OA?

Obesity has strong ties as a risk factor for OA, which can be modified by PA. Previous studies have examined the association of obesity with PA and found a strong graded relation between increasing BMI and less PA. For example, our group has found increasing BMI to be associated with fewer steps/day in a large cross-sectional study using data from the Multicenter Osteoarthritis (MOST) study.[25] A similar relationship has been observed using data from the Osteoarthritis Initiative.[26] These findings support the notion that adults with knee OA who are obese tend to be less active on average. Studies show that exercise-only interventions do reduce weight, but this effect is modest and diet-specific interventions are recommended to better target weight loss.[27] Weight loss is important for adults with knee OA, as previous studies have shown the best improvements in clinical outcomes of pain and physical function were in those who receive both exercise and diet interventions, rather than exercise alone.[15,28] Research does not suggest, however, that exercises need to be nonweight-bearing for people who are obese. A recent trial comparing weight-bearing vs nonweight-bearing exercises in adults with knee OA who were obese found no differences in pain and physical function, though there were fewer adverse events in the weight-bearing group.[29] It is noteworthy that although obesity is a risk factor for the development of knee OA, literature to date shows that participating in exercise interventions and greater PA is not at all linked to faster progression of OA. This is discussed in more detail in the next section.

What is the relation of PA with the development of knee OA?

Data from studies that investigate recreational PA (ie, activity occurring outside of work) do not support the common general public view that OA is the consequence of "wear and tear" (ie, overuse of the joint), and that further use only worsens existing damage.[30] Although there are some studies that indicate high levels of PA are associated with structural damage of the knee, it is unclear if such structural damage actually leads to OA, and most studies do not support the finding that PA leads to OA.[31]

Data from studies have investigated the relation of walking and running with the development of knee OA. In short, there is no evidence that walking or recreational running increases the risk of developing radiographic OA, knee pain, or symptomatic knee OA. For walking, Felson and colleagues reported that adults who were normal weight to overweight and reported walking at least 9 miles/week (ie, about 180 min/week, which satisfies many guidelines for PA) did not have increased risk of joint space loss or incident knee OA over a 9-year period.[32] Also, data from large observational cohorts that used monitors to measure walking reported that adults with mild-to-moderate knee OA could walk at least 10,000 steps/day without increased risk of structural worsening over 2 years.[33,34] For running, evidence from systematic reviews and metaanalyses does not point to recreational running increasing the risk for knee OA, but rather the opposite. For example, a metaanalysis including 17 studies with over 110,000 study participants found those who ran for recreation had lower risk of knee OA than nonrunners.[35] For elite runners, the risk of OA may not be increased compared to nonrunners, though this may hold true for those who remain uninjured.[36] For making clinical decisions, we highlight a narrative review that poses specific recommendations for patients who are runners vs those who are not running regularly.[37] This review recommended those who were already runners should be encouraged to continue running while taking measures to prevent injury, whereas nonrunners should be encouraged to engage in walking. These are important messages for patients since walking is the most common type of PA employed for exercise in adults,[38] and exercise is highly recommended for the treatment of knee OA.[39]

For participation in PA other than walking or running, a previous review concluded that recreational sport was not consistently related to the progression of radiographic or symptomatic knee OA.[40] This is in contrast to elite-level soccer, competitive weight lifting, wrestling, and recreational American football, all of which may be associated with knee OA from another systematic review.[41] The relationship between these sports and knee OA is challenging to study, however, due to the confounding effect of traumatic injury and its association with knee OA.[42] Nevertheless, clinicians should continue to recommend PA and exercise to their patients with knee OA, with emphasis on those activities that are at a recreational level.

For occupational PA, specific work-related tasks appear to influence the risk of symptoms and disease incidence. Specifically, there seems to be a positive relationship between the frequency of knee bending with knee pain, especially when combined with heavy lifting. A metaanalysis of 66 studies found adults who had jobs with frequent knee bending were 61% more likely to have knee pain compared to those with more sedentary jobs,[43] and another study reported that combining heavy lifting with kneeling increased risk for knee pain by 1.8 to 7.9 times.[44] More recently, Lo and colleagues reported that walking while working with materials increases the OA risk of incidence by 90% compared with those who primarily sit during work.[45] It is important to note that PA was measured using questionnaires in all of these studies. As well, there is a possibility that previous knee injury could moderate the relation of knee bending with knee OA, further supporting the need to prevent knee injury as much as possible in occupational settings.

At present, there is no conceptual model of how PA contributes to OA in terms of negative changes in structure and symptoms including pain and functional limitation. There is a possibility of a U-shaped relationship between loading and the development of knee OA, whereby underloading in addition to overloading is detrimental to knee health. This is based on the notion that knee cartilage requires a minimum amount of load to remain healthy,[46] and that low levels of PA are common in adults with knee OA. We recently reported on preliminary evidence of the relation of underloading, characterized by low steps/day, with worsening cartilage damage.[47] However, little is known about the relationship between low levels of PA (ie, underloading) and the development of knee OA, as most studies have focused on high-intensity activities.[48,49]

In sum, these findings support the notion that frequent local loading contributes to the development of knee pain,[50] namely, certain occupational tasks, including repeated knee bending and carrying heavy materials, appear to result in enough excessive loading to increase the risk of developing knee OA and pain. However, the loading that occurs from recreational activities appears to be below that which leads to the development of knee OA and symptoms.

Why is inactivity so prevalent in OA, and how do we encourage taking more steps in the right direction?

PA promotion is paramount for adults with knee OA. This is because many with knee OA are in a vicious cycle of pain and inactivity leading to decreased strength and mobility, which then lead to more pain and inactivity. However, the causes of inactivity are not so straightforward, as PA is a behavior that relies not only on physical capacity but also on a complex array of psychological factors such as self-efficacy,[51] positive affect,[52] and motivation,[53] to name a few. Encouraging small increases in PA (eg, taking more steps/day) can help facilitate an exit from this cycle or prevent it from starting. Accomplishing this can take on many forms. For example, a recent editorial by Li and colleagues[54] highlighted how the Canadian 24-hour movement guidelines attempt to help increase activity by specifying types of low intensity or sedentary activities that should be replaced with higher intensity activities (eg, walking).[55] Another approach we have highlighted is to simply make a goal of walking for at least 10 minutes/day, every day, as this duration of activity is associated with health benefits for adults with OA.[56] Regardless of the approach, the message from health professionals to be active is important.

Next steps: What is not known about PA and knee OA?

Moving forward, there are many areas of need within the fields of rehabilitation, OA, and PA research. First, and perhaps most importantly, there is great need to develop effective interventions that specifically target and promote PA for adults with OA. We previously found less than 10% of adults with knee OA meet recommended levels of PA[57] (ie, 150 min/week of moderate intensity).[10] Although previous studies have shown that wearable monitors are an effective strategy to increase PA in the general population,[58] to date there are no effective strategies to increase PA in adults with knee OA. Even total knee replacement—the definitive treatment for knee OA—does not increase PA![59]

Second, little is known about changes in PA following common interventions for OA. The absence of PA measures in the context of clinical trials is particularly problematic for adults with OA. Any change in PA following intervention is missed, which is unfortunate since sedentary behaviors are common in this patient population.[60] As well, positive changes in PA may be masked in trials reporting no changes in pain. For instance, participants may in fact become more active after an intervention due to a reduction in pain and, as a consequence, increase their walking or PA. However, because of the increased activity, their knee pain may remain unchanged from baseline values. Last, those who already regularly exercise may respond differently to an intervention than those who are inactive due to additive or synergistic effects of exercise not being known. Thus, there is a need to better investigate changes in and the additive effects of PA in clinical intervention studies for knee OA.

Conclusion

PA is an important health outcome for adults with OA. The measurement of PA has evolved to include affordable consumer-grade monitors, which can be used to capture estimates of walking (ie, steps/day). Also, research-grade monitors provide reliable and valid estimates of steps/day and time at different intensities of PA. Overall, there is an unclear relationship between PA and the development of OA. In the workplace, excessive loading appears related to the presence of knee pain; however, the relation of recreational PA with the development of knee OA is not established and may not exist. Regardless, the benefits of PA for the symptoms of OA including pain and physical function are well established. There remains an important public health need to develop, test, and refine interventions to increase PA in adults with OA.

REFERENCES

1. Allen KD, Thoma LM, Golightly YM. Epidemiology of osteoarthritis. Osteoarthritis Cartilage 2022;30:184-95.
2. Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep 1985;100:126-31.
3. Tudor-Locke C, Williams JE, Reis JP, Pluto D. Utility of pedometers for assessing physical activity. Sports Med 2002;32:795-808.
4. Feehan LM, Geldman J, Sayre EC, et al. Accuracy of Fitbit devices: systematic review and narrative syntheses of quantitative data. JMIR Mhealth Uhealth 2018;6:e10527.
5. Reid RER, Insogna JA, Carver TE, et al. Validity and reliability of Fitbit activity monitors compared to ActiGraph GT3X+ with female adults in a free-living environment. J Sci Med Sport 2017;20:578-82.
6. Sushames A, Edwards A, Thompson F, McDermott R, Gebel K. Validity and reliability of Fitbit Flex for step count, moderate to vigorous physical activity and activity energy expenditure. PLoS One 2016;11:e0161224.
7. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;40:181-8.
8. Bye TK, White DK, Voinier DR, et al. Transient change in steps and MVPA due to activity monitoring in adults with knee osteoarthritis [abstract]. Med Sci Sports Exerc 2021;53:214.
9. deJong A. The metabolic equivalent: reevaluating what we know about the MET. ACSM Health Fit J 2010;14:43-6.
10. Piercy KL, Troiano RP, Ballard RM, et al. The physical activity guidelines for Americans. JAMA 2018;320:2020-8.
11. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 compendium of physical activities: a second update of codes and MET values. Med Sci Sports Exerc 2011;43:1575-81.
12. American College of Sports Medicine. ACSM's exercise testing and prescription. Lippincott Williams & Wilkins; 2017. 592 p.
13. Vallance JK, Gardiner PA, Lynch BM, et al. Evaluating the evidence on sitting, smoking, and health: is sitting really the new smoking? Am J Public Health 2018;108:1478-82.
14. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act 2017;14:75.
15. 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;310:1263-73.
16. White DK, Tudor-Locke C, Zhang Y, et al. Daily walking and the risk of incident functional limitation in knee OA: an observational study. Arthritis Care Res 2014;66:1328-36.
17. White DK, Lee J, Song J, Chang RW, Dunlop D. Potential functional benefit from light intensity physical activity in knee osteoarthritis. Am J Prev Med 2017;53:689-96.
18. Fielding RA, Vellas B, Evans WJ, et al. Sarcopenia: an undiagnosed condition in older adults. Current consensus definition: prevalence, etiology, and consequences. International working group on sarcopenia. J Am Med Dir Assoc 2011;12:249-56.
19. White DK, Neogi T, Nevitt MC, et al. Trajectories of gait speed predict mortality in well-functioning older adults: the Health, Aging and Body Composition study. J Gerontol A Biol Sci Med Sci 2013;68:456-64.
20. Rejeski WJ, Ip EH, Marsh AP, Miller ME, Farmer DF. Measuring disability in older adults: the International Classification System of Functioning, Disability and Health (ICF) framework. Geriatr Gerontol Int 2008;8:48-54.
21. Hardy SE, Gill TM. Recovery from disability among community-dwelling older persons. JAMA 2004;291:1596-602.
22. Lee IM, Shiroma EJ, Kamada M, Bassett DR, Matthews CE, Buring JE. Association of step volume and intensity with all-cause mortality in older women. JAMA Intern Med 2019;179:1105-12.
23. van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. Arch Intern Med 2012;172:494-500.
24. Ekelund U, Steene-Johannessen J, Brown WJ, et al. Does physical activity attenuate, or even eliminate, the detrimental association of sitting time with mortality? A harmonised meta-analysis of data from more than 1 million men and women. Lancet 2016; 388:1302-10.
25. White DK, Neogi T, Zhang Y, et al. The association of obesity with walking independent of knee pain: the multicenter osteoarthritis study. J Obes 2012;2012:261974.
26. Lee J, Song J, Hootman JM, et al. Obesity and other modifiable factors for physical inactivity measured by accelerometer in adults with knee osteoarthritis. Arthritis Care Res 2013;65:53-61.
27. Thorogood A, Mottillo S, Shimony A, et al. Isolated aerobic exercise and weight loss: a systematic review and meta-analysis of randomized controlled trials. Am J Med 2011;124:747-55.
28. Messier SP, Loeser RF, Miller GD, et al. Exercise and dietary weight loss in overweight and obese older adults with knee osteoarthritis: the Arthritis, Diet, and Activity Promotion Trial. Arthritis Rheum 2004;50:1501-10.
29. Bennell KL, Nelligan RK, Kimp AJ, et al. What type of exercise is most effective for people with knee osteoarthritis and co-morbid obesity?: The TARGET randomized controlled trial. Osteoarthritis Cartilage 2020;28:755-65.
30. Bunzli S, O'Brien P, Ayton D, et al. Misconceptions and the

acceptance of evidence-based nonsurgical interventions for knee osteoarthritis. A qualitative study. Clin Orthop Relat Res 2019;477:1975-83.
31. Voinier D, White DK. Walking, running, and recreational sports for knee osteoarthritis: an overview of the evidence. Eur J Rheumatol 2022 Aug 9 (Epub ahead of print).
32. Felson DT, Niu J, Clancy M, Sack B, Aliabadi P, Zhang Y. Effect of recreational physical activities on the development of knee osteoarthritis in older adults of different weights: the Framingham Study. Arthritis Rheum 2007;57:6-12.
33. Dore DA, Winzenberg TM, Ding C, et al. The association between objectively measured physical activity and knee structural change using MRI. Ann Rheum Dis 2013;72:1170-5.
34. Øiestad BE, Quinn E, White D, et al. No association between daily walking and knee structural changes in people at risk of or with mild knee osteoarthritis. Prospective data from the Multicenter Osteoarthritis Study. J Rheumatol 2015;42:1685-93.
35. Alentorn-Geli E, Samuelsson K, Musahl V, Green CL, Bhandari M, Karlsson J. The association of recreational and competitive running with hip and knee osteoarthritis: a systematic review and meta-analysis. J Orthop Sports Phys Ther 2017;47:373-90.
36. Driban JB, Hootman JM, Sitler MR, Harris KP, Cattano NM. Is participation in certain sports associated with knee osteoarthritis? A systematic review. J Athl Train 2017;52:497-506.
37. Bosomworth NJ. Exercise and knee osteoarthritis: benefit or hazard? Can Fam Physician 2009;55:871-8.
38. Hulteen RM, Smith JJ, Morgan PJ, et al. Global participation in sport and leisure-time physical activities: A systematic review and meta-analysis. Prev Med 2017;95:14-25.
39. Kolasinski SL, Neogi T, Hochberg MC, et al. 2019 American College of Rheumatology/Arthritis Foundation guideline for the management of osteoarthritis of the hand, hip, and knee. Arthritis Rheumatol 2020;72:220-33.
40. Lefèvre-Colau MM, Nguyen C, Haddad R, et al. Is physical activity, practiced as recommended for health benefit, a risk factor for osteoarthritis? Ann Phys Rehabil Med 2016;59:196-206.
41. Driban JB, Hootman JM, Sitler MR, Harris KP, Cattano NM. Is participation in certain sports associated with knee osteoarthritis? A systematic review. J Athl Train 2017;52:497-506.
42. Esser S, Bailey A. Effects of exercise and physical activity on knee osteoarthritis. Curr Pain Headache Rep 2011;15:423-30.
43. McWilliams DF, Leeb BF, Muthuri SG, Doherty M, Zhang W. Occupational risk factors for osteoarthritis of the knee: a meta-analysis. Osteoarthritis Cartilage 2011;19:829-39.
44. Ezzat AM, Li LC. Occupational physical loading tasks and knee osteoarthritis: a review of the evidence. Physiother Can 2014; 66:91-107.
45. Lo GH, Richard MJ, McAlindon TE, et al. Increased risk of incident knee osteoarthritis in those with greater work-related physical activity. Occup Environ Med 2022;79:543-9.
46. Sun HB. Mechanical loading, cartilage degradation, and arthritis. Ann N Y Acad Sci 2010;1211:37-50.
47. Voinier D, Neogi T, Stefanik JJ, et al. Using cumulative load to explain how body mass index and daily walking relate to worsening knee cartilage damage over two years: the MOST study. Arthritis Rheumatol 2020;72:957-65.
48. Racunica TL, Teichtahl AJ, Wang Y, et al. Effect of physical activity on articular knee joint structures in community-based adults. Arthritis Rheum Wiley; 2007;57:1261-8.
49. Kretzschmar M, Lin W, Nardo L, et al. Association of physical activity measured by accelerometer, knee joint abnormalities and cartilage T2 measurements obtained from 3T MRI: data from the Osteoarthritis Initiative. Arthritis Care Res 2015;67:1272-80.
50. Felson DT, Lawrence RC, Dieppe PA, et al. Osteoarthritis: new insights. Part 1: the disease and its risk factors. Ann Intern Med 2000;133:635-46.
51. Marcus BH, Selby VC, Niaura RS, Rossi JS. Self-efficacy and the stages of exercise behavior change. Res Q Exerc Sport 1992;63:60-6.
52. White DK, Keysor JJ, Neogi T, et al. When it hurts, a positive attitude may help: association of positive affect with daily walking in knee osteoarthritis. Results from a multicenter longitudinal cohort study. Arthritis Care Res 2012;64:1312-9.
53. Hagger MS, Chatzisarantis NLD. An integrated behavior change model for physical activity. Exerc Sport Sci Rev 2014;42:62-9.
54. Li LC, Feehan LM, Hoens AM. Rethinking physical activity promotion during the COVID-19 pandemic: focus on a 24-hour day. J Rheumatol 2021;48:1205-7.
55. Ross R, Chaput JP, Giangregorio LM, et al. Canadian 24-Hour Movement Guidelines for adults aged 18-64 years and adults aged 65 years or older: an integration of physical activity, sedentary behaviour, and sleep. Appl Physiol Nutr Metab 2020;45 (10 Suppl 2):S57-102.
56. Jakiela JT, Waugh EJ, White DK. Walk at least 10 minutes a day for adults with knee osteoarthritis: recommendation for minimal activity during the COVID-19 pandemic. J Rheumatol 2021;48:157-9.
57. White DK, Tudor-Locke C, Felson DT, et al. Do radiographic disease and pain account for why people with or at high risk of knee osteoarthritis do not meet physical activity guidelines? Arthritis Rheum 2013;65:139-47.
58. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. JAMA 2007;298:2296-304.
59. Hammett T, Simonian A, Austin M, et al. Changes in physical activity after total hip or knee arthroplasty: a systematic review and meta-analysis of six- and twelve-month outcomes. Arthritis Care Res 2018;70:892-901.
60. Thoma LM, Dunlop D, Song J, et al. Are older adults with symptomatic knee osteoarthritis less active than the general population? Analysis from the Osteoarthritis Initiative and the National Health and Nutrition Examination Survey. Arthritis Care Res 2018;70:1448-54.