Osteoarthritis and Cartilage Open 6 (2024) 100498

Contents lists available at ScienceDirect

Osteoarthritis and Cartilage Open

journal homepage: www.elsevier.com/journals/osteoarthritis-and-cartilage-open/2665-9131

Review

Understanding the impact of physical activity level and sports participation on implant integrity and failure in patients following unicompartmental and total knee arthroplasty: A scoping review

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ARTICLE INFO

Handling Editor: Professor H Madry

Keywords:
Knee arthroplasty
Physical activity
Sports
Implant wear
Implant failure
Knee osteoarthritis

ABSTRACT

Objective: Recommendations discouraging high levels of physical activity and sports following unicompartmental (UKA) and total knee arthroplasty (TKA) have been questioned in recent years. This scoping review aimed to summarize the literature examining the impact of physical activity level and sports participation on implant integrity and failure in patients following UKA and TKA.

Methods: Five databases (Medline, Embase, SCOPUS, CINAHL, ProQuest) were searched up to April 17, 2024. Retrospective, prospective and cross-sectional studies were included if they assessed the impact of physical activity level and/or sports participation (exposure variables) on implant integrity and/or failure (outcome variables) at ≥1 year following UKA or TKA. Two authors independently conducted abstract/full text reviews and data charting. Extracted data were summarized using descriptive analysis.

Results: Of 2014 potential records, 20 studies (UKA: n = 6 studies, 2387 patients/TKA: n = 14 studies, 7114 patients) met inclusion criteria. Following both UKA & TKA, most patients regularly participated in light to moderate physical activities and lower impact sports (e.g. walking, cycling, golf). No studies reported a deleterious effect of physical activity level or sports participation on implant integrity or failure post UKA (mean follow-up: 3.3–10.3 years). Three studies reported an association between greater levels of physical activity with increased risk of implant failure post TKA (mean follow-up: 1–11.4 years).

Conclusions: No studies demonstrated an association between greater levels of physical activity and sports participation with increased implant wear or failure post UKA, whereas results were mixed following TKA. There is a need for large, prospective cohort studies with long-term follow-up.

1. Introduction

Osteoarthritis (OA) is the most common joint disease, affecting an estimated 595 million people worldwide [1]. Unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) are considered effective interventions in the management of patients with advanced radiographic knee OA who experience persistent pain and functional impairment [2]. Following knee arthroplasty, patients generally desire an increased functional capacity and to participate in physical activities and sports [3]. Although, most patients return to physical activity and sports following knee arthroplasty, there is a trend towards participation in lower-impact activities [4–6]. This trend may be explained by recommendations discouraging higher-impact activities and sports following knee arthroplasty to reduce the potential negative impact on implant component survivorship due to a greater number of loading cycles and knee joint forces [5,7,8].

Recommendations regarding physical activity and sports limitations following knee arthroplasty are mainly based on expert consensus [5],

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https://doi.org/10.1016/j.ocarto.2024.100498
Received 1 September 2023; Accepted 24 June 2024

with insight from studies assessing knee forces in vivo [8,9], and estimates from joint models [10–13]. However, these recommendations have been questioned in recent years due to evidence suggesting no increased risk of implant wear or failure with greater levels of physical activity [14–16] and sports participation [14,17,18]. For instance, previous research would suggest that high-impact sports [14] and high activity levels [16] do not increase the risk of implant failure at 7 and 12 years post TKA, respectively. However, other studies have reported conflicting findings [19–21,39]. Thus, whether participation in high-impact activities increases the risk of knee arthroplasty implant failure remains unclear, and may explain the often inconsistent and contradictory recommendations provided to patients.

The first steps in establishing guidance on physical activity and sports participation following UKA and TKA are to understand the evidence available to inform recommendations, to understand how studies on the topic are conducted and to identify where further research is needed. Thus, a broad overview of the literature on patients following primary UKA and TKA for knee OA is needed. The primary aim of this scoping review was to describe the literature examining the impact of physical activity and sports participation on implant integrity and failure in patients following UKA and TKA for tibiofemoral knee OA. The secondary aim was to identify knowledge gaps on the topic and provide recommendations for future research.

2. Methods

This scoping review was conducted and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews [22] (Supplemental Table 1). A scoping review design and methodology was used due to the descriptive and exploratory nature of the research question and study objectives [23,24]. We used the Arksey and O'Malley [25] framework to guide our review, with refinements proposed by more recently published guidelines [23,24,26]. The scoping review protocol was not registered previously.

Our research question was: *"What is known on the impact of physical activity and sports participation on implant integrity and implant failure in adults following UKA and TKA for tibiofemoral OA?* In accordance with the PCC framework [24], our population (P) was defined as "adults with primary UKA or TKA for tibiofemoral OA", the concept (C) was defined as "the impact of physical activity and sports participation on implant integrity and implant failure following UKA and TKA" and the Context (C) was "non-specific", meaning evidence could come from any settings. Physical activity was defined as, "any bodily movement produced by skeletal muscles that results in energy expenditure" [27]. Physical activity refers to all movement, including occupational, transport, domestic and leisure time [28]. Sports participation also involves physical activity, but differs in that sports adhere to a common set of rules or expectations, and a defined goal exists [28]. Lastly, implant integrity (e.g. implant wear) differs from implant failure in that it provides information on the general status of an implant that has not yet failed. The distinctions between physical activity and sports, and between implant integrity and implant failure were made to facilitate the identification of key constructs in included studies and to describe potential associations between these constructs.

2.1. Data sources and search strategy

Relevant studies were originally identified by searching five online databases: Medline, Embase + Embase Classic, SCOPUS, CINAHL and ProQuest Theses & Dissertations, from inception to June 8, 2021. An updated search of the same five databases was conducted on April 17, 2024. Database searches were conducted by the primary author (A.T.). Databases were selected based on their relevance to the topic and to ensure a comprehensive search strategy. ProQuest Theses & Dissertations was included to ensure that potentially relevant grey literature sources were not missed. Keywords and constructs (e.g. MeSH, Boolean phrases) used to execute searches were developed a priori from a preliminary search, search strategies from review articles [29–32], and in consultation with team members and an academic librarian. The following general search terms (in brackets) were adapted based on the database and were grouped by construct: 1) Patient Population (knee arthroplasty or knee replacement), 2) Implant Survivorship (prosthesis failure or reoperation or survivorship or revision or durability or wear or adverse or complications or failure) and 3) Physical Activity and Sports Participation (exercise or physical fitness or activity level or physical activity or sport or athlete or athletic). The full search strategies for each database can be found in Supplemental Tables 2a–2e.

2.2. Study selection

Studies were included if they were published in English or French, and assessed the impact of physical activity level and/or sports participation on implant integrity and/or failure ≥1 year following primary UKA or TKA for tibiofemoral OA in adults (18+ years). Studies reporting on multiple surgical interventions (e.g. TKA & THA) had to report the results of the knee arthroplasty group separately. Studies reporting on UKAs needed to specify which compartment was operated on (medial vs. lateral) and how many participants underwent each surgery. Studies that assessed post-operative physical activity level and sports participation using a self-developed self-report questionnaire were included if at least one parameter relating to physical activity/sports was reported (e.g. frequency, intensity, duration). Studies reporting on multiple patient populations (e.g. OA, rheumatoid arthritis) needed to have the majority (>50%) with tibiofemoral OA. Studies with no direct statistical analysis examining the relationship between physical activity level and/or sports participation with implant integrity and/or failure (e.g. correlation, multiple regression) were included if they reported on implant-related outcomes (e.g. number of revisions) for relevant sub-groups (e.g. low vs. high activity level). Authors of potential articles were contacted by the primary author (A.T.) if study information was missing (e.g. primary diagnoses for participants). See Table 1 for more information on inclusion and exclusion criteria.

2.3. Study screening

Results for individual database searches were merged in EndNote 20.1, and duplicates removed. Remaining records were imported into Rayyan (Rayyan Systems Inc, https://rayyan.ai/). Prior to title and abstract reviews, two raters (A.T. & P.I.) independently screened a random sample of 30 titles and abstracts to assess applicability of exclusion criteria, and inter-rater agreement and Cohen's kappa (K) between the two raters. Reviewers reached almost perfect level of agreement (97%, K = 0.87) [33], and proceeded with reviewing titles and abstracts. Afterwards, the same two raters (A.T. & P.I.) performed full-text screening to determine final study selection. Prior to full article reviews, two raters (A.T. & P.I.) independently screened a random sample of 15 full-text articles to assess applicability of exclusion criteria, and inter-rater agreement and Cohen's kappa (K) between the two raters. Reviewers reached almost perfect level of agreement (93%, K = 0.84) [33], and proceeded with reviewing the full-text articles. Consensus was reached on disagreements first between raters (A.T. & P.I.), and if required, with a third author (S.M.R.). Reference lists of included studies, review articles, and clinical guidelines were reviewed to identify additional records.

2.4. Data charting

We extracted the following information from included studies: 1. Study characteristics: year, design, location, mean follow-up, 2. Surgery and implant: type of surgery, implant-related information (company, model, etc.), 3. Study population: sample size, baseline participant characteristics (primary diagnosis, age, sex, etc.), 4. Assessment of physical activity and sports participation, 5. Assessment of implant

Table 1
Study inclusion and exclusion criteria.

Variable	Inclusion Criteria	Exclusion Criteria
Language	English or French language	Not English or French language
Study Population	Human participants	Animal models
	Adults (18+ years)	Not adults (<18 years)
	Primary unicompartmental knee replacement (UKA) or total knee arthroplasty (TKA) for tibiofemoral osteoarthritis (OA)	Surgical procedure other than UKA/TKA or following revision knee arthroplasty
Study Design	Retrospective, prospective or cross-sectional quantitative studies (case–control studies, randomized controlled trials, longitudinal cohort studies, case series), theses and dissertations	Case study, case reports, reviews and meta-analyses, qualitative studies
Article Format	Peer-reviewed research article or theses/dissertations	Editorial, commentary, conference abstract, report
Exposure	Assessed post-operative physical activity level and/or sports participation	No/inappropriate assessment of post-operative physical activity level and/or sports participation
Main outcome	Any outcome related to implant integrity and/or implant failure	No outcome related to implant integrity or implant failure
Statistical Analysis	Direct analysis examining the relationship between post-operative physical activity level/sports participation on implant integrity and/or implant failure OR Reported on implant integrity and/or implant failure for relevant sub-groups	No direct analysis and did not report on implant integrity or implant failure for relevant sub-groups

integrity and failure, 6. Statistical analysis, 7. Key study findings, and 8. Funding sources and disclosures of interest. Data extraction was completed by two independent raters (A.T. & P.I.) using a customised Microsoft Excel form [24]. The form was first piloted by comparing data extracted by the two raters (A.T. & P.I.) across a random sample of 5 studies to ensure accurate and relevant data were extracted [24].

2.5. Data synthesis

A descriptive analysis approach was used to summarize study characteristics, participant demographics, and information regarding physical activity level, sports participation, implant integrity and implant failure across studies. We reported means, standard deviations, ranges, proportions, and rates for numerical variables. Categorical variables were described by number (n) and percentage (%). UKA and TKA study findings were summarized separately.

2.6. Risk of bias assessment

Risk of bias (rating: low, moderate, high) was assessed by the primary author (A.T.) using the National Institute of Health Study Quality Assessment Tool for Case-Control Studies, and for Observational Cohort and Cross-Sectional Studies [34]. Consistent with the secondary aim of this review, risk of bias (optional for scoping reviews) was assessed to better provide recommendations for future research, and not to underpin clinical practice decisions [24]. As a result, one reviewer was deemed sufficient.

3. Results

The latest database search conducted on April 17, 2024 generated 1999 potential records (original search conducted on June 9, 2021). Fifteen additional records were identified through reference lists of relevant articles. Of the 2014 total records identified, 1347 underwent title/abstract screening, 141 were reviewed in full, and 20 articles were included [14–21,35–46] (Fig. 1). Two articles reported on the same dataset at a mean follow-up of 6.1 years [47] and 10.3 years [38] post UKA. Only the article with the longer follow-up was included [38]. For one article [46], only the TKA cohort was included, as no information was provided on how many participants underwent medial and lateral UKAs in the UKA cohort. Three studies were excluded because the primary diagnosis of participants receiving TKA was either not available [48] or no response was received from the corresponding author regarding missing data [49,50].

3.1. Study & participant characteristics

Study characteristics and baseline participant demographics are summarized in Table 2. In total, 20 studies across six countries (North America: n = 10, Europe: n = 10) were included. Of the 20 studies, 10 were retrospective cohort studies [14–17,19–21,37,43,46], six were prospective cohort studies [18,36,38,42,44,45], two were matched case-control studies [39,40], and two were cross-sectional studies [35,41].

Six studies (30%) included patients post UKA [15,18,38,42,43,45] and 14 studies (70%) included patients post TKA [14,16,17,19–21,35–37,39–41,44,46]. Implant-related information (e.g. company, design, bearing, fixation) is summarized in Supplemental Table 3. Data from 2387 patients following UKA (2788 knees, 52% females, mean age range: 52–66 years) and 7114 patients following TKA (8051 knees, 57% females, mean age range: 62–74 years) were included. The proportion of the study sample with a diagnosis of knee OA as the primary indicator for surgery ranged between 86 and 100% in UKA studies, and 65–100% in TKA studies. UKA procedures were done for medial compartment knee OA for all participants in five studies [15,18,38,42,43], and 89% of participants in one study [45]. Mean follow-up periods ranged from 3.3 to 10.3 years in UKA studies, and 1–11.4 years in TKA studies.

Funding sources and disclosures of interest for included studies are summarized in Supplemental Table 4. Briefly, funding sources were mentioned in nine studies (45%), and disclosures of interest were declared in 12 studies (60%).

3.2. Risk of bias assessment

Risk of bias assessment using the National Institute of Health Study Quality Assessment Tool is summarized in Supplemental Tables 5 and 6. All UKA studies (n = 6) had a "moderate" risk of bias [15,18,38,42,43,45]. For TKA studies (n = 14), seven studies had a "high" risk of bias [14,19,20,37,39,41,46], four studies had a "moderate" risk of bias [17,35,36,44], and three studies had a "low" risk of bias [16,21,40]. Common reasons for not meeting criteria in observational cohort and cross-sectional studies were not clearly defining the study population (present in 33% of studies) and not adjusting for potential confounders (present in 17% of studies). Common reasons for not meeting criteria in case-control studies were not indicating whether cases and/or controls were randomly selected from those eligible (unable to determine for all studies), and not using concurrent controls (present in zero studies).

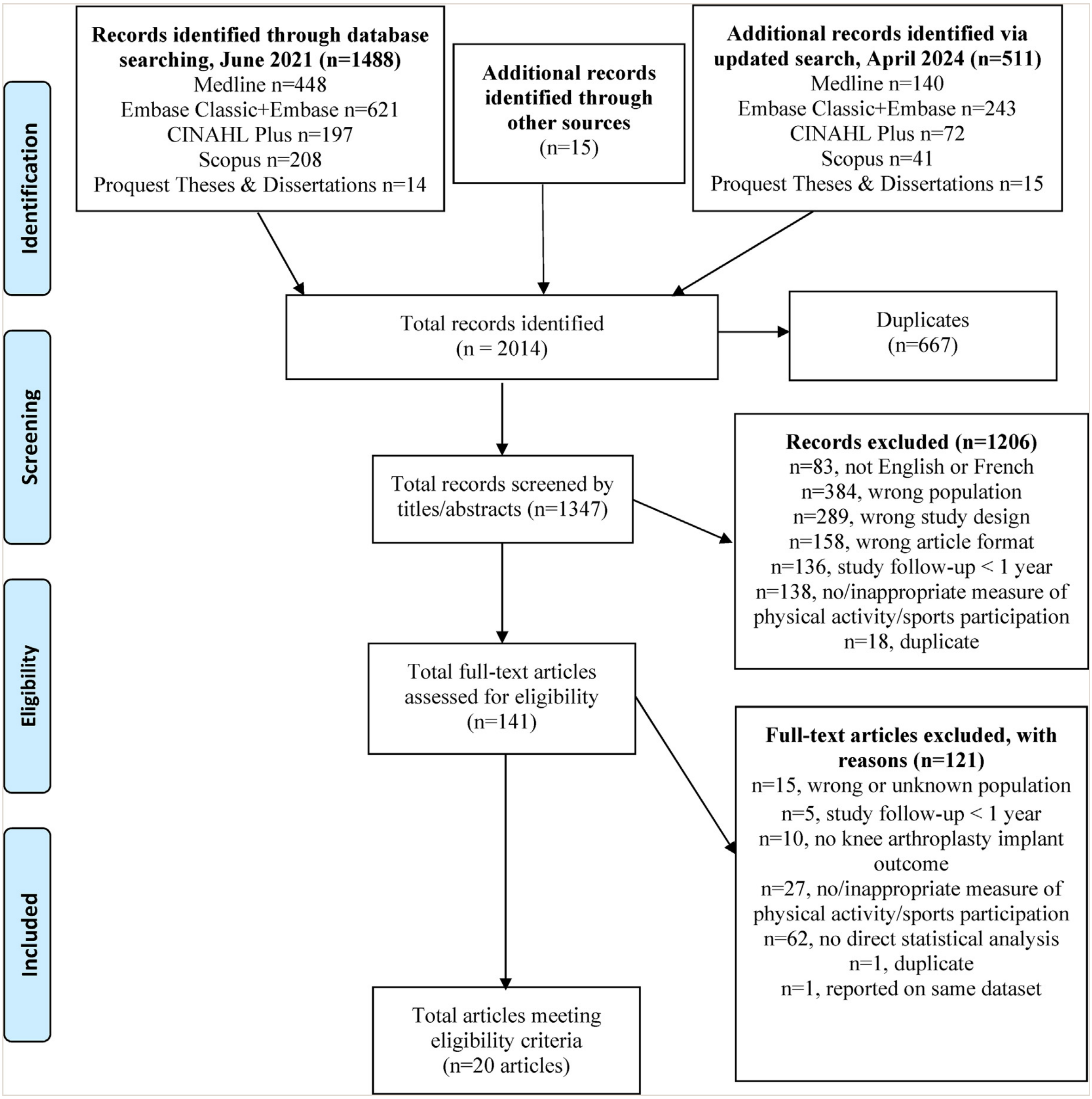

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews flow chart [22].

3.3. *Physical activity & sports participation*

A summary of how post-operative physical activity and sports participation was assessed in UKA and TKA studies is provided in Table 3. Seventeen studies (85%) assessed physical activity using self-report measures [14–17,19–21,35,36,38–43,45,46] and one study (5%) assessed physical activity using annual walk cycles estimated via a pedometer [44]. Five studies (20%) reported assessing sports participation using either a self-report questionnaire developed by the study authors [14,17,18,37] or the Modifiable Activity Questionnaire [40]. Generally, most patients tended to regularly participate in light to moderate physical activities and lower impact sports (e.g. walking, cycling, golf) following UKA and TKA.

3.4. *Implant integrity & failure*

The different implant-related outcomes and how they were assessed in UKA and TKA studies are summarized in Table 4. Implant integrity and failure, in relation to post-operative physical activity level or sports participation, were assessed in 12 studies [14–17,19,21,35,36,41,43–45] (60%) and 15 studies [14–16,18,20,21,35–40,42,43,46] (75%), respectively.

3.5. *The effect of physical activity & sports participation on implant integrity*

The key constructs and study findings for each study are summarized in Table 5. In UKA studies (n = 6), the association between post-operative physical activity with implant integrity was assessed in three studies [15,43,45] (50%), none of which reported a potential deleterious effect. No studies assessed the association between sports participation and implant integrity.

In TKA studies (n = 14), the association between post-operative physical activity and sports participation with implant integrity was assessed in nine studies [14,16,17,19,21,35,36,41,44] (64%) and two studies [14,17] (14%), respectively. No studies reported a potential deleterious effect.

3.6. *The effect of physical activity & sports participation on implant failure*

In UKA studies (n = 6), the association between post-operative physical activity and sports participation with implant failure was assessed in four studies [15,38,42,43] (67%) and one study [18] (17%), respectively. No studies reported a potential deleterious effect.

Table 2
Study characteristics & participant baseline demographic information.

Author & Year	Country	Surgical Procedure	Study Design	Mean Follow-Up	Number of participants (% female)	Primary Diagnosis n (%)	Mean age (range)
Crawford et al., 2019	USA	Medial UKA	Retrospective cohort study	9 years (range: 4–13.1)	487 (59)	OA: 576 knees (100%)[a]	62.3 years 58.9 years
Hamilton et al., 2017	United Kingdom	Medial UKA	Prospective cohort study	10.3 years (range: 5.3–16.6)	818 (52)	OA: 977 knees (98%) Osteonecrosis 23 knees (2%)	66 years (range: 32–88)
Mohammad et al., 2023	United Kingdom	Medial UKA	Prospective cohort study	6.5 years (SD: 2.7)	870 (46)	OA: 989 knees (99%) Osteonecrosis: 11 (1%)	66.2 years (SD: 10 years)
Pietschmann et al., 2013	Germany	Medial UKA	Retrospective cohort study	4.2 years (range: 1–10)	131 (56)	OA: 131 knees (100%)	65.3 years (range 44–90)
Presti et al., 2019	Italy	Medial UKA	Prospective cohort study	4 years (range: 2–6)	53 (72)	OA: 53 knees (100%)[a]	59.7 years (range 46–66)
Schai et al., 1998	USA	Medial & Lateral UKA	Prospective cohort study	3.33 years (range: 2–6)	28 (61) M-UKA: 25 L-UKA: 3	OA: 24 knees (86%) Osteonecrosis: 2 knees (7%) Post-traumatic arthritis: 2 knees (7%)	52 (range: 37–60)
Argenson et al., 2013	France	TKA	Retrospective cohort study	Minimum of 10 years	828 (67)	OA: 753 knees (89%) RA: 69 knees (8%) Osteonecrosis: 24 knees (3%)	71 years (range: 41–93)
Bauman et al., 2007	Canada	TKA	Cross-sectional survey	3.1 years	184 (59)	OA: 184 knees (100%)[a]	68.9 years (SD: 9.5 years, range: 41–88)
Bercovy et al., 2015	France	TKA	Prospective cohort study	7.5 years (range: 5–13)	482 (66)	OA: 536 knees (91%) Osteonecrosis: 17 knees (2.9%) RA: 16 knees (2.7%) Post-traumatic arthritis: 15 knees (2.6%)	70.6 (range: 40.1–91.2)
Bradbury et al., 1998	United Kingdom	TKA	Retrospective cohort study	5 years (range: 3–7)	160 (55)	OA: 142 patients (89%) Osteonecrosis: 7 patients (4%) RA: 7 patients (4%) Chondrocalcinosis: 3 patients (2%)	68 years (range: 27–87)
Crawford et al., 2020	USA	TKA	Retrospective cohort study	11.4 years (SD: 1.5, range: 4–13.1)	1611 (65)	OA: 2038 knees (100%)[a]	64.9, 62.3
Heck et al., 1992	USA	TKA	Matched case-control study	6 years (range: 0.8–9.6)	9 (44)	OA: 10 knees (83.3%) RA: 1 knee (8.3%) Gout: 1 knee (8.3%)	67.4 years (range: 60–85 years)
Jones et al., 2004	USA	TKA	Matched case-control study	6.4 years (SD: 2.3, range: 2–11)	52 (65)	OA: 76 knees (100%)	70.5 (SD: 8.9, range: 47–85)
Lavernia et al., 2001	USA	TKA	Retrospective cohort study	6.2 years (range: 2.3–11.3)	22 (68)	OA: 15 patients (65%) RA: 6 patients (26%) Osteonecrosis: 1 patient (4.3%)	68 years (SD: 14.0)
Luetzner et al., 2007	Germany	TKA	Cross-sectional study	Unilateral TKA: 5.5 years (range: 4.9–7.2) Bilateral TKA: 6.3 years (range: 4.8–10.2)	41 (63)	OA: 64 knees (100%)[a]	74 years (range: 67–79)
Mayr et al., 2015	Germany	TKA	Retrospective cohort study	6.4 ± 0.9 years	81 (53)	Grade IV knee OA: 81 knees (100%)	71.8 (SD: 5.4 years)
Mont et al., 2007	USA	TKA	Retrospective cohort study	7 years (range: 4–14)	114 (61)	OA: 141 knees (98%) RA: 1 knee (0.7%) Osteonecrosis: 2 knees (1.3%)	70 years (range: 41–86)

(*continued on next page*)

Table 2 (*continued*)

Author & Year	Country	Surgical Procedure	Study Design	Mean Follow-Up	Number of participants (% female)	Primary Diagnosis n (%)	Mean age (range)
Ponzio et al., 2018	USA	TKA	Retrospective cohort study	Last follow-up: 5–10 years	2016 (43)	OA: 2016 knees (100%)	66.3 years
Reiner et al., 2020	Germany	TKA	Prospective cohort study	Last follow-up: 1 year	25 (48)	OA: 25 patients (100%) Primary OA: 22 patients (88%) Secondary OA: 3 patients (12%)	64.7 years (range: 42–81)
Streck et al., 2023	USA	TKA	Retrospective cohort study	2.9 years (range: 1.1–7.2 years)	1489 (58)	OA: 1745 knees (100%)	Low activity: 65 years (SD: 6) Mod activity: 64 years (SD: 7) High activity: 64 years (SD: 6)

UKA: unicompartmental knee arthroplasty, TKA: total knee arthroplasty, OA: osteoarthritis, SD: standard deviation, M-UKA: medial UKA, L-UKA: lateral UKA.

[a] Study authors were contacted to confirm the primary diagnosis in patients undergoing a knee arthroplasty.

In TKA studies (n = 14), the association between post-operative physical activity and sports participation with implant failure was assessed in nine studies [14,16,20,21,35,36,39,40,46] (64%) and three studies [14,37,51] (21%), respectively. Three studies reported a potentially deleterious effect of post-operative physical activity level [20,21,39], but not sports participation, on implant failure. One retrospective study of 828 patients post TKA (mean follow-up: 10 years) demonstrated a significant correlation between increased revision rates with greater activity levels assessed using the Devane classification ($P = 0.03$) [20]. Similarly, a retrospective study classified patients post TKA as active (Lower Extremity Activity Scale score between 13 and 18, n = 1008) or inactive (Lower Extremity Activity Scale score between 7 and 12, n = 1008) [21]. Revision rates were significantly greater at 5–10 years post TKA for active patients (3.2% revision rate) when compared to inactive patients (1.6% revision rate, $P = 0.019$) [21]. Lastly, in a matched case-control study, the revision group (cases, n = 12 knees) had higher activity levels (assessed using the Modified OASDI Activity Level Scoring System) compared to the control group ($P = 0.02$) [39]. Conversely, one study reported a potential protective effect of physical activity level on implant failure, with the all-cause 12-year survivorship being higher for the high activity group (98%) when compared to the low activity group (95.3%, $P = 0.003$) [16].

4. Discussion

The main findings of this scoping review are that 1) no studies have shown an association between greater levels of physical activity and sports participation with increased implant wear or failure up to ten years post UKA, and 2) studies have not demonstrated a consistent association between greater levels of physical activity and implant failure up to 11 years post TKA. Our scoping review adds to the current body of literature on the topic by 1) providing a broad, up-to-date overview of the evidence available to inform physical activity and sports recommendations following UKA and TKA, 2) describing how studies on the topic were conducted and 3) identifying gaps in knowledge and future research priorities.

4.1. *The effect of physical activity & sports participation on implant integrity & failure*

Following UKA, no studies reported a potentially deleterious effect of greater physical activity levels and sports participation on implant integrity or failure. Three TKA studies reported an association between greater post-operative physical activity (but not sports participation) with implant failure rates [20,21,39]. However, the conclusions drawn from these studies were hampered by certain methodological limitations. For instance, the findings by Heck et al. are potentially confounded by the physical job demands of the included cases (e.g. plumber, construction worker) [39]. The Devane classification used to assess activity level in the study by Argenson et al. provides limited information on activity levels [20]. Lastly, Ponzio et al. found that revision rates were higher for active patients compared to inactive patients at 5–10 years post TKA [21]. However, activity level was not a risk factor for implant revision after accounting for confounding variables (e.g. sex, BMI, age) [21]. Therefore, the results of these studies must be interpreted with caution.

Kornuijt et al. published a recent systematic review and meta-analysis following the completion of the current manuscript demonstrating no association between high physical activity level and an increased risk of TKA implant revision [52]. Although similar, our scoping review provides a more broad overview of the most recent evidence available to inform recommendations following both UKA and TKA, and provides a more detailed description of how studies on the topic were conducted, where further research is needed and how future research can be improved.

Table 3
Assessment of post-operative physical activity and sports participation across studies.

	Outcome[a]	Assessment Method	n
UKA Studies (n=6)	Physical Activity	Tegner Activity Scale [38,42,45]	3
		University of California at Los Angeles (UCLA) activity scale [15,43]	2
	Sports Participation	Self-report questionnaire developed by authors [18]	1
	Outcome[a]	**Assessment Method**	**n**
TKA Studies (n=14)	Physical Activity	University of California at Los Angeles (UCLA) activity scale [16,19,35,36,41]	5
		Devane Classification [20]	1
		Modified OASDI Activity Level Scoring System [39]	1
		Lower Extremity Activity Scale [21,46]	2
		Estimated annual walking cycles [44]	1
	Sports Participation	Self-report questionnaire developed by authors [37]	1
	Both Physical Activity & Sports Participation	Modifiable Activity Questionnaire (MAQ), MET-hours per week [40]	1
		Total Knee Replacement Questionnaire, weighted activity score based on frequency and impact of specific activity or sport, developed by authors [14]	1
		Scoring system based on the impact and quantity of the specific activity or sport, developed by authors [17]	1

UKA: unicompartmental knee arthroplasty, TKA: total knee arthroplasty.
[a] Only post-operative physical activity and sports participation outcomes involved in analyses with implant-related outcomes are reported for each study.

Table 4
Assessment of implant-related outcomes across studies.

	Implant-Related Outcome[a]		Assessment Method	n
UKA Studies (n=6)	Implant Failure	Implant survivorship	Kaplan-Meier survival analysis [15,38,42]	3
		Number of revisions	Frequency count [15,18,42,43]	4
		Time to implant failure	Not applicable [38]	1
	Implant Integrity	Meniscal bearing thickness	Radiograph [15]	1
		Implant position	Radiograph [43]	1
		Width of lateral compartment	Radiograph [43]	1
		Radiolucent lines	Radiograph [45]	1
	Implant-Related Outcome*		**Assessment Method**	**n**
TKA Studies (n=14)	Implant Failure	Implant survivorship	Kaplan-Meier survival analysis [16,36,46]	3
		Number of revisions	Frequency count [14,16,20,21,35–37,39,40,46]	10
		Time to implant failure	Not applicable [16,21]	2
		Risk of implant revision	Odds ratio [21,46,51]	3
	Implant Integrity	Implant loosening	Radiograph [20,35,44]	3
			Scintigraphy [17]	1
		Osteolysis	Radiograph [21,35,44]	3
		Implant wear	Radiograph [16,17,21,35]	4
		Radiolucent lines	Radiograph [16,17,36]	3
		Implant alignment	Radiograph [17,44]	2
		Polyethylene wear at autopsy	Linear wear measured using a caliper [19]	1
			Visual wear assessed via visual inspection [19]	
			Volumetric wear measured using a specially designed device [19]	
		Blood serum metal ion concentrations	Measured via blood samples [41,44]	2

UKA: unicompartmental knee arthroplasty, TKA: total knee arthroplasty.
[a] Only implant-related outcomes involved in analyses with post-operative physical activity/sports participation outcomes are reported for reach study.

4.2. *Clinical implications*

The findings of this scoping review would suggest that it may be time to reevaluate previously established activity and sports recommendations following knee arthroplasty. More specifically, it may not be necessary to deter patients from participating in regular physical activity and sports (even at higher levels). However, it is not possible to provide definitive recommendations for clinical practice based on our findings for several reasons. Firstly, scoping reviews are generally exploratory and descriptive in nature and thus, are not designed to underpin clinical practice decisions [24]. Second, the furthest mean follow-up of studies included in this scoping review was 10 years post UKA and 11 years post TKA. Considering that 82% of TKA and 70% of UKAs last 25 years [53], further studies with longer-term follow-up (>10 years) are needed to confidently determine whether post-operative physical activity and sports participation may have a negative impact on implant integrity and/or failure. Lastly, there was significant between-study variability in knee arthroplasty implants and designs, and how physical activity and sports participation were assessed, making it difficult to synthesize results and provide specific recommendations.

There are also other factors to consider when recommending a physical activity or sport following knee arthroplasty [7]. Knee arthroplasty implant design and materials have evolved significantly over time, improving patient outcomes and implant longevity [54]. This may, in part, explain why older studies [19,39] have shown less favorable results for active patients compared to less active patients. Furthermore, higher contact stresses occur in knee flexion due to the contact geometry of knee arthroplasty implants [55]. Consequently, activities involving knee loading at greater angles of flexion (e.g. hiking, downhill skiing) may increase stress on the implant bearing surface and accelerate wear of the polyethylene insert [7]. Lastly, when compared to a TKA, a UKA provides improved knee mobility and kinematics [51,56]. This may allow patients to return to more technically demanding and higher-level activities.

Previous research has also suggested that implant wear is a function of use, and not time [57]. Athletic activities with increased loading cycles, joint loads and/or technical demands may induce important stress at the bone-implant fixation surface and accelerate wear of implant components, leading to premature implant failure and revision. However, according to consensus guidelines, patients may return to moderate-impact and certain higher-impact sports following knee arthroplasty if they had prior experience with the sport pre-operatively, as they have the learned muscle control and proprioception to safely return [5]. Therefore, patients should be made aware of the potential

Table 5
Key constructs and study findings.

Author & Year	Surgery	Physical Activity	Sports Participation	Implant Failure	Implant Integrity	Key Study Findings
Crawford et al., 2019	UKA	✓		✓	✓	Implant revisions were performed in 8.4% of the low activity group and 6.2% of the high-activity group ($P = 0.43$). At the mean 9-year follow-up, survival to endpoint of revision for any cause for the high activity group was 94.0% (95% CI: 90.9–97.1%) and 92.1% (95% CI: 90.7–93.5%) for the low activity group ($P = 0.60$). There was also no difference in mean meniscal bearing thickness between groups ($P = 0.65$).
Hamilton et al., 2017	UKA	✓		✓		The 15-year implant survival was 90.1% (95% CI: (72.1–100%) in the high activity group and 92.5 (95% CI: 86.7–98.4%). The difference between groups was not significant ($P = 0.51$).
Mohammad et al., 2023	UKA	✓		✓		The 10-year implant survival in the low/medium (Tegner Activity Scale <4) and high (Tegner Activity Scale ≥5) post-operative activity groups were 98.1% (CI: 96.5–99.0) and 96.7% (CI: 91.3–98.8) respectively. No significant difference between groups (HR: 1.39 [CI 0.45–4.30, $P = 0.57$]).
Pietschmann et al., 2013	UKA	✓		✓	✓	No significant correlation between implant position with sports activity ($P > 0.05$) at a mean follow-up of 4.2 years. No difference in revision rate between active and inactive groups (2 per group).
Presti et al., 2019	UKA		✓	✓		There were no implant failures or revisions at a mean follow-up of 4 years, regardless of sport (low-impact sport vs. high-impact sport).
Schai et al., 1998	UKA	✓			✓	No significant correlation between activity level and the presence of tibial radiolucent lines ($P = 0.08$) at a mean follow-up of 3.3 years.
Argenson et al., 2013	TKA	✓		✓		At a minimum of 10 years follow-up, there was a significant correlation between revision rate with activity level assessed using the Devane classification ($P = 0.03$), whereby risk of TKA implant mechanical complications (i.e. implant loosening) increased with greater activity.
Bauman et al., 2007	TKA	✓		✓	✓	There were no documented implant revisions, evidence of osteolysis, implant loosening, or signs of implant wear, regardless of UCLA score at a mean follow-up of 3.1 years.
Bercovy et al., 2015	TKA	✓		✓	✓	There were no significant correlations between UCLA activity score and radiolucent lines at the tibial or femoral interface ($P = 0.2$) at a mean follow-up of 7.5 years. None of the UCLA ≥8 patients had reoperation, revision or modification of the implant interfaces, and Kaplan–Meier survivorship in this group was 100%.
Bradbury et al., 1998	TKA		✓	✓		Similar revision rate in patients who returned to sports (9.8%) vs. patients who did not (9.2%) at a mean follow-up of 5 years.
Crawford et al., 2020	TKA	✓		✓	✓	The all-cause 12-year survivorship was greater in the high activity group (98%, 95% CI: 97.4–98.6%) compared to the low activity group ($P = 0.003$). In patients who did not have a revision, radiographic radiolucencies and/or polyethylene wear were documented in 5 knees (0.4%) in the low-activity group and 7 knees (0.9%) in the high-activity group ($P = 0.23$).
Heck et al., 1992	TKA	✓		✓		At a mean follow-up of 6 years, the revision group (cases, n = 12 knees) had higher activity levels compared to the control group ($P = 0.02$)
Jones et al., 2004	TKA	✓	✓	✓		No association between leisure activity, occupational activity or total physical activity with the risk of revision arthroplasty at a mean follow-up of 8 years ($P > 0.05$).
Lavernia et al., 2001	TKA	✓			✓	Patients with pre-operative UCLA activity score of 5–6 (moderate activity) demonstrated greater extent ($P = 0.001$) and severity ($P<0.001$) of polyethylene insert creep or deformation compared to less active patients at a mean follow-up of 6.2 years. Stepwise multiple regression analysis demonstrated that pre-operative UCLA score was the most important predictor of extent (%) of involvement of deformation (Coefficient: 1.841 ± 0.835 SE, $P = 0.039$).
Luetzner et al., 2007	TKA	✓			✓	No influence of activity level on measured blood serum metal ion concentrations at a mean follow-up of 5.5 years.
Mayr et al., 2015	TKA	✓	✓		✓	At a mean follow-up of 6.4 years, there was no evidence of tibial inlay wear, assessed via the height of the tibial inlay, or evidence of implant loosening, regardless of sport or activity (low-, medium- or high-impact).
Mont et al., 2007	TKA	✓	✓	✓	✓	No revisions, progressive radiolucencies or osteolysis observed in either the low-activity or high-activity group at a mean follow-up of 7 years.

(*continued on next page*)

Table 5 (*continued*)

Author & Year	Surgery	Physical Activity	Sports Participation	Implant Failure	Implant Integrity	Key Study Findings
Ponzio et al., 2018	TKA	✓		✓	✓	At 5–10 years post TKA, revision rates were significantly greater in active patients (n = 32, 3.2%) vs. inactive patients (n = 16, 1.6%) (*P* = 0.019). However, activity level was shown not to be a risk factor for revision TKA, after controlling for relevant variables (i.e. age, sex, BMI, among others). Osteolysis and wear (9.4% in the active group compared with 0% in the inactive group) were more frequent in the active group, but the difference did not reach significance.
Reiner et al., 2020	TKA	✓			✓	At 1 year follow-up, there was no correlation between blood cobalt ion concentrations and number of walking cycles (β = 0.08, *P* = 0.788). No signs of osteolysis or implant loosening were detected at 1-year follow-up.
Streck et al., 2023	TKA	✓		✓		The overall revision rate for TKA was 1.5%. The 5-year survival rates were 95.8% in the low activity group, 97.4% in the moderate activity group and 99.6% in the high activity group.

Studies demonstrating a potentially deleterious effect of post-operative physical activity or sports participation on implant integrity and/or failure are in bold.
UKA: unicompartmental knee arthroplasty, **TKA**: total knee arthroplasty, **UCLA**: University of California at Los Angeles, **CI**: confidence interval, **BMI**: body mass index.

risks of higher activity levels or high-impact sports on long-term implant survival, which are not entirely known. This would allow for patients to make an informed decision regarding which activities to participate in following their knee arthroplasty, with guidance from their orthopaedic surgeon and physiotherapist.

4.3. *Future directions*

A secondary aim of this scoping review was to identify knowledge gaps and provide recommendations for future research. There is a need for large, high-quality prospective cohort studies with long-term (>10 years) follow-up. Authors should ensure that the study population is clearly defined and key potential confounding variables (e.g. age, sex, body mass index) are accounted for in statistical analyses. To ensure transparency, it is crucial that authors declare funding sources and their role in the study, as well as potential disclosures of interest. Considering the significant between-study variability in the assessment of physical activity levels and sports participation, a more consistent approach is needed in future research. Furthermore, the categorical nature of self-report questionnaires provides fairly broad descriptions of various activities associated with each level on a given scale, but fail to provide relevant information such as the intensity and frequency of activities. One potential solution may be the use of objective measures (ex: pedometer, fitness watch) to improve estimates of physical activity and sports participation. Lastly, research is needed examining the association between physical activity and sports participation with implant integrity or failure according to different implant designs (e.g. cemented vs. cementless, mobile vs. fixed), and in patient sub-groups. For instance, outcomes could be stratified by age, seeing as the risk of implant revision rates is increased in younger patients [58]. There is also limited research on patient populations that participate in vigorous physical activity and/or high-impact sports. This is likely because these types of activities are often discouraged by orthopaedic surgeons post-operatively.

4.4. *Limitations*

There are certain limitations that must be considered. First, there was significant between-study variability, as well as a lack of standardized, objective measures for the assessment of physical activity levels and sports participation, with little information regarding relevant parameters (e.g. duration, frequency, intensity). Additionally, there was significant between-study variability in the knee arthroplasty implant designs used, and some study samples had mixed primary diagnoses for knee arthroplasty. Together, these limitations make it difficult to summarize individual study outcomes (e.g. types of physical activities and sports and parameters), as well as make between-study comparisons. Second, only one author assessed risk of bias, and most included studies had a moderate to high risk of bias. Third, studies with follow-up periods <5 years may not have had sufficient time to observe any potential negative impact of physical activity level or sports participation on implant integrity or failure. Furthermore, several potentially relevant articles were excluded due to language [59] and not having conducted analyses between relevant sub-groups (e.g. low vs. high physical activity) [50, 59–63]. However, these excluded studies also support the notion that higher levels of physical activity [59] and participation in higher impact sports such as tennis [62] and downhill skiing [63] appear to be safe in the short-to mid-term following TKA. We also acknowledge that only six prospective cohort studies were deemed eligible, including three with <55 participants. Additionally, only three studies reported on long-term outcomes (>10 years). Therefore, our conclusions are generalizable to mid-term follow-up after knee arthroplasty.

4.5. *Conclusions*

To summarize, no studies have shown an association between greater levels of post-operative physical activity and sports participation with increased implant wear or failure up to 10 years following UKA. Furthermore, studies have not demonstrated a consistent association between greater post-operative levels of physical activity and implant failure up to 11 years post TKA. However, there were few large, high-quality prospective cohort studies with long-term (>10 years) follow-up. As a result, it is unclear whether post-operative physical activity level and sports participation are detrimental to long-term implant survivorship following UKA and TKA.

Funding

Mr. Teoli was supported by a Doctoral Training Bursary from the Fonds de recherche du Québec – Santé (302814). This funding source had no role in the study design, data collection and analysis, decision to publish, or preparation of the manuscript. The remaining authors did not receive any funds, grants, or other financial support for the submitted work.

Authors' contributions

AT: study conception, methodology, development of search strategy and execution of searches, study screening and selection, data charting, data synthesis, risk of bias assessment, writing (original draft, review and editing). **PI**: study screening and selection, data charting, writing (review and editing). **AB**: methodology, writing (review and editing). **JA**: methodology, writing (review and editing), supervision. **SMR**: study conception, methodology, development of search strategy, writing (review and editing), supervision.

Availability of data and materials

All data generated or analysed during this study are included in this published article and its supplementary information files.

Declaration of competing interest

Mr. Teoli provides paid continuing education courses and webinars on knee osteoarthritis best practice for rehabilitation professionals. Dr. Antoniou participates on a Data Safety Monitoring Board or Advisory Board for the Canadian Orthopaedic Association and the Orthopaedic Research Society, has a leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid (Trepso Therapeutics), and has patents planned, issued or pending: PCT/CA2014/000656: "Methods and Compositions for Treatment of Cartilage and Disc Disorders". All remaining authors have no financial or non-financial competing interests to disclose.

Acknowledgements

The authors would like to thank Jill Boruff, liaison librarian to the School of Physical and Occupational Therapy at McGill University, for her guidance on the development of the search strategies used in this scoping review.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ocarto.2024.100498.

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