

[Orthopaedic Surgery]



Aerobic Physical Fitness and Recreational Sports Participation After Total Knee Arthroplasty: A Systematic Review

Sue D. Barber-Westin, BS,^{*†} and Frank R. Noyes, MD[†]

Context: Total knee arthroplasty (TKA) is routinely performed in younger patients who desire to be active in fitness and recreational sports. The activities patients can participate in without symptoms and the level of aerobic fitness routinely maintained are important to investigate.

Objective: To determine physical activity (PA) and recreational sports resumed after primary TKA, symptoms or limitations with these activities, and the effect of postoperative rehabilitation on achieving fitness and sports goals.

Data Sources: A systematic review of the literature from 2005 through 2015 was conducted using the PubMed database.

Study Selection: Original investigations that were conducted at least 1 year after primary TKA and reported the percentage of patients who returned to recreational activities or routinely participated in aerobic PA recommended by the American Heart Association (AHA) were included in this study.

Study Design: Systematic review.

Level of Evidence: Level 4.

Data Extraction: Data were extracted as available from 19 eligible studies. Assessment of study quality was rated using the MINORS (Methodological Index for Non-Randomized Studies) instrument.

Results: There were 5179 knees (mean age, 67.5 years) followed for a mean 4.8 years postoperatively. Marked variability was present between studies regarding the percentage of patients who resumed recreational activities (34%-100%), most of which were low impact. Only 2 studies used accelerometers to measure PA; these reported a low range (0%-16.5%) of patients who met AHA guidelines. Few studies determined whether symptoms or limitations were experienced during PA. None described rehabilitation exercises or factors that would influence patients' ability to return to recreational or fitness activities.

Conclusion: Little evidence is available regarding the effect of TKA on return to recreational and (objectively measured) aerobic fitness. The extent of symptoms or limitations during PA and the long-term effects of such problems remain unclear. Valid predictions cannot be made on factors that may affect return to recreational sports or other aerobic PA after TKA.

Keywords: total knee arthroplasty; physical fitness; recreational activities

In 2013, Weinstein et al⁶⁷ calculated that 655,800 total knee arthroplasty (TKA) recipients in the United States were 50 to 59 years of age, and 984,700 patients were 60 to 69 years of age, indicating a large number of individuals who were expected to be active in fitness and recreational activities. The number of projected TKAs in the United States was estimated by Kurtz

et al³⁵ to increase 673% from 2005 to 2030 (from 450,000 to 3.48 million procedures). Studies show a disproportionate increase in the percentage of younger individuals (<60 years of age) requiring this procedure.^{27,44} TKA is now performed in many former athletes as well as individuals who wish to be physically active postoperatively. Therefore, the question of what

From [†]Cincinnati SportsMedicine & Orthopaedic Center—Mercy Health and the Noyes Knee Institute, Cincinnati, Ohio

*Address correspondence to Sue D. Barber-Westin, BS, c/o Cincinnati SportsMedicine & Orthopaedic Center—Mercy Health and the Noyes Knee Institute, 10663 Montgomery Road, Cincinnati, OH 45242 (email: sbwestin@csoref.org).

The authors report no potential conflicts of interest in the development and publication of this article.

DOI: 10.1177/1941738116670090

© 2016 The Author(s)

recreational activities patients may participate in without symptoms of knee pain and swelling after surgery is valid. In addition, the level of aerobic physical activity (PA) that is reached and routinely maintained as recommended by the American Heart Association (AHA) and the American College of Sports Medicine (ACSM) is important to investigate as a public health issue, considering the millions of TKA recipients in the United States and worldwide.^{16,21,51}

In 2007, the AHA and the ACSM published recommendations regarding the types and level of PA needed by healthy adults aged 18 to 65 years²¹ and adults aged older than 65 years^{2,51} to maintain or improve health parameters. The recommendations for aerobic activity were moderate-intensity activity for a minimum of 30 minutes for 5 days each week (150 min/wk) or vigorous-intensity activity for at least 20 minutes for 3 days each week (60 min/wk). Moderate-intensity activity produces noticeable increases in heart rate and breathing, whereas vigorous-intensity activity produces large increases in heart rate and breathing. Muscle-strengthening exercises should be performed a minimum of 2 days a week and should include 8 to 10 resistance (weight) exercises. These recommendations were based on studies that show a dose-response relationship between PA and lowering the risk of cardiovascular disease, stroke, type 2 diabetes, some forms of cancer, and premature mortality.^{16,21,57} In 2011, the ACSM further defined the quantity and quality of exercise to improve physical fitness and health in adults.¹⁶

Several studies have shown that patients who participate in recreational activities over their lifetime may develop knee osteoarthritis (OA) and require TKA at a younger age than normally expected.^{14,63,65} This is especially true in young patients who sustain anterior cruciate ligament (ACL) injuries and require meniscectomy^{8,19,46} since OA may develop in many knees even if ACL reconstruction successfully restores normal knee stability.^{1,17,28} One investigation from Ontario, Canada reported a nearly 7-fold significant difference in ACL-reconstructed patients (followed 15 years postoperatively) and a matched control cohort in the cumulative incidence of TKA (1.4% and 0.2%, respectively; cumulative incidence, 7:1, respectively; $P < 0.001$).³⁶

Former athletes have high expectations after TKA of resuming recreational activities,²⁹ and these expectations correlate strongly with postoperative patient satisfaction.^{25,52,60} Unfortunately, many patients have residual quadriceps and hamstrings muscle weakness 1 to 3 years after TKA,⁵⁹ which strongly influences the ability to return to recreational and fitness training activities as well as patient satisfaction rates. The issue of what is required in the postoperative rehabilitation program to successfully restore muscle strength and neuromuscular function to levels that allow patients to resume recreational activities or AHA fitness guidelines has not been addressed.

The primary purpose of this systematic review was to determine PA levels and recreational sports routinely reported after primary unilateral TKA. We also determined whether participation in these activities caused knee symptoms such as pain and swelling. In addition, the effect of postoperative

rehabilitation on achieving fitness and sports goals in studies that met the inclusion criteria was analyzed.

METHODS

Literature Search Strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed in conducting this study.³⁸ An online search was performed using PubMed for the years 2005 to 2015 using the key phrases and words *total knee arthroplasty*, *total knee replacement*, *sport*, *recreation*, *athletic*, *athlete*, *activity*, *physical activity*, *fitness monitor*, *fitness*, *activity monitor*, *activity measures*, and *energy expenditure*. The full text was accessed if the abstract suggested that this might be a clinical study in the topic of interest. In addition, reference lists from general review articles, systematic reviews, and meta-analyses obtained from the search were examined to find any other original research investigations not otherwise obtained.

Study Selection and Quality Assessment

To be included in the review, studies were required to (1) be an original investigation that was conducted on patients who underwent primary unilateral TKA for knee OA, (2) report the number or percentage of patients who participated in any sport or recreational activity or who routinely participated in PA as recommended by the AHA and ACSM, and (3) have a minimum follow-up of 1 year postoperatively.

Exclusionary criteria were articles that were off-topic or related to biomechanics or surgical techniques only, studies that included revision TKAs, studies that included TKA for reasons other than knee OA, studies that combined TKA with other total joint arthroplasty procedures, studies that did not provide data related to recreational activities, studies that only provided means \pm standard deviations (SDs) of activity scales, and duplicate publication.

The Methodological Index for Non-Randomized Studies (MINORS) instrument was used to rate the methodological quality of the investigations.⁶¹ This instrument has satisfactory reliability, internal consistency, and validity and has been shown to be able to differentiate low- from high-quality nonrandomized studies.⁶¹ Eight items of the instrument were completed, with each item scored from 0 to 2, with 0 representing the item not reported; 1, reported but inadequate; and 2, reported and adequate. The MINORS score is reported as a percentage of the total available points (8 items, 16 points), as recommended by Wylie et al.⁷² In addition, the level of evidence for each study was documented as described by Wright et al.⁷¹

Data Extraction

The following data were extracted from each article when available: number of knees, number of men and women, age, follow-up, activity rating instruments, objective activity rating monitors (accelerometers), type of TKA, percentage of patients who returned to recreational activities, types of activities

patients participated in, change in activity level (compared with preoperative), time to return to recreational activities, frequency of participation, symptoms or limitations with activities, correlations with other factors on return to activities, percentage of time spent performing PA, comorbidities, complications, and all information regarding postoperative rehabilitation.

RESULTS

The search identified 786 articles, including 755 research investigations and 31 review articles. On further analysis, 736 research studies were excluded (along with the review articles), leaving 19 studies for our investigation. The average MINORS score was 66% (Table 1). The level of evidence was rated as 3 or 4 in all studies.

There were a total of 5179 knees with a mean age of 67.5 years (range, 19-88 years). Patient sex, provided in 14 studies, included 2556 women and 1483 men. The mean follow-up was 4.8 years (range, 1-27 years). A variety of outcome instruments were used to determine recreational, physical, or daily activities, including several that were developed by authors that had not been validated. Objective measurement of PA with an activity monitor (accelerometer) was used in 2 studies.

Eleven studies described the prostheses used in the cohort, 4 studies indicated that a variety had been used, and 4 did not include this information.

Physical Activity Guidelines

Three studies provided data related to the achievement of the AHA and ACSM recommended PA guidelines. Two studies that used accelerometers for 1 week at the 6-month²⁰ and 12-month³⁹ postoperative time periods reported 0% and 16.5% of patients, respectively, met these guidelines. One study³² used the Short Questionnaire to Assess Health-Enhancing Physical Activity (SQUASH) to determine routine PA and reported that 50.8% met the AHA guidelines. None of these studies provided information regarding symptoms or limitations experienced with PA.

Recreational Sports Activities

Sixteen studies detailed recreational and sports activities patients participated in postoperatively (see the Appendix, available at <http://sph.sagepub.com/content/by/supplemental-data>). Of these, 3 studies^{26,48,49} only included patients who were active in athletics. The studies reported a wide range of patients who returned to recreational activities (34%-100%; Figure 1). The mean percentage of patients participating in the most common activities is shown in Figure 2. Evidence was not available regarding the number of sports patients routinely participated in, although some studies indicated patients were involved in more than 1 sports activity.^{48,49} Frequency and duration of participation and time to return to recreational or exercise activities are shown in Table 2.

Only 5 studies described symptoms or limitations that occurred with activity. A "major limitation" during participation

was found in 14% in 1 study³ and in 6% in another investigation.⁴ Pain in the knee was reported during activity in 16% in 1 study²⁴ and in 17% in another.²⁶ One investigation²³ reported that 26% of patients had pain in their knee and 26% had a feeling of instability during participation.

Huch et al²⁴ reported that the factors responsible for a reduction in recreational activities 5 years postoperative were pain in the TKA joint in 13%, pain elsewhere than the TKA joint in 27.5%, precaution in 47%, and other reasons in 11%. Hopper and Leach²³ reported pain in the TKA joint in 40%, pain in other regions in 12%, precaution in 44%, and aging in 4% at a mean 1.8 years postoperative. Dahm et al¹² reported that activities were limited by other joints in 53% (643/1206) of patients, and Argenson et al⁴ found that 19% (20/104) of patients were no longer participating a mean 10.6 years postoperatively for reasons not related to TKA.

Four studies assessed factors that could have had an influence on return to recreational activities. Chatterji et al¹⁰ found no correlation between age and sex regarding activity level, and Chang et al⁹ reported no associations between sociodemographic factors, pain relief, or postoperative range of knee motion on recreational activity levels. Dahm et al¹² reported that higher activity levels were related to age younger than 70 years, male sex, and body mass index >30 kg/m². Kersten et al³² found that patients younger than 65 years spent significantly more time on PA than those 65 years of age and older.

Postoperative Rehabilitation and Return to Recreational Activities

None of the studies described the postoperative rehabilitation program with regard to exercises, protocols, or factors that could influence return to recreational or fitness activities. One investigation stated that "most" patients had no formal rehabilitation after their hospital discharge.¹⁰ In this study, 75% returned to some type of activity; the majority were walking for exercise, swimming, bowling, or participating in water aerobics. Another study stated that 38% had no formal rehabilitation after hospital discharge.¹² The most common activities in this study were walking, bicycling, swimming, dancing, and hiking.

The effect of comorbidities and postoperative complications, such as arthrofibrosis and residual muscle weakness, on the outcome of TKA with regard to PA resumed postoperatively was not addressed in any study.

DISCUSSION

Important goals of TKA in younger active patients include maintaining a healthy lifestyle through physical fitness activities, returning to desired realistic recreational or sports activities, and returning to occupational activities if required.^{15,18,29,31,50,54,66,70} However, in patients who wish to resume recreational and occupational activities after TKA, the high loads placed on the knee joint may result in chronic effusions and muscle dysfunction. This is especially true in patients who return to

Table 1. Study characteristics

Study, (Level of Evidence)	Knees, n, (% FU)	MINORS, % ^a	Age, y, Mean	FU, y, Mean (Range)	Activity Monitor	Activity Rating Instruments
Mayr et al ⁴² (4)	81 (NA)	75	71.8	6.4 (NA)	None	KSS, KOOS, WOMAC, authors' own questionnaire
Harding et al ²⁰ (4)	52 (91)	75	69.0	0.5 (NA)	ActiGraph	Oxford, SF-12, UCLA Activity Score
Lutzner et al ³⁹ (3)	97 (NA)	69	68.9	1.0 (NA)	activPAL	KSS
Chang et al ⁹ (4)	369 (65)	69	68.8	2 (1-3)	None	KSS, WOMAC, SF-36, UCLA Activity Score, authors' own questionnaire
Parvizi et al ⁵⁶ (4)	661 (64)	75	54.0	2.6 (1-4)	None	Patient-Specific Functional Scale, authors' own questionnaire
Argenson et al ⁴ (4)	108 (93)	75	69.0	10.6 (10-11.8)	None	KSS, KOOS, UCLA Activity Score
Jones et al ³¹ (4)	83 (92)	81	66.5	1 (NA)	None	SF-36, WOMAC, Self-Efficacy for Exercise, Historical Leisure Activity
Kersten et al ³² (3)	830 (64)	50	72.0	3 (1-5)	None	SQUASH
Meding et al ⁴³ (4)	98 (57)	56	NA	21.1 (20-27)	None	KSS, UCLA Activity Score
Bonnin et al ⁶ (4)	141 (NA)	56	66.4	3.7 (1.1-5.9)	None	SF-12, WOMAC, Knee Function Survey
Jackson et al ²⁶ (4)	93 (62)	63	66.0	8.7 (6.4-12.1)	None	KSS, UCLA Activity Score, authors' own questionnaire
Argenson et al ³ (4)	483 (94)	75	71.6	3 (2-4)	None	KSS, KOOS, UCLA Activity Score
Dahm et al ¹² (4)	1206 (74)	56	67.0	5.7 (2-10)	None	KSS, UCLA Activity Score, authors' own questionnaire
Hopper and Leach ²³ (3)	76 (90)	56	62.1	1.8 (NA)	None	Oxford, authors' own questionnaire
Mont et al ⁴⁹ (4)	33 (NA)	63	66.0	3.7 (2-9.3)	None	Authors' own questionnaire
Bauman et al ⁵ (4)	184 (81)	56	68.9	3 (NA)	None	KSS, Oxford, UCLA Activity Score
Mont et al ⁴⁸ (3)	114 (NA)	75	70.0	7 (4-14)	None	Authors' own questionnaire
Chatterji et al ¹⁰ (4)	144 (81)	56	70.8	1.5 (1-2)	None	Oxford, Grimby, authors' own questionnaire
Huch et al ²⁴ (3)	389 (NA)	69	66.0	5 (NA)	None	Authors' own questionnaire

FU, follow-up; KOOS, Knee Injury and Osteoarthritis Outcome Score; KSS, Knee Society Score; MINORS, Methodological Index for Non-Randomized Studies; NA, not available or not applicable; SF, Short Form; SQUASH, Short Questionnaire to Assess Health-Enhancing Physical Activity; UCLA, University of California at Los Angeles; WOMAC, Western Ontario and McMaster Universities Index of Osteoarthritis.
^aGiven as percentage of total available points (16).

Table 2. Frequency and duration of participation and time to return to recreational sports or exercise activities

Study	Frequency, Duration	Time to Return to Activities
Jones et al ³¹	Mean, 19.6 h/wk (range, 0-125.6); moderate intensity activities	NA
Hopper and Leach ²³	Mean, 2×/wk; minimum, 37.5 mins/session; low-impact activities	Mean, 4.1 mo
Huch et al ²⁴	% of cohort, all types of recreational activities: 15%, <1 h/wk; 15%, 1-2 h/wk; 5%, >2 h/wk; 65% none	NA
Kersten et al ³²	Mean, 52 ± 140 min/wk—sports Mean, 167 ± 135 min/wk—walking Mean, 122 ± 242 min/wk—cycling	NA
Mont et al ⁴⁹	Mean, 4×/wk (range, 1-7); mean, 3.5 h/wk (range, 1-10); high-impact activities	NA
Mont et al ⁴⁸	High-activity group: mean, 11×/wk; low-activity group: mean, 4×/wk, any exercise activity	NA
Mayr et al ⁴²	Mean, 5.3 h/wk any sport	NA
Jackson et al ²⁶	Studied only golf: 33%, 1×/mo; 36%, 2-7×/mo; 31%, >7×/mo	3 mo in 13%, 4-6 mo in 44%, 7-9 mo in 20%, 10-12 mo in 8%, >12 mo in 15%
Argenson et al ³	NA	Mean, 6 ± 4 mo
Argenson et al ⁴	NA	Mean 6 ± 3 mo
Chatterji et al ¹⁰	NA	5-6 wk croquet, badminton, aqua aerobics; 8 wk exercise walking; 12-13 wk exercise class, cycling, golf; 18 wk bowling; 30 wk tennis

NA, not available.

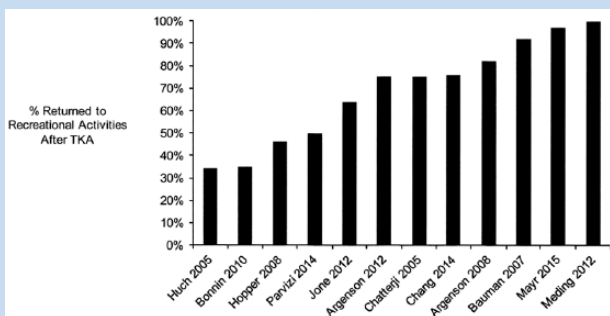


Figure 1. A wide range of patients returned to recreational activities after total knee arthroplasty (TKA).

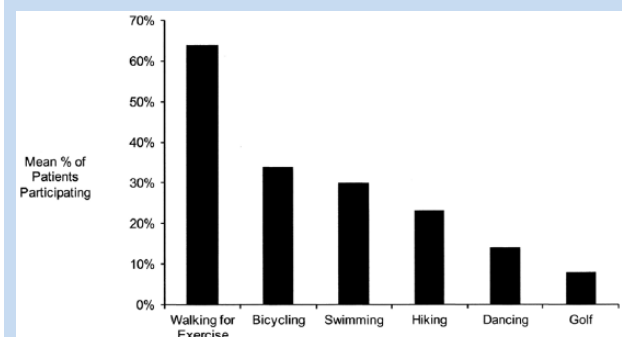


Figure 2. The most common activities patients participated in after total knee arthroplasty were low impact in nature.

high-impact occupations that may preclude participation in recreational activities due to a mechanical overload of the joint that produces pain and swelling. There was a wide range of patients who resumed recreational activities after TKA

(34%-100%). We were unable to determine whether the lack of participation in recreational or aerobic activities was due to the effects of the operation (pain or swelling), the natural aging

process, or other factors. In addition to aging, there are complex factors that affect participation in recreational activity and PA such as income, educational status, area of residency (rural versus suburban), personal barriers and beliefs, self-efficacy, and social support.^{11,37,55,64} The reasons patients elect not to participate in recreational activities after TKA are important to determine, especially in studies in which return to PA is a main focus. The question of what recreational activities should be resumed after TKA remains unanswered, especially with regard to moderate- to high-impact athletics. Other reviews describe subjective expert opinion regarding the most appropriate activities after TKA.^{22,29,54,66} However, the available evidence is low quality (level 3 or 4). One study focused solely on patients who resumed high-impact activities (tennis, aerobics, jogging, racquetball, squash), which represented only 4% of TKAs performed at 3 institutions over an 8-year period.⁴⁹ This study did not report whether symptoms or limitations were experienced in any patients in the small cohort, but the authors remarked that high-impact activities were not appropriate for the majority of TKA patients.

The 2 studies that used accelerometers to track PA after TKA reported dismal results in terms of percentages of patients who met AHA and ACSM recommendation.^{20,39} Investigators have shown that only a small percentage of adults meet these guidelines. For instance, Jefferis et al³⁰ measured PA in 2450 healthy adults aged 70 to 93 years with an accelerometer and found that only 15% of men and 10% of women achieved more than 150 minutes a week of PA. The US National Health and Nutrition Examination survey (2003-2006) in 7000 adults aged 20 to 79 years reported that only 10% to 15% of older adults met the minimum AHA standard.⁶² The proportion of waking time spent sedentary rose with age, from 55% (7.7 hours/day) in those 20 to 29 years of age to 67% (9.6 hours/day) in those 70 to 79 years old. In a cohort of 6763 individuals aged 65 years and older, Kraschnewski et al³⁴ showed that only 18.8% of men and 14% of women met ACSM strength training recommendations. Again, whether the data from our study and those from control populations regarding problems achieving PA guidelines were strictly related to aging or to other factors is unclear and worthy of future study.

Only 1 systematic review of 26 studies has been conducted regarding how PA levels are quantified after total joint (hip and knee) arthroplasty.⁵⁰ Naal and Impellizzeri⁵⁰ reported noteworthy heterogeneity among studies with regard to instruments and methodology used to measure activity and provided recommendations to standardize future studies. They noted patients undergoing total joint arthroplasty are less active than recommended AHA levels. Other authors recommended “changing the conversation” for sedentary patients from the AHA guidelines (which can be overwhelming) to light activity throughout the day.⁶² This includes reducing prolonged sitting and increasing light activities by 20 minutes. Accelerometers can provide realistic data of all types of activity (light, moderate, and vigorous) and give feedback and motivation to patients.⁶² Total daily step count is a beneficial motivator, and Garber

et al¹⁶ recommended ≥ 7000 steps/day, which could be achieved by increasing step counts by ≥ 2000 as necessary to achieve this level.

Clinical studies usually employ patient self-reporting of activity levels with questionnaires such as the University of California at Los Angeles (UCLA) activity scale⁷³ and the SQUASH.⁶⁹ These data are not always reliable, may be subject to recall bias,^{13,68} and may overestimate PA compared with objective activity measurements.^{13,20,62} For example, there was no change in PA parameters 6 months after TKA measured with an accelerometer in 25 patients, while there was a significant increase in the patient-reported UCLA activity scores between the preoperative and follow-up evaluations (3 ± 1 and 5 ± 3 , respectively; $P < 0.001$).²⁰

None of the studies in this review provided data regarding symptoms or functional limitations during PA. For patient counseling purposes, future studies should provide these data to ensure that preoperative patient expectations are realistic in terms of activities that are resumed after surgery. Another important concept is the comparison of lifetime and preoperative PA levels with those achieved after surgery. For instance, Chatterji et al¹⁰ detailed the number of patients who took up activities postoperatively who had not been active preoperatively. These authors also determined the number of patients who participated in recreational activities preoperatively but who did not resume these activities after surgery. Lifetime PA was determined in only 2 studies^{24,42} and preoperative PA was provided in 7 studies^{3,9,10,23,24,26,42} in our review.

No study provided detail regarding physical therapy or the role of the therapist in guiding a patient back to recreational or fitness activities. The therapist has an important position in monitoring younger active patients throughout the postoperative time period who have greater demands on their knee from either an occupational or recreational activity standpoint. Rehabilitation programs that incorporate strength, balance, flexibility, and neuromuscular function are recommended to safely resume PA.^{45,47,58} Objective assessment of muscular and neuromuscular function prior to release to activities is also recommended.^{7,33,40,41} A careful balance of joint loads must be managed to reduce chronic knee joint effusions (which is an indicator of the need to reduce activities) and chronic muscle weakness. In a systematic review of 15 studies on lower limb strength after TKA, patients had weaker quadriceps and hamstrings strength compared with controls up to 3 years postoperatively.⁵⁹ These limitations result in difficulty with stair climbing and other daily activities and prevent return to recreational or physical fitness activities.⁵³

A limitation of this review was the low level of evidence in the included studies, which were typically retrospective or observational in nature. There is concern with transfer bias that was present in 8 studies that lost 19% to 38% of eligible patients to follow-up. A lack of consensus regarding activity rating instruments was apparent and represents a problem when comparing results between studies. The UCLA Activity Score⁷³ was collected in 7 studies. However, there are ambiguous terms

(very active, active, moderate, regularly participate, sometimes participate) in this instrument that can make completion difficult. It would be helpful to use a scale that determines frequency of participation according to the number of times performed per week and intensity of the activity according to the anticipated stresses incurred in the knee joint.

Another limitation in this study was that the effect of comorbidities and postoperative complications on the outcome of TKA with regard to PA resumed postoperatively was not addressed in any study. The successful return to a healthy lifestyle most likely involves not only patient desires and lifetime PA behavior but associated comorbidities and complications such as arthrofibrosis and muscular weakness.

In summary, there is poor evidence regarding the effect of TKA on return to recreational activity, sports, and aerobic PA. The variables responsible for the wide range of patients who resumed these activities are multifactorial and require further study. The extent of symptoms or limitations experienced during PA and the long-term effects of such problems remain unclear. There are few studies that have objectively measured PA or that used validated outcome measures of recreational activity. The effect of comorbidities and postoperative complications on patient PA levels is unknown. With the current data available, it is impossible to provide valid predictions on factors that may affect a patient's ability to return to recreational sports or other aerobic PA after TKA.

REFERENCES

- Ahn JH, Kim JG, Wang JH, Jung CH, Lim HC. Long-term results of anterior cruciate ligament reconstruction using bone-patellar tendon-bone: an analysis of the factors affecting the development of osteoarthritis. *Arthroscopy*. 2012;28:1114-1123.
- American College of Sports Medicine, Chodzko-Zajko WJ, Proctor DN, et al. American College of Sports Medicine position stand. Exercise and physical activity for older adults. *Med Sci Sports Exerc*. 2009;41:1510-1530.
- Argenson JN, Parratte S, Ashour A, Komistek RD, Scuderi GR. Patient-reported outcome correlates with knee function after a single-design mobile-bearing TKA. *Clin Orthop Relat Res*. 2008;466:2669-2676.
- Argenson JN, Parratte S, Ashour A, Saintmard B, Aubaniac JM. The outcome of rotating-platform total knee arthroplasty with cement at a minimum of ten years of follow-up. *J Bone Joint Surg Am*. 2012;94:638-644.
- Bauman S, Williams D, Petruccioli D, Elliott W, de Beer J. Physical activity after total joint replacement: a cross-sectional survey. *Clin J Sport Med*. 2007;17:104-108.
- Bonnin M, Laurent JR, Parratte S, Zadegan F, Badet R, Bissery A. Can patients really do sport after TKA? *Knee Surg Sports Traumatol Arthrosc*. 2010;18:853-862.
- Boonstra MC, De Waal Malefijt MC, Verdonchot N. How to quantify knee function after total knee arthroplasty? *Knee*. 2008;15:390-395.
- Brophy RH, Rai MF, Zhang Z, Torgomyan A, Sandell LJ. Molecular analysis of age and sex-related gene expression in meniscal tears with and without a concomitant anterior cruciate ligament tear. *J Bone Joint Surg Am*. 2012;94:385-393.
- Chang MJ, Kim SH, Kang YG, Chang CB, Kim TK. Activity levels and participation in physical activities by Korean patients following total knee arthroplasty. *BMC Musculoskelet Disord*. 2014;15:240.
- Chatterji U, Ashworth MJ, Lewis PL, Dobson PJ. Effect of total knee arthroplasty on recreational and sporting activity. *ANZ J Surg*. 2005;75:405-408.
- Crombie IK, Irvine L, Williams B, et al. Why older people do not participate in leisure time physical activity: a survey of activity levels, beliefs and deterrents. *Age Ageing*. 2004;33:287-292.
- Dahm DL, Barnes SA, Harrington JR, Sayeed SA, Berry DJ. Patient-reported activity level after total knee arthroplasty. *J Arthroplasty*. 2008;23:401-407.
- de Groot IB, Bussmann HJ, Stam HJ, Verhaar JA. Small increase of actual physical activity 6 months after total hip or knee arthroplasty. *Clin Orthop Relat Res*. 2008;466:2201-2208.
- Elleuch MH, Guermazi M, Mezghanni M, et al. Knee osteoarthritis in 50 former top-level soccer players: a comparative study. *Ann Readapt Med Phys*. 2008;51:174-178.
- Farr J, Jiranek WA. Sports after knee arthroplasty: partial versus total knee arthroplasty. *Phys Sportsmed*. 2009;37:53-61.
- Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43:1334-1359.
- Gerhard P, Bolt R, Duck K, Mayer R, Friederich NF, Hirschmann MT. Long-term results of arthroscopically assisted anatomical single-bundle anterior cruciate ligament reconstruction using patellar tendon autograft: are there any predictors for the development of osteoarthritis? *Knee Surg Sports Traumatol Arthrosc*. 2013;21:957-964.
- Golant A, Christoforou DC, Slover JD, Zuckerman JD. Athletic participation after hip and knee arthroplasty. *Bull NYU Hosp Jt Dis*. 2010;68:76-83.
- Granan LP, Bahr R, Lie SA, Engebretsen L. Timing of anterior cruciate ligament reconstructive surgery and risk of cartilage lesions and meniscal tears: a cohort study based on the Norwegian National Knee Ligament Registry. *Am J Sports Med*. 2009;37:955-961.
- Harding P, Holland AE, Delany C, Hinman RS. Do activity levels increase after total hip and knee arthroplasty? *Clin Orthop Relat Res*. 2014;472:1502-1511.
- Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116:1081-1093.
- Healy WL, Sharma S, Schwartz B, Iorio R. Athletic activity after total joint arthroplasty. *J Bone Joint Surg Am*. 2008;90:2245-2252.
- Hopper GP, Leach WJ. Participation in sporting activities following knee replacement: total versus unicompartmental. *Knee Surg Sports Traumatol Arthrosc*. 2008;16:973-979.
- Huch K, Muller KA, Sturmer T, Brenner H, Puhl W, Gunther KP. Sports activities 5 years after total knee or hip arthroplasty: the Ulm Osteoarthritis Study. *Ann Rheum Dis*. 2005;64:1715-1720.
- Husain A, Lee GC. Establishing realistic patient expectations following total knee arthroplasty. *J Am Acad Orthop Surg*. 2015;23:707-713.
- Jackson JD, Smith J, Shah JP, Wisniewski SJ, Dahm DL. Golf after total knee arthroplasty: do patients return to walking the course? *Am J Sports Med*. 2009;37:2201-2204.
- Jain NB, Higgins LD, Ozumba D, et al. Trends in epidemiology of knee arthroplasty in the United States, 1990-2000. *Arthritis Rheum*. 2005;52:3928-3933.
- Janssen RP, du Mee AW, van Valkenburg J, Sala HA, Tseng CM. Anterior cruciate ligament reconstruction with 4-strand hamstring autograft and accelerated rehabilitation: a 10-year prospective study on clinical results, knee osteoarthritis and its predictors. *Knee Surg Sports Traumatol Arthrosc*. 2013;21:1977-1988.
- Jassim SS, Douglas SL, Haddad FS. Athletic activity after lower limb arthroplasty: a systematic review of current evidence. *Bone Joint J*. 2014;96-B:923-927.
- Jefferis BJ, Sartini C, Lee IM, et al. Adherence to physical activity guidelines in older adults, using objectively measured physical activity in a population-based study. *BMC Public Health*. 2014;14:382.
- Jones DL, Bhanegaonkar AJ, Billings AA, et al. Differences between actual and expected leisure activities after total knee arthroplasty for osteoarthritis. *J Arthroplasty*. 2012;27(7):1289-1296.
- Kersten RF, Stevens M, van Raay JJ, Bulstra SK, van den Akker-Scheek I. Habitual physical activity after total knee replacement. *Phys Ther*. 2012;92:1109-1116.
- Ko V, Naylor JM, Harris IA, Crosbie J, Yeo AE. The six-minute walk test is an excellent predictor of functional ambulation after total knee arthroplasty. *BMC Musculoskelet Disord*. 2013;14:145.
- Kraschewski JL, Sciamanna CN, Ciccolo JT, et al. Is exercise used as medicine? Association of meeting strength training guidelines and functional limitations among older US adults. *Prev Med*. 2014;66:1-5.
- Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am*. 2007;89:780-785.
- Leroux T, Ogilvie-Harris D, Dwyer T, et al. The risk of knee arthroplasty following cruciate ligament reconstruction: a population-based matched cohort study. *J Bone Joint Surg Am*. 2014;96:2-10.
- Li F, Harmer PA, Cardinal BJ, et al. Built environment, adiposity, and physical activity in adults aged 50-75. *Am J Prev Med*. 2008;35:38-46.
- Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. *BMJ*. 2009;339:b2700.
- Lutzner C, Kirschner S, Lutzner J. Patient activity after TKA depends on patient-specific parameters. *Clin Orthop Relat Res*. 2014;472:3933-3940.

40. Marmon AR, McClelland JA, Stevens-Lapsley J, Snyder-Mackler L. Single-step test for unilateral limb ability following total knee arthroplasty. *J Orthop Sports Phys Ther.* 2013;43:66-73.
41. Marmon AR, Milcarek BI, Snyder-Mackler L. Associations between knee extensor power and functional performance in patients after total knee arthroplasty and normal controls without knee pain. *Int J Sports Phys Ther.* 2014;9:168-178.
42. Mayr HO, Reinhold M, Bernstein A, Suedkamp NP, Stoehr A. Sports activity following total knee arthroplasty in patients older than 60 years. *J Arthroplasty.* 2015;30:46-49.
43. Meding JB, Meding LK, Ritter MA, Keating EM. Pain relief and functional improvement remain 20 years after knee arthroplasty. *Clin Orthop Relat Res.* 2012;470:144-149.
44. Mehrotra C, Remington PL, Naimi TS, Washington W, Miller R. Trends in total knee replacement surgeries and implications for public health, 1990-2000. *Public Health Rep.* 2005;120:278-282.
45. Meier W, Mizner RL, Marcus RL, Dibble LE, Peters C, Lastayo PC. Total knee arthroplasty: muscle impairments, functional limitations, and recommended rehabilitation approaches. *J Orthop Sports Phys Ther.* 2008;38:246-256.
46. Mihelic R, Jurdana H, Jotanovic Z, Madjarevic T, Tudor A. Long-term results of anterior cruciate ligament reconstruction: a comparison with non-operative treatment with a follow-up of 17-20 years. *Int Orthop.* 2011;35:1093-1097.
47. Mistry JB, Elmallah RD, Bhave A, et al. Rehabilitative guidelines after total knee arthroplasty: a review. *J Knee Surg.* 2016;29:201-217.
48. Mont MA, Marker DR, Seyler TM, Gordon N, Hungerford DS, Jones LC. Knee arthroplasties have similar results in high- and low-activity patients. *Clin Orthop Relat Res.* 2007;460:165-173.
49. Mont MA, Marker DR, Seyler TM, Jones LC, Kolisek FR, Hungerford DS. High-impact sports after total knee arthroplasty. *J Arthroplasty.* 2008;23(6 suppl 1): 80-84.
50. Naal FD, Impellizzeri FM. How active are patients undergoing total joint arthroplasty? A systematic review. *Clin Orthop Relat Res.* 2010;468:1891-1904.
51. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Circulation.* 2007;116:1094-1105.
52. Noble PC, Condit MA, Cook KF, Mathis KB. The John Insall Award: patient expectations affect satisfaction with total knee arthroplasty. *Clin Orthop Relat Res.* 2006;452:35-43.
53. Noble PC, Gordon MJ, Weiss JM, Reddix RN, Condit MA, Mathis KB. Does total knee replacement restore normal knee function? *Clin Orthop Relat Res.* 2005;(431):157-165.
54. Papalia R, Del Buono A, Zampogna B, Maffulli N, Denaro V. Sport activity following joint arthroplasty: a systematic review. *Br Med Bull.* 2012;101:81-103.
55. Parks SE, Housemann RA, Brownson RC. Differential correlates of physical activity in urban and rural adults of various socioeconomic backgrounds in the United States. *J Epidemiol Community Health.* 2003;57:29-35.
56. Parvizi J, Nunley RM, Berend KR, et al. High level of residual symptoms in young patients after total knee arthroplasty. *Clin Orthop Relat Res.* 2014;472:133-137.
57. Paterson DH, Warburton DE. Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *Int J Behav Nutr Phys Act.* 2010;7:38.
58. Piva SR, Teixeira PE, Almeida GJ, et al. Contribution of hip abductor strength to physical function in patients with total knee arthroplasty. *Phys Ther.* 2011;91:225-233.
59. Schache MB, McClelland JA, Webster KE. Lower limb strength following total knee arthroplasty: a systematic review. *Knee.* 2014;21:12-20.
60. Scott CE, Bugler KE, Clement ND, MacDonald D, Howie CR, Biant LC. Patient expectations of arthroplasty of the hip and knee. *J Bone Joint Surg Br.* 2012;94:974-981.
61. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (minors): development and validation of a new instrument. *ANZ J Surg.* 2003;73:712-716.
62. Sparling PB, Howard BJ, Dunstan DW, Owen N. Recommendations for physical activity in older adults. *BMJ.* 2015;350:h100.
63. Spector TD, Harris PA, Hart DJ, et al. Risk of osteoarthritis associated with long-term weight-bearing sports: a radiologic survey of the hips and knees in female ex-athletes and population controls. *Arthritis Rheum.* 1996;39:988-995.
64. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc.* 2002;34:1996-2001.
65. Tveit M, Rosengren BE, Nilsson JA, Karlsson MK. Former male elite athletes have a higher prevalence of osteoarthritis and arthroplasty in the hip and knee than expected. *Am J Sports Med.* 2012;40:527-533.
66. Vogel LA, Carotenuto G, Basti JJ, Levine WN. Physical activity after total joint arthroplasty. *Sports Health.* 2011;3:441-450.
67. Weinstein AM, Rome BN, Reichmann WM, et al. Estimating the burden of total knee replacement in the United States. *J Bone Joint Surg Am.* 2013;95:385-392.
68. Welk GJ, Kim Y, Stanfill B, et al. Validity of 24-h physical activity recall: physical activity measurement survey. *Med Sci Sports Exerc.* 2014;46:2014-2024.
69. Wendel-Vos GC, Schuit AJ, Saris WH, Kromhout D. Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *J Clin Epidemiol.* 2003;56:1163-1169.
70. Witjes S, Goutteborge V, Kuijjer PP, van Geenen RC, Poolman RW, Kerkhoffs GM. Return to sports and physical activity after total and unicompartmental knee arthroplasty: a systematic review and meta-analysis. *Sports Med.* 2016;46:269-292.
71. Wright JG, Swiontkowski MF, Heckman JD. Introducing levels of evidence to the journal. *J Bone Joint Surg Am.* 2003;85-A:1-3.
72. Wylie JD, Hartley MK, Kapron AL, Aoki SK, Maak TG. Failures and reoperations after matrix-assisted cartilage repair of the knee: a systematic review. *Arthroscopy.* 2016;32:386-392.
73. Zahir CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC. Assessing activity in joint replacement patients. *J Arthroplasty.* 1998;13:890-895.

For reprints and permission queries, please visit SAGE's Web site at <http://www.sagepub.com/journalsPermissions.nav>.