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Review article

VO_2 max before and after hip and knee replacement surgery for osteoarthritis patients: a narrative review

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ABSTRACT

Purpose: This narrative review investigates cardiovascular fitness in patients undergoing hip and knee replacement for osteoarthritis (OA), with a focus on changes in VO_2 max before and after surgery. VO_2 max is a key physiological marker of aerobic capacity that is associated with post-operative outcomes and long-term health. For nurses involved in orthopaedic care, understanding how VO_2 max is affected by surgery and rehabilitation can inform patient education, discharge planning, and postoperative recovery strategies.

Principal results: Patients scheduled for total knee or hip replacement commonly present with low preoperative VO_2 max compared to matched healthy controls. While some studies hypothesise that this is due to reduced physical activity, direct measurement of activity levels or multivariate adjustment was generally lacking. Postoperatively, structured rehabilitation programmes may lead to improvements in VO_2 max, although findings vary based on the type, intensity, and duration of the intervention. Low-frequency or home-based exercise showed small improvements, while more intensive programmes, such as high-intensity interval training, had greater effects. However, many studies excluded patients with common comorbidities, limiting generalisability.

Major conclusions: Hip and knee replacement surgery may provide a critical window for improving cardiovascular fitness, especially when accompanied by targeted rehabilitation. These findings have important implications for nursing practice. Nurses can play a pivotal role in promoting structured aerobic exercise, supporting use of wearable technologies, and ensuring recovery pathways address cardiorespiratory health alongside joint mobility. Further research is needed to determine optimal rehabilitation strategies, improve inclusivity in VO_2 assessment, and evaluate long-term outcomes in diverse patient populations.

1. Introduction

Osteoarthritis (OA) is a prevalent condition leading to significant joint pain and disability, often necessitating hip or knee replacement surgery. Activity levels for many patients after hip and knee replacement can be disappointingly low despite successful surgery (Arnold et al., 2016; Hammett et al., 2018; Harding et al., 2014). This is significant, given the high societal cost of surgery (Kjellberg and Kehlet, 2016) and the knowledge that increased physical activity in older age is beneficial for a wide range of medical, psychological, and societal reasons. A recent meta-analyses of systematic reviews found that cardiorespiratory fitness has the largest risk reduction for all-cause mortality, incident heart failure, and cardiovascular mortality among those living with cardiovascular disease when comparing high versus low cardiovascular fitness (Justin et al., 2024). Fifty-two percent of total knee replacements (TKR) and 34% of total hip replacements (THR) had at least one of the studied risk factors associated with postoperative cardiac events (Chokshi et al., 2024). These findings underscore the need to better understand the role of physical fitness, particularly cardiovascular capacity, in optimising recovery and long-term outcomes following THR and TKR.

Among the most used indicators of cardiovascular fitness is VO_2 max, a metric that may help predict recovery trajectories after surgery. VO_2 max, is a measure of the maximum rate of oxygen consumption measured during incremental exercise, and it may be useful in predicting post-operative outcomes (Moran et al., 2016). It is an important indicator of cardiovascular and overall physical fitness (Ashfaq et al., 2022; Buttar et al., 2022) and a low VO_2 max is associated with a higher risk of perioperative death, postoperative cardiopulmonary complications (Kallianos et al., 2014), and postoperative ventilation time (Chaudhry et al., 2021), and so may lead to a longer recovery time after

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surgery. Given these associations, VO_2 max may serve as a valuable benchmark for identifying patients at higher risk of adverse surgical outcomes.

However, in many clinical populations, including those undergoing THR and TKR, VO_2 max can be difficult to achieve, and so VO_2 peak is often used as a practical alternative. VO_2 peak, which is affected by body weight and muscle mass and so often normalised by muscle or fat-free mass (Mahmoud et al., 2022), refers to the highest observed value during an exercise test, and is used when a true plateau in oxygen uptake is not reached. This is common in clinical populations such as patients before and after THR and TKR. Alongside VO_2 max and VO_2 peak, measures such as lactate or anaerobic threshold offer additional insight into a patient's functional endurance. These thresholds, which indicate the point at which exercise becomes more anaerobic, often improve before VO_2 max or peak values and can be particularly useful in tracking early cardiovascular gains during recovery following THR and TKR. Therefore, in addition to VO_2 max and peak, other physiological markers such as the lactate threshold can provide early indicators of functional improvement after surgery.

Accurately measuring VO_2 max, however, presents significant challenges in elderly and mobility-impaired populations, particularly those with advanced osteoarthritis of the hip or knee. VO_2 max is usually measured in a lab-based setting, with measurements being collected whilst the individual performs maximal, graded exercise (Pillsbury et al., 2013). Whilst this method is considered to be the gold standard of measuring cardiovascular fitness levels, these tests can be unachievable for an elderly population with end stage knee or hip osteoarthritis and in a lot of pain (Poole and Jones, 2017), limiting the clinical utility of the test and making clinical research difficult in this area. However, newer methods of estimating VO_2 max, such as seismocardiography have been developed, which measure VO_2 max in a resting supine position, therefore making it more accessible to the elderly and those in pain. Although this method is still relatively new, research has shown that this device has good results in comparison to the gold standard, and could be used for testing on a wider range of the population (Sørensen et al., 2020). Such technological advancements offer new possibilities for assessing cardiovascular health in patients previously excluded from traditional testing, opening the door to broader clinical applications.

In this narrative review, we aim to summarise the current evidence on VO_2 max and VO_2 peak in patients undergoing THR and TKR, and discuss the evidence for exercise-based rehabilitation programmes in enhancing postoperative aerobic capacity and supporting recovery.

2. Methods

A web-based literature search was conducted in August 2025, using the EBSCO host platform. The databases searched within EBSCO included CINAHL (The Cumulative Index to Nursing and Allied Health Literature) Ultimate, and Medline Complete. An additional search was carried out using PubMed.

A search strategy (Box 1) was created to find articles that investigated VO_2 max levels before or after hip or knee replacement surgery and any post-surgery intervention related to exercise. The databases were searched using the article's title and abstract up to August 2025. Studies were included if they were (1) assessing VO_2 max or peak levels and (2) involving patients who had undergone, or were due to undergo, hip or knee replacement. Studies were excluded if (1) the study did not focus on the study population; (2) VO_2 max or peak were not measured; (3) any intervention studied was not related to exercise; (4) the article was not a study or review; (5) the article was not available in the English language; or (6) there was no access to the full text.

2.1. Data extraction and outcome measures

Two investigators (CB, TI) independently screened citations, extracted data and assessed methodological quality using a standardized data extraction sheet. Any disagreement was resolved through consultation. Full papers for all relevant studies were evaluated. The outcome measures were pre-operative VO_2 max or peak, post-operative VO_2 max or peak, and changes in VO_2 max or peak measurement, before or after total hip or knee replacement, and/or before and after a post-surgery exercise intervention. A modified version of the Downs and Black checklist was used to qualitatively appraise the methodological quality of the studies in this review (Downs and Black, 1998) and can be found in Supplementary Materials, Section 1.

2.2. Reporting

PRISMA guidance (Page et al., 2021) was used to transparently report the search and study selection process (Fig. 1); however, a full systematic review approach was not undertaken due to heterogeneity in study design and outcomes. A narrative approach was adopted to allow critical appraisal and synthesis of findings from both randomised and observational studies, with the aim of contextualising within current clinical challenges and emerging measurement technologies.

3. Results

From 221 initial records, 65 duplicates were removed. Of the remaining 156, 79 were excluded by title, and two could not be retrieved. After abstract screening of 75 records, 61 were excluded for predefined reasons, resulting in 14 studies included. The flow diagram (Fig. 1) outlines this process (Page et al., 2021). Table 1 presents the 14 articles that were included in this review, comprised of six randomised controlled trials (RCT) (Husby et al., 2009, 2010; Morishima et al., 2014; Patterson et al., 1995; Pötzelsberger et al., 2015; Roxburgh et al., 2024), and 8 observational trials (Casazza et al., 2020; Kornuijt et al., 2024; Philbin et al., 1995; Ries et al., 1995, 1996, 1997; Roxburgh et al., 2021; Tordi et al., 2010). The five RCTs (split into 6 papers) examined interventions (1 pre-surgery, 3 post-surgery, and 1 looking at changes between pre- and post-surgery) and included high-intensity interval training (HIIT), interval walking training (IWT), home-based exercise programmes, and skiing. Using the Downs and Black quality assessment checklist (see Supplementary Materials, Section 1), only one of these

Box 1
Search strategy.

VO2 max OR VO2-max OR maxim* oxygen consumption OR maxim* oxygen uptake OR peak oxygen consumption OR peak oxygen uptake OR maxim* aerobic capacity OR peak aerobic capacity.

AND

hip replacement* OR knee replacement* OR hip arthroplasty OR knee arthroplasty OR TKR OR TKA OR THR OR THA OR joint replacement* OR joint arthroplasty.

* Indicates truncation; TKR – total knee replacement; TKA – total knee arthroplasty; THR – total hip replacement; THA – total hip arthroplasty.

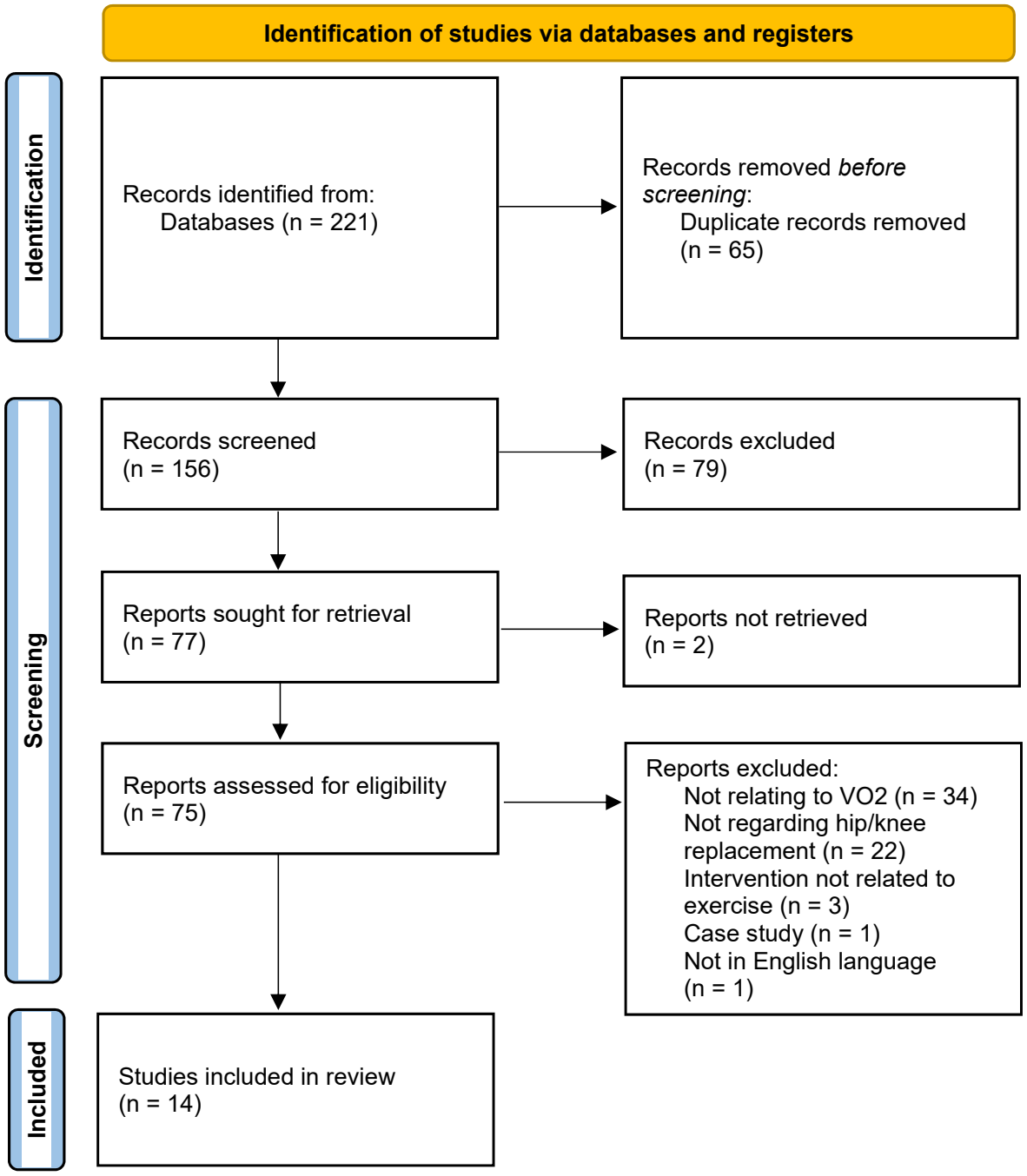

Fig. 1. The PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) flow diagram outlines the screening process for this review.

studies was rated as 100% (Morishima et al., 2014).

3.1. Sample characteristics

There was a total of 458 participants included in the 14 studies that investigated VO_2 max and peak levels in patients having hip or knee replacement surgery. The two Husby et al. papers are using the same group of participants, so these individuals have only been counted once (Husby et al., 2009, 2010). The group of papers published by Ries and Philbin have been reported separately, as it is not clear whether the same patients have been used (Philbin et al., 1995; Ries et al., 1995, 1996).

Patient characteristics can be seen in Table 2. The search strategy did not restrict studies by surgical indication; however, all included studies recruited patients undergoing arthroplasty for osteoarthritis. The average age across all studies ranged between 55 and 74, with seven of the studies having age as an inclusion criterion. Patterson et al. (1995) and Pötzelsberger et al. (2015) focused on patients between the ages of 60 and 80, whilst both Husby et al. (2009, 2010) studies only recruited patients below 70. Ries et al. had much wider parameters and excluded patients below 45 (Ries et al., 1997) in one study, and under 50 in two others (Ries et al., 1995, 1996), unlike the other seven studies that did not have age requirements (Casazza et al., 2020; Kornuijt et al., 2024; Morishima et al., 2014; Philbin et al., 1995; Roxburgh et al., 2021, 2024; Tordi et al., 2010). Whilst one study did not report on gender (Casazza et al., 2020), two studies focused exclusively on females (Morishima et al., 2014; Patterson et al., 1995), and aside from two (Pötzelsberger et al., 2015; Tordi et al., 2010), the remaining nine studies had a higher amount of female participants compared to male (Husby et al., 2009,

Table 1
Summary of studies.

Study	Study Design	Number Recruited	Participants	Method	Results
Submaximal cardiopulmonary exercise testing to assess preoperative aerobic capacity in patients with knee osteoarthritis scheduled for total knee arthroplasty: a feasibility study. (Kornuijt et al., 2024)	Observational	$n = 14$	Pre-TKR	3–6 weeks before surgery, participants performed submaximal CPET, as well as questionnaires.	The median VO_2 at the VAT was 12.8 mL/kg/min.
Cardiovascular fitness and health in patients with end-stage osteoarthritis. (Philbin et al., 1995)	Observational (Controlled cohort)	Hip OA $n = 19$ Hip Control $n = 19$ Knee OA $n = 19$ Knee Control $n = 19$	Pre-TKR or -THR	Participants underwent a CPET using arm or leg ergometry to evaluate cardiovascular fitness.	OA patients demonstrated reduced peak oxygen consumption compared to control group.
Relationship between severity of gonarthrosis and cardiovascular fitness. (Ries et al., 1995)	Observational (Controlled cohort)	TKR $n = 16$ Medically treated $n = 17$ Healthy control $n = 14$	Pre-TKR	Participants performed cardiopulmonary exercise testing to investigate the relationship between osteoarthritis and cardiovascular fitness.	Inactivity due to severe arthritis symptoms can result in lower VO_2 scores.
Cardiopulmonary exercise testing in severe osteoarthritis: a crossover comparison of four exercise modalities. (Roxburgh et al., 2021)	Observational (Crossover of testing)	$n = 15$	Pre-TKR or-THR	Comparing four exercise modalities – treadmill, elliptical cross-trainer, cycle and arm ergometer. The order that participants completed them were assigned randomly.	Mean VO_2 was 20–30% greater on the lower limb modalities (e.g., cycle ergometer and elliptical cross-trainer) than on the arm ergometer.
Upper-limb high-intensity interval training or passive heat therapy to optimize cardiorespiratory fitness prior to total hip or knee arthroplasty: a randomized controlled trial. (Roxburgh et al., 2024)	RCT	Heat $n = 30$ HIIT $n = 30$ Home $n = 33$	Pre-THR or -TKR	Heat therapy group underwent 3 hot-water immersion and light-resistance exercise sessions per week. HIIT group underwent supervised exercise on arm-ergometer or cross-trainer. Home group performed a home-based exercise programme.	16% increase in peak VO2 within HIIT group and increased to a greater extent than the Heat and Home groups.
Total knee arthroplasty: fitness, heart disease risk, and quality of life. (Casazza et al., 2020)	Observational (Control cohort)	TKR $n = 7$ Control $n = 7$	Pre- and post-TKR	Cardiovascular fitness, CHD risk factors, and quality of life measured and compared between patients who had TKR and 7 matched controls.	No significant changes in peak VO_2 in either group.
Early maximal strength training is an efficient treatment for patients operated with total hip arthroplasty. (Husby et al., 2009)	RCT	Maximal strength training $n = 12$ Conventional rehabilitation $n = 12$	Pre- and post-THR	Maximal strength group performed training 5 times a week for 4 weeks in addition to conventional rehabilitation. Conventional rehabilitation group received supervised physical therapy for 4 weeks, 3–5 times per week.	VO_2 max increased significantly in both groups but no significant differences in VO_2 max between groups.
Improvement in cardiovascular fitness after total knee arthroplasty. (Ries et al., 1996)	Observational (Controlled cohort)	TKR $n = 19$ Control $n = 16$	Pre- and post-TKR	Participants performed an exercise test to measure cardiovascular fitness, to determine the effect of TKR compared to being treated medically.	As postoperative time increased, TKR patients experienced significant increases in maximum oxygen consumption, compared to the control group.
Effect of total hip arthroplasty on cardiovascular fitness. (Ries et al., 1997)	Observational (Controlled cohort)	THR $n = 30$ Control $n = 18$	Pre- and post-THR	Fitness assessed on graded maximal exercise bike at baseline, 6 months, 1 year and 2 years.	THR group showed significant improvements in peak oxygen consumption, although not significant when adjusted by body weight. Arthritis group had no improvements in cardiovascular fitness.
Evaluation of cardiorespiratory functional reserve from arm exercise in the elderly. (Tordi et al., 2010)	Observational	$n = 17$	Pre- and post-THR	Maximal incremental exercise tests using an arm crank ergometer performed 1 month before, and 2 months after surgery.	There were no significant differences between VO_2 peak at the two timepoints.
Early postoperative maximal strength training improves work efficiency 6–12 months after osteoarthritis-induced total hip arthroplasty in patients younger than 60 years. (Husby et al., 2010)	RCT	Maximal strength training $n = 12$ Conventional rehabilitation $n = 12$	6–12 months post-THR	Maximal strength group performed training 5 times a week for 4 weeks in addition to conventional rehabilitation. Conventional rehabilitation group received supervised physical therapy for 4 weeks, 3–5 times per week. Followed up at 6 and 12 months after THR.	Work efficiency was significantly higher in the strength training group compared to conventional rehabilitation at 6- and 12-months post-surgery, which led to reduced VO_2 readings due to lower energy and oxygen consumption.
Effects of home-based interval walking training on thigh muscle strength and aerobic capacity in female total hip arthroplasty patients: a randomized, controlled pilot study. (Morishima et al., 2014)	RCT pilot	Interval walking training (IWT) $n = 14$ Control $n = 14$	More than 2 months post-THR	IWT group completed 60 min of fast walking at >70% VO_2 peak per week for 12 weeks. Control remained as normal.	IWT group VO_2 peak and VO_2 anaerobic threshold increased by 8% ($p = 0.08$) and 13% ($p = 0.002$) respectively. IWT VO_2 improvements were significantly higher than control group.

(*continued on next page*)

Table 1 (*continued*)

Study	Study Design	Number Recruited	Participants	Method	Results
The effect of minimal exercise in elderly women after hip surgery. (Patterson et al., 1995)	RCT	Exercise $n = 13$ Control $n = 7$	At least 6 months post-THR	Exercise group participated in a twice a week exercise programme for 3 months.	Exercise group had increase in VO_2 peak when compared to baseline but did not statistically differ from control.
Alpine Skiing With total knee ArthroPlasty (ASWAP): effects on strength and cardiorespiratory fitness. (Pötzelsberger et al., 2015)	RCT	Skiing intervention $n = 13$ Control $n = 14$	Post TKR (not recent)	Skiing group performed guided ski training over 12 weeks. Control continued normal activities.	No differences in VO_2 peak found for skiing or control group, although muscle strength increased in operated leg for skiing group.

TKR – total knee replacement; CPET – cardiopulmonary exercise test; VAT – ventilatory anaerobic threshold; OA – osteoarthritis; THR – total hip replacement; RCT – randomised controlled trial; HIIT – high intensity interval training.
TKR – total knee replacement; CHD – coronary heart disease; RCT – randomised controlled trial; THR – total hip replacement.
RCT – randomised controlled trial; THR – total hip replacement; IWT – interval walking training; ASWAP – Alpine Skiing With total knee ArthroPlasty; TKR – total knee replacement.

2010; Kornuijt et al., 2024; Philbin et al., 1995; Ries et al., 1995, 1996, 1997; Roxburgh et al., 2021, 2024).

Four of the studies did not describe body mass index (BMI) data (Patterson et al., 1995; Philbin et al., 1995; Ries et al., 1995; Tordi et al., 2010). Of the remaining 10, only one study used participants that, on average, had a BMI within healthy parameters (Morishima et al., 2014). The average BMI for the other study participants ranged from 27 up to 34. Every study had exclusion criteria, but some had a more extensive list. Many of the studies had overlapping criteria, with eight studies stating an exclusion criteria relating to cardiovascular issues (Casazza et al., 2020; Husby et al., 2009, 2010; Morishima et al., 2014; Patterson et al., 1995; Roxburgh et al., 2021, 2024; Tordi et al., 2010). Ten studies also included physical restrictions, such as being unable to walk without assistive devices (Morishima et al., 2014), potential struggles with the exercise testing itself (Kornuijt et al., 2024; Philbin et al., 1995; Roxburgh et al., 2021, 2024; Tordi et al., 2010), contraindications to exercise testing (Kornuijt et al., 2024; Philbin et al., 1995; Roxburgh et al., 2021, 2024) and diseases that may influence physical testing (Husby et al., 2009, 2010).

3.2. Studies evaluating preoperative VO_2 max

Prior to hip or knee replacement surgery, patients with OA typically exhibited reduced physical activity levels due to pain and functional limitations, leading to diminished cardiovascular fitness and VO_2 max. Philbin et al. (1995) used cardiopulmonary exercise testing (CPET) to evaluate cardiovascular fitness of 37 patients waiting for a TKR or THR. OA patients demonstrated reduced mean peak oxygen consumption (hips 14.9 ml/kg/min (SD 4.2), knees 12.8 ml/kg/min (SD 3.7)) when compared to healthy control groups which had been matched for age and sex (hips 19.0 ml/kg/min (SD 4.6), knees 17.6 ml/kg/min (SD 5.2)). Similarly, Ries et al. (1995) aimed to test the relationship between osteoarthritis and cardiovascular fitness, and found that 16 patients about to have TKR had lower mean VO_2 max scores (13.9 ccO2/Kg/min (SD 3.3)) than 17 patients with less severe OA (16.2 ccO2/Kg/min (SD 4.1)) and 14 healthy patients (21.5 ccO2/Kg/min (SD 3.9)).

Kornuijt et al. (2024) conducted a feasibility study using submaximal cardiopulmonary exercise testing (CPET) in 14 patients scheduled for TKR. All participants were able to complete the test, although many found it physically demanding, with reports of dizziness, fatigue, and pain during the following week. No adverse events occurred. The study reported a median ventilatory anaerobic threshold (VAT) of 12.8 mL/kg/min (IQR 11.3–13.6), indicating that patients transitioned to anaerobic metabolism at relatively low levels of exertion, consistent with reduced endurance capacity. Additionally, the median oxygen uptake efficiency slope (OUES), adjusted for body weight, was 23.1 (IQR 20.2–28.9), reflecting reduced efficiency in the body's ability to utilise oxygen during graded exercise. These findings support the utility of submaximal CPET in capturing meaningful cardiorespiratory limitations in patients awaiting joint replacement, even when maximal exertion cannot be reached.

Roxburgh et al. (2021) compared CPET across different modalities in patients with severe OA scheduled for replacement. The findings revealed that lower limb modalities such as treadmill and elliptical cross-trainer elicited higher peak oxygen consumption and anaerobic threshold values compared to arm ergometry. This underscores the importance of involving the lower limbs in postoperative rehabilitation to maximize VO_2 max improvements. Further research by Roxburgh et al. (2024) compared 3 groups of patients; one group experienced hot water immersion and light-resistance exercise; one group had high-intensity interval training; and one group completed home-based exercise. A 16% increase was found in peak VO_2 within the HIIT group, whilst increases in the two other groups were much less.

3.3. Studies evaluating changes in VO_2 max following surgery

Several of the studies examining change following surgery indicated improvements in aerobic capacity. Ries et al. (1996) found that participants who had TKR experienced a significant increase in maximum oxygen consumption as postoperative time increased (mean maximum oxygen consumption by body weight changed to 16.4 ml/kg/min (SD 5.4) two years after surgery from 13.9 ml/kg/min (SD 4.0) pre-surgery) when compared to the control group with OA of the knee (non-significant change to 17.3 ml/kg/min (SD 3.6) from 16.3 ml/kg/min (SD 3.2)). Similarly, in a further study comparing patients who had undergone THR to a control group with hip OA, Ries et al. (1997) reported significant improvements in absolute peak oxygen consumption (mL/min) in the surgical group (mean 1351 mL/min (SD 352) 24 months post-surgery compared to 1179 mL/min (SD 395) pre-surgery). However, when adjusted for body weight (mL/kg/min), the change was not statistically significant. This distinction suggests that some of the observed improvement may reflect weight changes or increased overall workload capacity rather than a proportional gain in relative aerobic efficiency. However, Tordi et al. (2010) found no significant changes between VO_2 peak 1 month before, and 2 months after surgery for 17 THR patients were tested. Similarly, Casazza et al. (2020) found no significant changes in peak VO_2 for both patients who underwent TKR ($n = 7$) and their matched controls ($n = 7$) who did not undergo surgery.

Husby et al. (2009) compared maximal strength training ($n = 12$) with conventional rehabilitation ($n = 12$) post total hip replacement. Although both groups individually demonstrated improvements in VO_2 max readings, there were no significant differences in VO_2 max between the two groups, despite the intervention group training 5 times extra per week on top of the conventional rehabilitation.

3.4. Studies evaluating postoperative VO_2 max

Studies of VO_2 max and peak a few months following surgery were

Table 2
Participant data.

Study	Number of participants recruited	% Female	Average age	Average BMI	Particular exclusion criteria
Kornuijt et al. (2024)	14	64.3%	Median – 73.5	Male – 33.0, Female – 30.3	Contraindications for CPET, unable to get on/off cycle ergometer, serious comorbidities (e.g. malignancy and stroke), cognitive impairment, unable to sign ICF, unable to understand Dutch, CPET planned less than 3 weeks or more than 6 weeks before TKR.
Philbin et al. (1995)	Hip Int - 19 Hip Con – 19 Knee Int – 19 Knee Con – 19	% female, average age and average BMI for Philbin study below are based only on participants that completed final follow-up assessments.			No principal diagnosis of primary or secondary OA, contraindication for cardiopulmonary exercise testing, and patients undergoing revision arthroplasties.
		Hip Int – 68.4% Hip Con – 68.4% Knee Int – 72.2% Knee Con – 72.2%	Hip Int – 68.1 Hip Con – 68.5 Knee Int – 68.4 Knee Con – 68.2	N/A	
Ries et al. (1995)	TKR – 16 Medical – 17 Healthy – 14	TKR – 68.8% Medical – 64.7% Healthy – 50%	TKR – 69.6 Medical – 67.8 Healthy – 70.4	N/A	Undergoing a revision procedure, diagnosed with inflammatory arthritis, mentally impaired, unable to sign ICF, under 50.
Roxburgh et al. (2021)	15	66.7%	68	31.4	Contraindication to non-physician supervised maximal exercise testing. Contraindications – moderate to severe aortic and/or mitral stenosis; hypertrophic cardiomyopathy; history of malignant or exertional arrythmias and/or syncope; intracardiac shunt; genetic channelopathies; New York Heart Association class 3 heart failure; severe left ventricular dysfunction and/or severe pulmonary arterial hypertension; cardiovascular event within 3 months (e.g. angina, myocardial infarction); implantable cardioverter defibrillator and/or pacemaker; pathology limiting upper-limb exercise (e.g. shoulder joint osteoarthritis); and any other medical condition deemed a significant risk to study participation.
Roxburgh et al. (2024)	Heat – 30 HIIT – 30 Home - 33	% female, average age and average BMI for Roxburgh study below are based only on participants that completed final follow-up assessments.			A contra-indication to non-physician-supervised maximal exercise testing, stable or unstable angina, myocardial infarction within the last 3 months, an implantable cardioverter defibrillator and/or pacemaker, revision arthroplasty, staged bilateral total joint replacement, pathology limiting upper-limb exercise (i.e., shoulder-joint OA), any other medical condition deemed by the study anaesthetist or cardiologist as a significant risk to study participation, no radiographic evidence of severe osteoarthritis and inability to travel to the study centre to complete all sessions.
		Heat – 52% HIIT – 48% Home – 58%	Heat – 66 HIIT – 71 Home - 67	Heat – 31.6 HIIT – 32.2 Home – 32.0	
Casazza et al. (2020)	Int – 7 Con – 7	N/A	Int – 55.6 Con – 59.3	Int – 33.4 Con – 34.3	No known systemic disease such as heart or lung disease, patients undergoing revision surgery, abnormal (except for their musculoskeletal problems) physical examinations, lung function or ECG.
Husby et al. (2009)	Int – 12 Con - 12	Int – 58.3% Con – 66.7%	Int – 58 Con – 56	Int – 28.1 Con – 28.2	Over 70, primary OA NOT main cause of THR, ASA score of 2 or above, muscular or skeletal disease that might influence the training and physical testing performance, heart or lung diseases, and diabetes mellitus.
Ries et al. (1996)	Int - 19 Con - 16	% female, average age and average BMI for Ries study below are based only on participants that completed follow-up assessments at 1-year.			Patients having revision TKR or other operation, under 50 years old, non-symptomatic osteoarthritis of the knee.
		Int – 62.5% Con – 62.5%	Int – 67.6 Con – 66.4	Int – 30.8 Con – 30.1	
Tordi et al. (2010)	17	11.8%	74.03	N/A	Cardiovascular disease, cerebrovascular disease or upper limb musculoskeletal impairment, unable to complete a full exercise test safely.
Husby et al. (2010)	Int – 12 Con – 12	% female, average age and average BMI for Husby study below are based only on participants that completed final follow-up assessments.			Over 70, primary OA NOT main cause of THR, ASA score of 2 or above, muscular or skeletal disease that might influence the training and physical testing performance, heart or lung diseases, and diabetes mellitus.
		Int – 58.3% Con – 60.0%	Int – 59 Con – 57	Int – 28 Con – 27	
Morishima et al. (2014)	Int – 14 Con – 14	% female, average age and average BMI for Husby study below are based only on participants that completed final follow-up assessments.			Unable to walk independently without assistive devices, suffering from an acetabular and/or femoral prosthesis failure or other comorbidities or the presence of any cardiopulmonary, neurologic, or cognitive diseases.
		100%	Int – 60.3 Con – 59.9	Int – 23.0 Con – 24.7	
Patterson et al. (1995)	Int – 13 Con – 7	100%	Int – 70.8 Con – 71.0	N/A	Below 61 or above 80, THR within the last 6 months, evidence of significant respiratory or cardiac disease, using medication likely to affect cardiorespiratory or neuromuscular efficiency (such as beta-blockade).
Pötzelsberger et al. (2015)	Int – 13 Con – 14	Int – 30.8% Con – 42.9%	Int – 69.8 Con – 70.9	Int – 28.7 Con – 30.4	Bilateral TKR, under 60 or above 80, chronic diseases, metabolic and hormonal disorders, blood clotting disorder, regular intake of pain relief medication.

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Table 2 (*continued*)

Study	Number of participants recruited	% Female	Average age	Average BMI	Particular exclusion criteria
Ries et al. (1997)	Int – 30 Con – 18	Int – 63.3% Con – 61.1%	Int – 66 Con – 67	Int – 28.8 Con – 29.1	Inflammatory arthritis, revision of a previous replacement, under 45, non-symptomatic arthritis.

CPET-cardiopulmonary exercise test; ICF – informed consent form; TKR – total knee replacement; Int – intervention group; Con – control group; BMI – body mass index; N/A – not available; OA – osteoarthritis.
HIIT – high intensity interval training; BMI – body mass index; OA – osteoarthritis; Int – intervention group; Con – control group; ECG – electrocardiogram; THR – total hip replacement; ASA – American Society of Anaesthesiologists classification; TKR – total knee replacement; N/A – not available.
Int – intervention group; Con – control group; BMI – body mass index; OA – osteoarthritis; THR – total hip replacement; ASA – American Society of Anaesthesiologists classification; N/A – not available; TKR – total knee replacement.

found to have mixed outcomes and there was no consensus on the most effective type or amount of exercise. Morishima et al. (2014) found that interval walking training in female THR patients (n = 14) led to an 8% increase in VO_2peak and a 13% increase in anaerobic threshold, a significantly higher increase than for those in the control group (n = 14) who maintained their usual sedentary lifestyle. Patterson et al. (1995) reported small improvements in VO_2 peak and walking speed in elderly women who participated in a low-frequency exercise programme after THR (n = 13) (significant change from 19.3 ml/kg/min at baseline, to 21.9 ml/kg/min post-intervention), but no difference was found with the control group (n = 7), previous THR patients who continued their normal activities (21.5 ml/kg/min at baseline to 21.4 ml/kg/min post-intervention). Pötzelsberger et al. (2015) examined a 12-week skiing intervention in patients (intervention n = 13, control n = 14) who had had total knee replacement (TKR) and observed gains in muscle strength, but no significant changes in VO_2 peak for either the intervention or control groups.

An extension of Husby et al., 's 2009 study (Husby et al., 2010), evaluated the effects of early postoperative maximal strength training in total hip replacement patients under 60. While no significant between-group differences in VO_2 max were reported at 6 or 12 months, patients in the strength training group (n = 12) demonstrated significantly improved work efficiency (29% at 6 months and 30% at 12 months) and lower submaximal oxygen consumption compared to those receiving conventional rehabilitation alone (n = 12). This suggests that strength training may improve cardiovascular economy during submaximal activity, even in the absence of significant changes in VO_2 max.

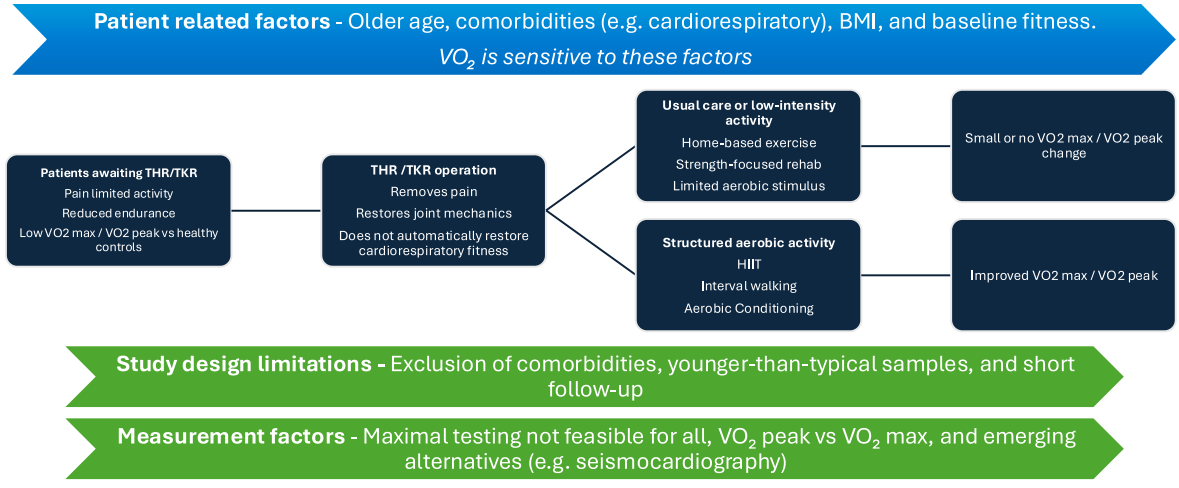
4. Discussion

Patients with osteoarthritis awaiting THR and TKR exhibit significantly lower preoperative VO_2 max levels compared to age-matched healthy controls. While some authors (Ries et al., 1995, 1997) suggest that this may reflect reduced physical activity related to pain and joint dysfunction, this hypothesis has not been tested using direct activity measurements or multivariate adjustment in the included studies.

Postoperatively, VO_2 max tends to improve, particularly when patients participate in structured exercise programmes (Husby et al., 2009; Morishima et al., 2014; Patterson et al., 1995). These improvements were observed even with low-frequency or home-based interventions, although the degree of benefit varied depending on the type, intensity, and timing of the exercise prescribed.

This suggests that aerobic-specific training may be necessary to elicit meaningful cardiorespiratory adaptations. Rehabilitation programmes should therefore include tailored aerobic components, rather than relying solely on general physical activity. Notably, activities such as recreational skiing demonstrated improvements in muscle strength without corresponding gains in aerobic capacity (Pötzelsberger et al., 2015), reinforcing the need to differentiate between strength and endurance outcomes when evaluating postoperative recovery.

These findings are summarised in Fig. 2, and align with broader concerns in orthopaedic care that physical activity often does not meet expected levels after THR and TKR, despite technically successful surgical outcomes (Arnold et al., 2016; Hammett et al., 2018; Harding et al., 2014). This highlights the importance for nursing staff and rehabilitation teams to monitor not just mobility but also cardiovascular recovery,



Schematic overview of changes in VO_2 max or VO_2 peak in patients undergoing THR and TKR for osteoarthritis. Patients commonly present with reduced preoperative cardiorespiratory fitness. Surgery alone does not consistently improve VO_2. Meaningful gains are more frequently observed when postoperative care includes structured aerobic rehabilitation. Observed outcomes are influenced by patient factors (age, comorbidities), study selection criteria, and measurement constraints, contributing to variability across studies.

Fig. 2. Conceptual overview of changes in VO_2 before and after hip and knee arthroplasty.

a factor often overlooked in traditional care pathways. The discrepancy between self-reported and objectively measured physical activity reinforces the need for standardised, quantifiable metrics such as VO_2 max to track recovery accurately (Luna et al., 2017).

However, although VO_2 max provides an objective marker of cardiorespiratory capacity, it does not fully capture the lived experience of recovery following THR and TKR. Symptoms such as fatigue, perceived exertion, activity limitation, and exercise intolerance are highly relevant to postoperative function and may influence engagement with rehabilitation. VO_2 based assessments should therefore be interpreted alongside functional and patient-reported outcomes to provide a more holistic understanding of recovery.

While VO_2 max remains the gold standard for assessing aerobic capacity, its measurement poses substantial practical challenges in older or functionally limited populations (Pillsbury et al., 2013; Poole and Jones, 2017). These individuals may struggle to perform the maximal effort required for conventional testing due to pain or limited mobility, which can compromise both the feasibility and reliability of assessments. Emerging technologies such as seismocardiography offer a promising alternative for VO_2 max estimation, enabling assessment in a broader patient population, including those unable to complete traditional lab-based tests. However, these methods require further validation in surgical populations before routine clinical adoption (Sørensen et al., 2020).

One of the strengths of this review is its focus on objective, physiological measures of cardiorespiratory fitness, which offer greater clinical relevance than subjective assessments alone. The inclusion of both randomised and observational studies provides a comprehensive overview of current evidence, and the quality of the included studies was generally moderate to high based on Downs and Black criteria (Downs and Black, 1998) (see Supplementary Materials).

Nevertheless, the review is limited by the small number of available studies, methodological heterogeneity, and narrow participant selection. Many studies excluded patients with common age-related comorbidities (e.g. cardiovascular or pulmonary conditions) despite these being highly prevalent in the THR and TKR patients. Given that VO_2 is sensitive to such conditions, this limits both the external validity of findings and their applicability to routine clinical care. Notably, older adults, who make up the majority of THR and TKR patients, were underrepresented in most studies, despite being the population most likely to benefit from cardiorespiratory fitness improvements. Additionally, many studies reported only short-term follow-up, limiting insights into the long-term trajectory of VO_2 max recovery and maintenance. Although the search strategy did not restrict inclusion by surgical indication, all eligible studies identified recruited patients undergoing THR and TKR for osteoarthritis. This reflects the current evidence base rather than an intentional limitation of scope. Given that osteoarthritis is the predominant indication for primary THR and TKR, the findings remain clinically relevant; however, VO_2 responses following THR and TKR for other indications (e.g. inflammatory arthritis or fracture) remain underexplored.

The findings of this review are broadly consistent with earlier meta-analyses which suggest that cardiorespiratory fitness may be a major predictor of morbidity and mortality across a range of patient groups (Justin et al., 2024). However, compared to reviews that focused on self-reported physical activity outcomes, this study highlights the need for objective fitness measurements to truly capture postoperative recovery.

5. Conclusion

This review highlights that THR and TKR surgeries may offer an opportunity to improve cardiovascular fitness, with evidence suggesting that VO_2 max can increase following surgery, particularly when structured exercise-based rehabilitation is implemented. Improvements in aerobic capacity have the potential to support not only physical recovery but also long-term health outcomes for patients with osteoarthritis. However, the current evidence base remains limited by small sample sizes, varied intervention protocols, and a lack of representation from older adults and individuals with comorbidities, who are often the primary recipients of these procedures.

As orthopaedic care evolves, there is a growing need to integrate cardiorespiratory fitness considerations into routine postoperative management. THR and TKR should not be viewed solely as procedures to restore joint function, but also as key touchpoints to enhance physical activity levels. Technologies such as seismocardiography (Sørensen et al., 2020) may enable the safe and accessible assessment of VO_2 max in clinical settings, thereby supporting more inclusive evaluation and follow-up strategies across diverse patient groups.

These findings have important implications for orthopaedic nursing. Nurses are central to post-surgical care and are often responsible for patient education, early mobilisation, and coordination of discharge planning. Understanding the role of VO_2 max and aerobic fitness in recovery can help nurses tailor advice, encourage participation in structured exercise, and identify patients who may require additional cardiovascular support. Moreover, nursing teams could play a key role in the integration of accessible VO_2 monitoring technologies, such as seismocardiography, into routine care. By doing so, they can help ensure that recovery pathways are inclusive, individualised, and effective across the full spectrum of patients undergoing joint replacement.

CRediT authorship contribution statement

Chloe Bascombe: Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Formal analysis. **Tikki Immins:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Robert G. Middleton:** Writing – review & editing, Supervision, Formal analysis. **Thomas W. Wainwright:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Conceptualization.

Ethics approval and consent to participate

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Declaration of competing interest

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List of abbreviations

ASA	American Society of Anaesthesiologists classification
ASWAP	Alpine Skiing With total knee ArthroPlasty
BMI	Body Mass Index
CHD	Coronary Heart Disease
CINAHL	Cumulative Index to Nursing and Allied Health Literature
Con	Control group.
CPET	Cardiopulmonary Exercise Testing
ECG	Electrocardiogram
HIIT	High-Intensity Interval Training

ICF	Informed Consent Form
Int	Intervention group.
IWT	Interval Walking Training
N/A	Not Available
OA	Osteoarthritis
RCT	Randomised Controlled Trial
THA	Total Hip Arthroplasty
THR	Total Hip Replacement
TKA	Total Knee Arthroplasty
TKR	Total Knee Replacement
UTD	Unable to Determine.
VAT	Ventilatory Anaerobic Threshold
VO_2 max	Maximum oxygen consumption
VO_2 peak	Highest observed value during an exercise test

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijotn.2026.101257.

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