OPTIMISING TREATMENT OF YOUNGER, ACTIVE KNEE OSTEOARTHRITIS PATIENTS

– surgical options and functional outcomes –

Alexander Hoorntje

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GENERAL INTRODUCTION

Nowadays, orthopaedic surgeons are facing a substantial challenge. More and more relatively young, active end-stage knee osteoarthritis (OA) patients experience severe functional limitations that merit surgical treatment. Knee arthroplasty (KA) is a well-established and successful treatment for end-stage knee osteoarthritis. Yet, in younger, active KA patients, there is a significant risk of revision as well as postoperative dissatisfaction. In part, this dissatisfaction is explained by the inability to return to patient relevant activities such as sport and work. Knee osteotomy and knee joint distraction, which are joint preserving surgical alternatives to KA, may allow for a return to more knee-demanding activities. However, data on these functional outcomes including return to sport and work is sparse, while such outcomes are often crucial to younger patients. The research presented in this thesis explores three areas regarding knee surgery in relatively young, active patients: current functional outcomes including return to sport and work after joint preserving knee OA surgery, prognostic factors associated with these functional outcomes, and strategies for optimisation of patient relevant functional outcomes, including satisfaction after KA.

Knee osteoarthritis, an imminent epidemic?

Globally, knee OA is a leading cause for disability due to pain and functional impairments[1,2]. The incidence of knee OA is on the rise, and by 2020 was projected to be among the top five leading causes of years lived with disability worldwide[2,3]. Causes for this significant rise include an ageing global population and the skyrocketing incidence of obesity[2,4]. Also, the rise in life-expectancy has prompted lawmakers to extend working years and delay pension ages[5]. Consequently, workers performing heavy knee-demanding jobs are incrementally exposed to the risk of developing knee OA[2,6,7]. Finally, increased and prolonged sports participation results in growing numbers of knee joint injuries, associated with knee OA later in life[2,8,9]. Thus, we should be aware of a growing wave of knee OA patients, including relatively young patients, experiencing severe pain and functional impairments that merit surgical intervention.

Knee arthroplasty, the gold standard for treating knee osteoarthritis

For decades, knee arthroplasty (KA) has been considered the gold standard for the treatment of end-stage knee OA[10]. Utilization of KA has been stimulated by widely reported satisfactory results regarding pain reduction and quality of life improvement[10–12]. Other contributors to greater utilization of KA were improved equity in access to health-care services and increased patient demand, possibly driven by lower patient acceptance of pain and higher mobility requirements[9,11,13]. Nowadays, one in ten American citizens over the age of 80 received a KA[13], while UK and New Zealand registries estimated that, at the age of 50, the lifetime risk of receiving a KA was 8–10%[11,14]. In the Netherlands, KA utilization was predicted to increase by 300% between 2005 and 2030, to a total of about 58,000 KAs annually[15]. Considering the aforementioned factors – the obesity epidemic, delayed pension age, intensified sports participation – it seems comprehendible that the largest increase in KA utilization is seen in active patients of working age.

Indeed, KA utilization data from the Organisation for Economic Co-operation and Development (OECD) countries between 2005 and 2011 showed a 63% growth rate in patients <65 years of age, more than double the rate of 28% in patients ≥65 years of age[16]. By 2030, 55% of primary total KAs in the US is estimated to be implanted in patients <65 years of age[17]. Yet, accumulating evidence is warning us that this global trend might be a cause for concern.

Concerns about high revision rates in younger knee arthroplasty patients
Consistently, registry studies have reported significantly higher revision rates in patients undergoing KA <60 years of age[18-20]. While the lifetime revision risk for a 65-year old KA patient is 7%[11], research found a 35% revision risk in male KA patients aged 50–54 years (Figure 1), with a median time to revision of 4.4 years[21]. Perhaps even more important are the lower satisfaction scores that have been reported after KA in younger patients[22,23]. Hence, performing KA in younger, active patients is not always appealing to surgeons, and as treatment not a sure long-term winner to patients. Despite these caveats, KA often remains an excellent solution for invalidating end-stage knee OA in relatively young patients who are insufficiently served by non-operative treatments. However, concerns regarding increased revision risk and lower patient satisfaction have also opened the way for a revival of joint preserving alternative surgical options[24].

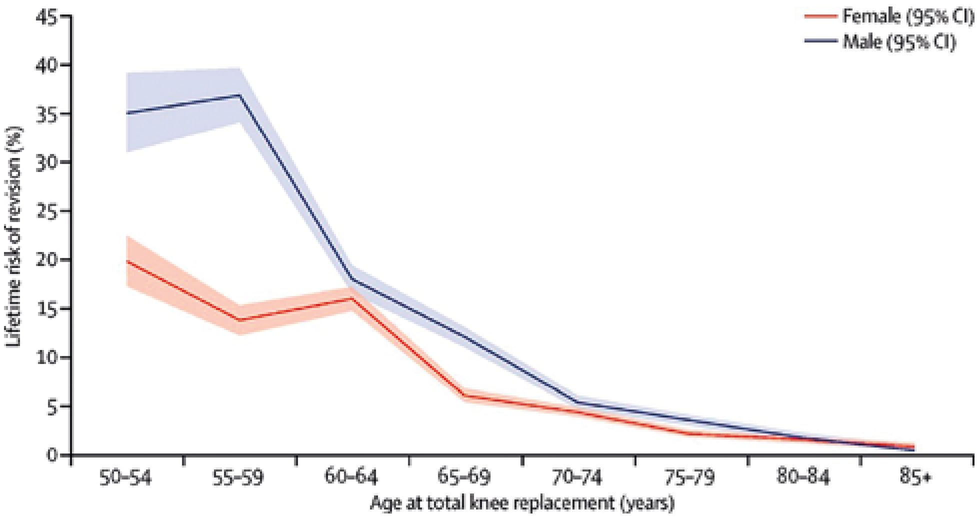

Fig. 1 Lifetime risk of revision after total knee replacement (plot showing estimates of lifetime risk of total knee replacement revision against age at the time of primary total knee replacement. [Reprinted by permission from the authors: Bayliss et al., The Lancet, 2017[21]]

Joint preserving surgical alternatives to knee arthroplasty

Knee osteotomy

For decades, knee osteotomy has been a well-established treatment for unicompartmental knee OA. With a knee osteotomy, the mechanical leg axis is realigned, and hereby the weight-bearing axis is transferred away from the affected compartment (Figure 2a, 2b)[25,26]. High tibial osteotomy (HTO) is commonly performed for medial compartment OA in the presence of a tibial deformity, while distal femoral osteotomy (DFO) is mostly used for lateral compartment OA in the presence of a femoral deformity[25,27]. With the rise of KA in the 1970s, use of knee osteotomy declined rapidly[28,29]. Osteotomies were considered more technically demanding than KA, and the outcomes and complications less predictable[25,30]. However, substantial advances have been made in patient selection, surgical technique, fixation methods and rehabilitation[25,31]. Accordingly, modern-day evidence consistently reports good and reproducible symptomatic improvement and good survival rates up to 10 years after knee osteotomy[28,30,32,33]. A shift back towards performing knee osteotomy rather than KA was already found in Japan and Korea[34,35], although this trend was not observed in Western registries[29,35,36].

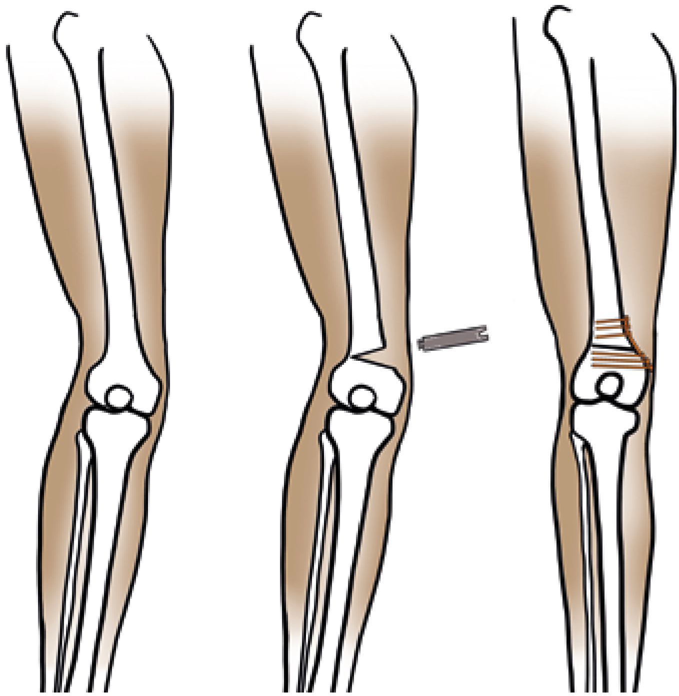

Fig. 2a Schematic representation of medial closing wedge distal femoral osteotomy (illustration by D. de Weerdt)

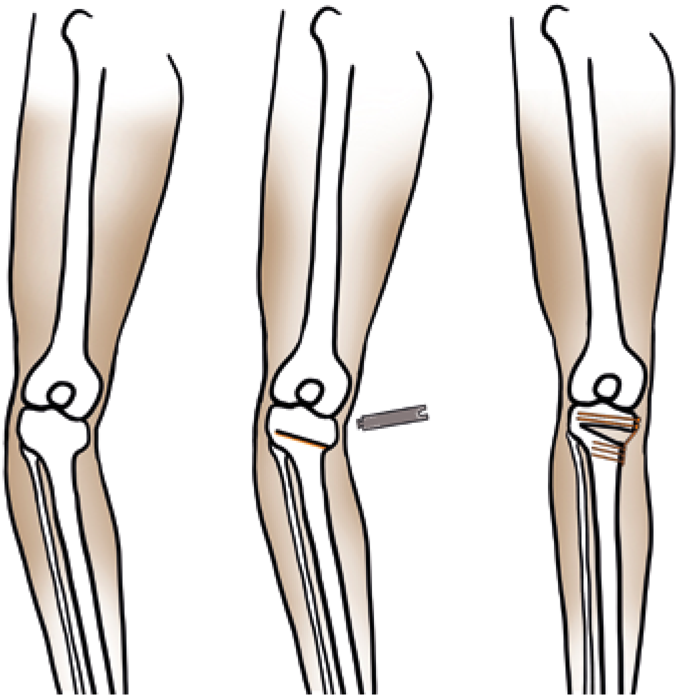

Fig. 2b Schematic representation of medial opening wedge high tibial osteotomy (illustration by D. de Weerdt)

Knee joint distraction

Knee joint distraction (KJD) is a less well-known but promising alternative joint preserving treatment option in younger OA patients. With KJD, an external fixation device is used to gradually separate the bony ends of the distal femur and proximal tibia, for a certain period of time, usually 6-8 weeks (Figure 3)[37]. Already, KJD treatment showed radiographic improvement of joint space width (JSW; Figure 4), and increased cartilage thickness on MRI, indicative of cartilage regeneration[38]. A preserved treatment effect up to five years has been described, with increased minimum JSW at five years posttreatment compared to pre-treatment[39]. In addition, a RCT comparing KJD with HTO, for patients with medial compartment OA who were eligible for HTO, reported similar improvements for both groups in patient-reported clinical outcomes including pain scores[40,41]. However, data on patient relevant functional outcomes such as resumption of sport and work activities are lacking.

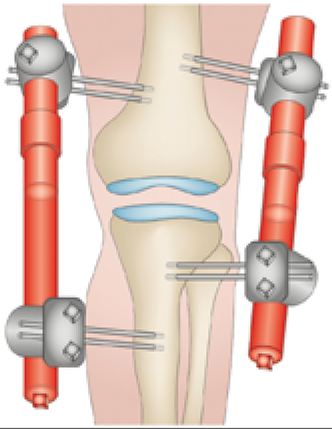

Fig. 3 Schematic representation of knee-joint distraction device. Half pins are drilled through soft tissue into the tibia and femur. Tubes connect both fixations medial and lateral and allow gradual distraction of the joint.
[Reprinted by permission from Springer Nature: Mastbergen et al., Nature Reviews Rheumatology, 2013[37]]

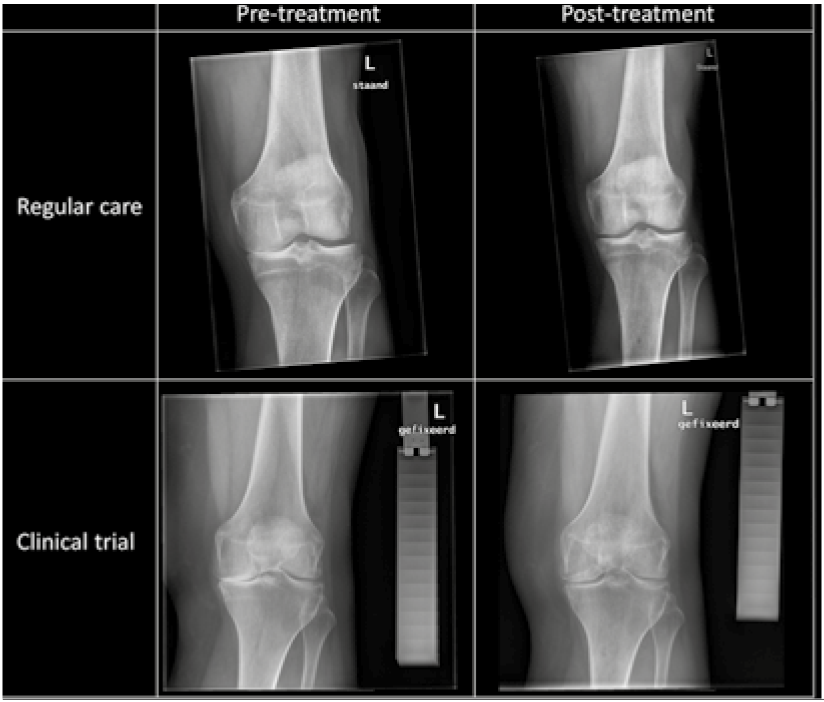

Fig. 4 Representative standing AP radiographs of patients treated with knee joint distraction pre-treatment and one year post-treatment. The aluminium step wedge is used to quantify joint space width. [Reprinted by permission of the authors: Jansen et al., PLoS ONE, 2020[42]]

Joint preservation, are we missing information?

The possibility to return to knee-demanding activities, including return to sport (RTS) and return to work (RTW), is especially important in the younger knee OA population[43,44]. After KA, a return to highly knee-demanding sport and work activities is possible though not very likely[45,46]. Since knee osteotomy and KJD are promoted for younger patients, they should arguably perform well in terms of RTS and RTW[47]. Also, maintaining the native knee joint theoretically results in more natural kinematic function and greater tolerance for high-impact activities. However, the extent of RTS and RTW after modern-day knee osteotomy is still largely unknown. And, although the possibility of undertaking knee-demanding activities, including recreational sports, after KJD has been hypothesized[40], actual rates of RTS and RTW have not been reported.

Improving patient satisfaction after knee arthroplasty in younger patients

When KA is indicated, younger patients and their surgeons may expect highly satisfying results based on regularly collected patient-reported outcome measures (PROMs). Yet, excellent outcomes, as expressed by PROMs such as the Oxford Knee Score and Knee Injury and Osteoarthritis Outcome Score, apparently do not reflect patient satisfaction in younger KA patients[23,48]. Up to 20% of KA patients remain dissatisfied[49,50], and as stated previously, the dissatisfaction risk is higher in relatively young patients[22,23]. Since the strongest predictor of patient satisfaction appears to be fulfilment of preoperative expectations[50–52], it stands to reason that setting realistic goals and supporting patients to attain their personal goals could lead to improved satisfaction. Therefore, methods to tailor KA rehabilitation towards a patient-centred approach sound promising.One possible instrument to tailor the rehabilitation to patients' personal goals is Goal Attainment Scaling (GAS)[53,54]. Originally, GAS was developed as a method to score the extent to which patients' individual goals are attained during an intervention[54,55]. In addition, GAS scores can also be used as a direct feedback instrument for patients during rehabilitation, by reliably monitoring their progress. Involving the patient in the formulation of their own rehabilitation goals increases the chances of actually attaining these clinically relevant goals[56–58]. Accordingly, this approach resulted in high patient satisfaction in varying rehabilitation settings, e.g. in children with motor delays and geriatric patients with multiple chronic conditions, including musculoskeletal diseases[55,59]. Despite these promising results, GAS has never been used to guide rehabilitation after KA.

Considering the societal perspective

Lastly, rates of return to work are of interest not only to patients, their families and physicians, but also to tax payers, health insurance companies and policymakers. Therefore, we too should consider the societal perspective, when considering available treatment options for knee OA in younger patients[60]. In addition to individual treatment costs, a treatment's potential to restore knee functioning, and thus the patient's future ability to contribute to society, may be taken into account[61]. For the US, a positive overall net economic impact was calculated for total KA in a 50-year old patient, compared to non-operative treatment[61]. This positive impact was almost fully attributable to improved work participation following KA, and the model favoured non-operative treatment over KA when the rate of RTW was <81%. The latest systematic review on RTW after KA reported rates between 59% and 98%, with a pooled estimate of 82%[62], which is just above this threshold. Knee osteotomy showed favourable cost-effectiveness compared to KA in terms of quality-adjusted life-years, although the net economic impact was not considered[60]. Obtaining a reliable estimate of RTW after knee osteotomy and KJD may serve future modelling of the societal impact of joint preserving alternatives to KA.

OUTLINE OF THIS THESIS

The main objective of this thesis is to facilitate the shared-decision making for the best surgical treatment strategy in relatively young and active knee OA patients, based on their individual expectations and activity goals. Our approach addresses three main topics: current functional outcomes of joint preserving alternatives to KA, prognostic factors for patient relevant outcomes after knee osteotomy and KA, and strategies to optimize outcomes and patient satisfaction in relatively young, active knee KA patients.

The first part of this thesis describes functional outcomes, such as return to sport and work, after DFO, HTO and KJD. The second part presents prognostic factors that are associated with functional outcomes, including physical activity and sport and work resumption, after KA and knee osteotomy. The third part evaluates whether patient relevant outcomes can be improved, with a special focus on the added value of the intervention of GAS on performance of activities and satisfaction, after unicompartmental and total KA in younger, active patients.

Part I – Current functional outcomes for sport and work of joint preserving surgery
A clear overview of the extent of return to sport and work following knee osteotomies was lacking. Therefore, **Chapter 1** provides a systematic overview of the rate and timing of return to sport and work after osteotomies around the knee, and of confounders that might influence the resumption of sport and work activities. While multiple studies have described sport and work resumption after HTO, such robust data was lacking for DFO. Therefore, **Chapter 2** presents patient-reported pre- and postoperative sport and work participation after DFO, including time to RTS and RTW. Given the significantly increased revision risk after KA in relatively young, active patients, joint preserving alternatives increasingly regain attention. In addition to knee osteotomy, KJD shows promising results and may prove useful in postponing the need for KA. **Chapter 3** reports a scoop, namely the first sport and work outcomes after KJD, in patients who were randomized to undergo either KJD or HTO.

Part II – Predicting patient relevant outcomes for sport and work

To improve patient education and enhance shared decision-making, we investigated prognostic factors that are possibly associated with patient relevant outcomes, including physical activity and participation in sport and work. Physical activity has proven beneficial effects on work participation and sick leave in healthy persons. Therefore, in **Chapter 4,** we present a study on the effect of preoperative physical activity on work resumption after total KA.

The identification of prognostic factors often requires large patient groups for sufficient statistical power. In **Chapter 5** and **Chapter 6,** we use a novel approach using a directed acyclic graph to develop an a priori model of assumed relationships between HTO and return to sport and work, respectively. Hereby, we can reduce the number of required variables in our regression models, thus increasing statistical power.

Part III – Optimising functional outcomes and patient satisfaction

Improvements in surgical pathways for KA led to rapid recovery protocols, which in turn resulted in higher patient satisfaction. **Chapter 7** reports the results of a case-control study investigating a same day discharge protocol for unicompartmental KA. Specifically, patient satisfaction and symptoms of anxiety and depression are analysed.

The most important factor for patient satisfaction after KA seems to be fulfilment of preoperative expectations. Therefore, our randomized-controlled ACTION trial focused on the attainment of patient relevant activity goals. Hypothetically, active, working patients with severe knee osteoarthritis would increase their physical activity levels after KA. The results of an activity monitor study in 120 patients are reported in **Chapter 8**, comparing pre- and postoperative physical activity levels in patients who underwent regular rehabilitation versus rehabilitation based on GAS.

To improve patient satisfaction in relatively young, working KA patients, we introduced GAS rehabilitation. In **Chapter 9**, patient satisfaction with the performance of activities is compared in a randomized-controlled trial between GAS rehabilitation and regular outpatient rehabilitation for working patients undergoing KA.

Finally, the results of our studies are connected and placed in a broader perspective in the general discussion. Here, we also present possible next steps and future opportunities in the treatment of knee osteoarthritis in younger, active patients.

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PART I

CURRENT FUNCTIONAL OUTCOMES FOR SPORT AND WORK OF JOINT PRESERVING SURGERY

CHAPTER 1

High Rates of Return to Sports Activities and Work After Osteotomies Around the Knee: A Systematic Review and Meta-Analysis

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ABSTRACT

Background Knee osteotomies are proven treatment options, especially in younger patients with unicompartmental knee osteoarthritis, for certain cases of chronic knee instability, or as concomitant treatment for meniscal repair or transplantation surgery. Presumably, these patients wish to stay active. Data on whether these patients return to sport (RTS) activities and return to work (RTW) are scarce.

Objectives Our aim was to systematically review (1) the extent to which patients can RTS and RTW after knee osteotomy and (2) the time to RTS and RTW.

Methods We systematically searched the MEDLINE and Embase databases. Two authors screened and extracted data, including patient demographics, surgical technique, pre- and postoperative sports and work activities, and confounding factors. Two authors assessed methodological quality. Data on pre- and postoperative participation in sports and work were pooled.

Results We included 26 studies, involving 1321 patients (69% male). Mean age varied between 27 and 62 years, and mean follow-up was 4.8 years. The overall risk of bias was low in seven studies, moderate in ten studies, and high in nine studies. RTS was reported in 18 studies and mean RTS was 85%. Reported RTS in studies with a low risk of bias was 82%. No studies reported time to RTS. RTW was reported in 14 studies; mean RTW was 85%. Reported RTW in studies with a low risk of bias was 80%. Time to RTW varied from 10 to 22 weeks. Lastly, only 15 studies adjusted for confounders.

Conclusion Eight out of ten patients returned to sport and work after knee osteotomy. No data were available on time to RTS. A trend toward performing lower-impact sports was observed. Time to RTW varied from 10 to 22 weeks, and almost all patients returned to the same or a higher workload.

Key Points

- Most patients return to sports activities after knee osteotomy, with a tendency to lower-impact sports, and most patients return to work at the same or an even higher workload.
- Systematic comparison of current literature is hampered by heterogeneity in patient populations, operative techniques, and the overall lack of accounting for possible confounding factors such as physical and mental comorbidities, preoperative sports level and work status, patient motivation, and surgeon's advice.
- Future prospective studies are needed to gain better insight into the reasons patients do not return to sport or work. These studies should correct for confounders and use the pre-symptomatic phase as a reference point when assessing return to sport and work.

INTRODUCTION

Osteotomies around the knee, such as high tibial osteotomy (HTO) and distal femoral osteotomy (DFO), are well-accepted procedures for the treatment of early-stage unicompartmental knee osteoarthritis (OA) due to varus- or valgus malalignment[1–3]. With the rise of knee arthroplasty (KA) surgery in the 1970s, use of these procedures declined rapidly, as osteotomies were considered more demanding than KA and the outcomes and complications less predictable[4,5]. However, KAs clearly also have their limitations, especially for younger patients in terms of the low percentage of patients returning to high-impact activities, and the possible higher risk of polyethylene wear if they do[6,7]. Thus, since patients with knee OA are becoming younger and wish to perform more demanding high activities[8,9], osteotomies around the knee have gained renewed attention. The current thought is that a knee osteotomy may postpone or even avoid KA and presumably allow patients to return to more demanding activities, since native joint structures are preserved.

In addition to the high demands of present-day patients, several other reasons exist for the renewed attention on and increased use of osteotomies around the knee. Outcomes from HTO and DFO have significantly improved with new operative techniques, improved fixation devices, updated evidence-based guidelines, and careful patient selection[4,10,11]. As a result, several studies have demonstrated distinct relief of pain and significant functional improvements after HTO and DFO[2,4,12]. Survival rates of 87–99% at 5 years and 66–84% at 10 years have been reported for HTO[13–15], and of 74–90% at 5 years and 64–82% at 10 years for DFO[16-20]. Given these good results, it is reasonable to first consider a knee osteotomy when indication criteria are suitable[4,21].

Indications for osteotomies have also been extended. In addition to the treatment of unicompartmental OA, osteotomies around the knee are increasingly performed as a concomitant treatment to correct alignment in ligament reconstruction, articular cartilage restoration procedures, and meniscal repair or transplantation surgery[22–26]. In these patients, who are mostly younger and more active, the function of the osteotomy is to (1) reduce strain on the reconstructed ligament graft or the posterolateral corner in cases of varus alignment or (2) unload the involved compartments and thereby reduce stress to the biological repair tissue and potentially prevent or postpone progression of early knee OA. Good results for these combined procedures in terms of functional outcome and survival have also been reported[23,26].

Thus, osteotomies around the knee are increasingly performed in younger patients and show good results in unicompartmental OA and in reconstructive knee surgery. Johnstone et al. suggested that, if osteotomies are being promoted for younger patients, it is important that they perform well in terms of return to sport (RTS) and return to work (RTW)[27]. However, studies that report on RTS and RTW after osteotomies around the knee are sparse, and a clear message is lacking in the literature. Consequently, the actual extent to which patients RTS and RTW is still largely unknown. Therefore, the purpose of the present study was to systematically summarize the available evidence on the extent to which patients RTS and RTW after osteotomies around the knee as well as timing of the return.

METHODS

Search Strategy

We used the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) guidelines for this systematic review[28]. Before commencing the literature search, a research protocol was developed and agreed upon by all authors. This protocol was published online at the PROSPERO International prospective register of systematic reviews (http://www.crd.york.ac.uk/PROSPERO/; registration number CRD42016029929). The clinical librarian (JD) developed the search strategy in close cooperation with the first author (AH). We used the World Health Organization International Clinical Trials Registry Platform (WHO-ICTRP) database to identify relevant search terms and to search for ongoing clinical trials on our subject. We searched the electronic databases MEDLINE via PubMed and Embase via OvidSP for relevant literature and the Cochrane database for systematic reviews. Searches were performed up until 21 September 2016. In all databases, the following four categories of keywords and related synonyms were used to build a sensitive search strategy and to provide a systematic search: osteotomy, sport, work, and recovery of function. Search terms were truncated using an asterisk (*) to find all terms beginning with a specific word. Within each keyword category, the different synonyms were combined using the Boolean command ''OR'' and categories were linked with the Boolean command ''AND''. The exact details of the search strategy can be found in the Electronic Supplementary Material (ESM) Appendix S1. The reference lists of selected studies were screened to identify additional studies for inclusion. We also performed a forward search using Web of Science to see which of these studies had been referred to by other authors after publication.

Eligibility Criteria and Study Selection

We used the Rayyan screening tool for systematic reviews to screen titles and abstracts[29]; all abstracts were screened by two independent reviewers (AH, PK). Discrepancies were resolved by discussion; where there was doubt, the article was included in the full-text screening process. One author (AH) then selected suitable studies based on the eligibility criteria established in the research protocol. This selection was then reviewed by a second author (SW), and discrepancies were resolved by discussion. Inclusion criteria were as follows: observational or intervention studies describing patients with malalignment who underwent any type of corrective knee osteotomy for any indication and who were participating in sport activities and/or working before the surgery and intended to RTS and/or RTW after surgery. No language restrictions were used. The primary outcomes were the percentage and number of patients to RTS and RTW, preferably described in terms of level, duration, and frequency. Secondary outcomes included activity-specific outcome measures, namely the Tegner activity score (0–10; higher is better), the Lysholm score (0–100; higher is better), the International Knee Documentation Committee (IKDC) objective score (0–100; higher is better), the University of California, Los Angeles (UCLA) activity score (0–10; higher is better), and the Naal activity score, which investigates pre- and postoperative engagement in 20 different sports activities. The Reichsausschuss für Arbeitszeitermittlung (REFA; German workload classification) Association classification system (from ''0 = work with no physical strain'' to ''4 = work with most heavy physical strain'') was also collected as a work-related outcome measure.

Methodological Quality

We assessed the risk of bias of the included studies using the Quality in Prognosis Studies (QUIPS) tool[30]. This quality-assessment tool includes six domains of potential bias: (1) study participation, (2) study attrition, (3) prognostic factor measurement, (4) outcome measurement, (5) study confounding, and (6) statistical analysis and reporting. Each domain contains two or more sub-domains that should be rated as "yes", "partial", "no", or "unsure". The answers to each sub-domain are then combined, leading to a "low", "moderate", or "high" risk of bias. The first author (AH) assessed the quality of all included studies; this was then repeated independently by two other authors (PK, KK), who each assessed the risk of bias for half of the included studies. Disagreements were resolved by discussion and, if necessary, involving a third reviewer. The details of the quality assessment can be found in the ESM Appendix S2. We considered a study to have an overall low risk of bias when the methodological risk of bias was rated as low or moderate in all six domains, with at least four domains rated as low. A study was rated as having an overall high risk of bias if two or more of the domains were scored as high. In-between quality was scored as moderate. Results of the studies with a low risk of bias are discussed in the text and those of the studies with a moderate or high risk of bias are presented in the data extraction table (Table 1).

Data Extraction

One author (AH) extracted data from all selected original studies, and this was independently repeated by one other author (SW). Disagreements were resolved by discussion. The authors used a standardized data extraction form that included the following: (1) study information: author, year, country, and reference number; (2) study design and follow-up; (3) information about study population: cohort, population size, sex, age, body mass index (BMI), comorbidities; (4) description of rehabilitation protocols used; (5) definition of outcome measures; (6) preoperative activity and definition (e.g. pre-symptomatic or at time of surgery); (7) postoperative activity; (8) RTS and RTW percentages and time to RTS and RTW; (9) confounding factors taken into account for RTS and RTW, such as age, sex, BMI, restricting comorbidities, complications, preoperative sports or work level, surgeon advice, or psychosocial factors. Authors were contacted if data were missing or only available in graphs. If this information was not provided, available data were read off the graphs.

Pooling Data

Data were pooled from the studies that described pre- and/or postoperative participation in specific types of sports and categorised into low, intermediate, or high-impact sports according to the levels of impact on the knee joint (ESM Appendix S3). This classification complies with Vail et al. and is supported by a biomechanical study from Kuster et al., which considered both peak loads and flexion angles of the knee[31,32]. We calculated pooled RTS percentages by comparing pooled pre- and postoperative sports participation data. In addition, we compared percentages for RTS to the preoperative level and the pre-symptomatic level. We also pooled RTW data for studies that provided pre- and postoperative work data.

RESULTS

Literature Search

Figure 1 presents the PRISMA flowchart for our search strategy. Our primary search retrieved 1176 potentially relevant citations. After deleting 387 duplicates, we applied our inclusion criteria to the titles and abstracts of 789 articles. Of the 789 screened articles, disagreement occurred in 45 cases (6%), which were all resolved by discussion. This selection yielded 87 potentially relevant full-text articles, which were then reviewed. For the full-text screening, disagreement occurred in four (5%) cases, which were resolved by discussion. We subsequently excluded 61 articles for various reasons (Fig. 1). Noyes et al. published two studies involving the same cohort, so we only included the study with the longest follow-up[33]. We performed reference screening and forward citation tracking on the remaining articles, which yielded one additional article[34]. Finally, 26 articles were included.

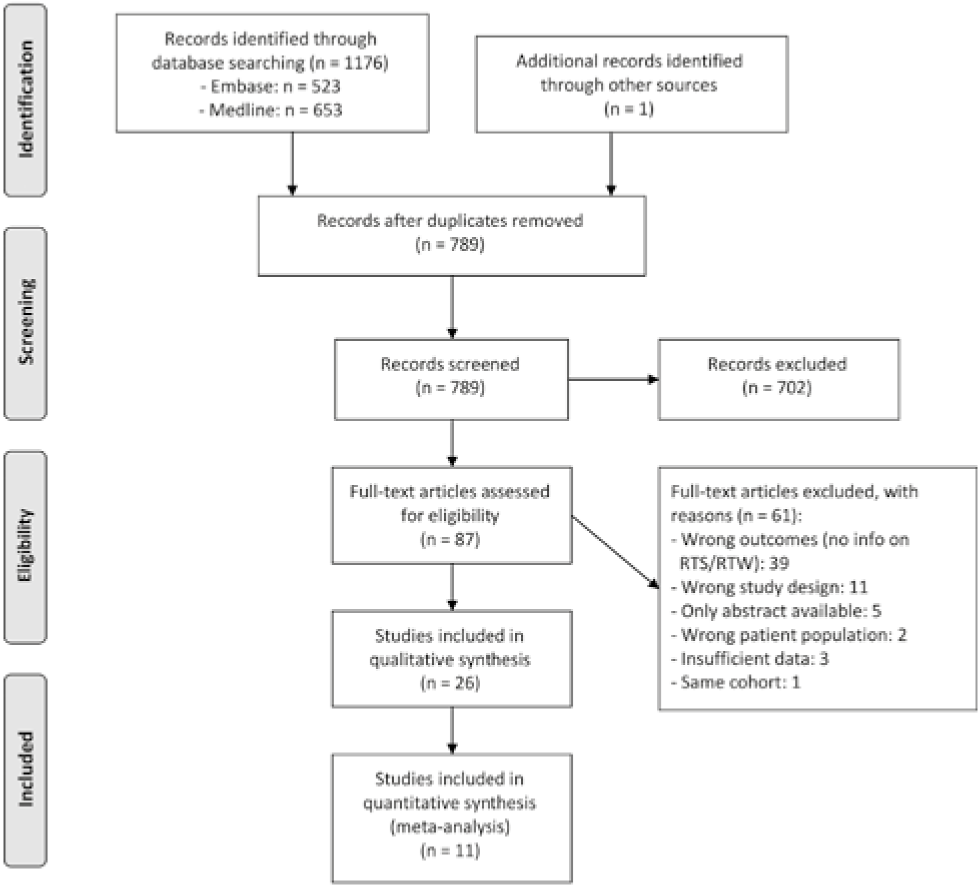

Fig. 1 PRISMA flow diagram

Study Characteristics

Demographic Data

Table 1 presents the results of the data extraction. Studies were published between 1983 and 2016, and all the included studies were observational, with four cross-sectional studies, five prospective cohort studies, 14 retrospective cohort studies, and three retrospective case series. One study was performed in Brazil, one in Finland, five in France, nine in Germany, one in Greece, one in Italy, one in South Korea, one in Sweden, one in Switzerland, and five in the USA. The majority of studies were written in English (n = 24), one was in French, and one was in Italian. The total number of included patients was 1321 (range 6–181), sex was specified in 24 studies (1251 patients; 857 (69%) male). Mean age ranged from 27 to 62 years (range 14–80). The mean duration of follow-up was 4.8 years (range 1.8–11.0). Patients' BMI was specified in 12 studies, with mean BMI varying from 21 to 30 kg/m2. Three of 26 studies included information on comorbidities.

Surgical Technique

Nine studies included only medial opening-wedge (MOW) HTO, four only lateral closing-wedge (LCW) HTO, six both MOW HTO and LCW HTO, one MOW HTO and MOW HTO + LCW DFO[35], one both MOW HTO and lateral opening-wedge (LOW) DFO[36], one both LCW and medial closing-wedge (MCW)[37], and one LOW DFO[38]. One study reported the use of LCW HTO and a 'Mittelmeier' HTO, which was not further specified[39], one study performed MOW HTO with external fixation (hemicallotasis technique)[40], and one study only mentioned the use of both varising and valgising HTO, but the type was not further specified[41]. For fixation, 20 studies used plate fixation, with six studies using the TomoFix plate, two studies using the Peak-carbon plate, one study using the Puddu plate, and 11 studies using other types of plates (for more details, see Table 1). Seven studies used staples, two studies used external fixators, two studies used plaster casts, and three studies did not describe their fixation method. Concomitant surgery was performed in eight studies, with anterior cruciate ligament (ACL) reconstruction performed in five studies, autologous chondrocyte implantation performed in two studies, and meniscal allograft transplantations performed in one study (Table 1).

Methodological Quality

Overall, 7 of 26 studies scored a low risk of bias, ten studies scored a moderate risk of bias, and nine studies scored a high risk of bias. The lowest risk of bias was found for the prognostic factor domain, describing the type of osteotomy performed and any additional surgery, for which no study scored a high risk of bias. The highest risk of bias was found for the confounding factors (e.g. patient-related factors, surgeons' advice, rehabilitation), with 17 studies scoring a high risk and only four studies scoring a low risk of bias. Table 2 summarizes the methodological assessment for the risk of bias.

Table 2 Methodological assessment according to six domains of potential bias (QUIPS)

Study (n = 26)	Study participation	Study attrition	Prognostic factor	Outcome	Confounding factors	Analysis	Overall risk of bias[a]
Ampollini et al.[52]	Moderate	Low	Low	Moderate	High	Moderate	Moderate
Bode et al.[25]	Low	Low	Low	Low	High	Low	Moderate
Bonnin et al.[49]	Moderate	High	Moderate	Low	High	Low	High
Boss et al.[51]	Moderate	Low	Low	High	High	Low	High
Boussaton et al.[41]	Moderate	Low	Moderate	High	High	Moderate	High
Cotic et al.[53]	Low	Low	Low	Low	Moderate	Low	Low
Dahl et al.[40]	Low	Low	Low	Low	Moderate	Low	Low
De Carvalho et al.[38]	Low	Moderate	Low	Moderate	High	Low	Moderate
Dejour et al.[54]	Moderate	High	Low	Low	High	High	High
Faschingbauer et al.[44]	Low	Moderate	Low	Low	Moderate	Low	Low
Gomoll et al.[36]	Low	Low	Low	Low	High	High	High
Hoell et al.[34]	Moderate	Moderate	Low	Low	High	High	High
Isolauri et al.[37]	High	High	Moderate	High	High	High	High
Korovessis et al.[39]	Low	Moderate	Moderate	Moderate	High	Low	Moderate
Lerat et al.[55]	High	High	Moderate	Moderate	High	Low	High
Minzlaff et al.[47]	Low	Low	Low	Moderate	Low	Low	Low
Nagel et al.[50]	High	High	Low	Low	Moderate	Moderate	High
Niemeyer et al.[46]	Low	Low	Low	Low	High	Low	Moderate
Noyes et al.[33]	Moderate	Low	Low	Moderate	High	Low	Moderate
Saier et al.[45]	Low	Moderate	Low	Low	Low	Low	Low
Salzmann et al.[48]	Moderate	Moderate	Low	Moderate	High	Moderate	Moderate
Saragaglia et al.[35]	High	Moderate	Low	Moderate	Low	Low	Moderate
Schröter et al.[43]	Low	Moderate	Low	Low	High	Low	Moderate
Waterman et al.[42]	Low	Low	Moderate	Low	Low	Moderate	Low
Williams et al.[56]	Moderate	Moderate	Low	Moderate	High	Moderate	Moderate
Yim et al.[57]	Low	Low	Low	Moderate	Moderate	Low	Low

QUIPS Quality in Prognosis Studies

[a] We considered a study to be of low risk of bias when the methodological risk of bias was rated as low or moderate on all of the six domains, with at least four rated as low. A study was scored as high risk of bias if two or more of the domains were scored as high.

Return to Sport

In total, 19 of 26 studies reported the percentage of patients returning to different types of sport activities. Mean RTS percentages varied from 48 to >100%, with >100% indicating that more patients participated in sports activities postoperatively than preoperatively. A definition of pre-operative sports participation was provided in 16 of 26 studies. Seven studies describing the preoperative sports level as the moment prior to surgery (pre-surgery level) found RTS varied from 66 to >100%. Nine studies describing the preoperative sports level as the moment before the onset of knee symptoms (pre-symptomatic level) found that 68–100% could return to this level. Of the studies with low risk of bias, five provided RTS percentages: 63% (at 10 years), 78, 92, 100 and >100% (more patients participated in sports postoperatively than preoperatively). None of the included studies reported on the timing of RTS.

Data could be pooled for 16 studies that reported exact numbers of patients participating in sports pre- and/or postoperatively. Overall, RTS was 94%, but this depended on how the preoperative sports level was defined (Table 3). Seven studies used the pre-surgery level and found an average RTS of >100%. Nine studies used the pre-symptomatic level and found an average RTS of 85%. For the studies scoring a low risk of bias, three studies used the pre-surgery level and found an average RTS of 89%. Two studies used the pre-symptomatic level and found an average RTS of 78%. In total, 11 studies reported specific numbers of sports that were practiced pre- and postoperatively (Table 4). Preoperatively, 453 patients practiced an average of 1.9 sports, including 47% low-impact sports, 35% intermediate-impact sports and 18% high-impact sports. Postoperatively, 592 patients practiced an average of 1.9 sports, including 58% low-impact sports, 32% intermediate-impact sports and 10% high-impact sports. Five of 11 pooled studies were rated as having a low risk of bias. In these studies, 204 patients practiced an average of 1.9 sports preoperatively, including 55% low-impact sports, 32% intermediate-impact sports and 12% high-impact sports. Postoperatively, 204 patients practiced an average of 1.9 sports, including 56% low-impact sports, 35% intermediate-impact sports and 9% high-impact sports.

Table 3 Pooled data for numbers of patients participating in any sport pre- and postoperatively

Preoperative reference for RTS	No. of pts participating in any sport preoperatively	No. of pts participating in any sport postoperatively	RTS (%)
Overall (16 studies)	463	434	94
Pre-surgery status as reference for RTS (7 studies)	150	167	111
Pre-symptomatic status as reference for RTS (9 studies)	313	267	85
Low risk of bias studies (5 studies)	181	149	82

pts patients *RTS* return to sport

Table 4 Pooled data for pre- and postoperative sports participation for different types of sports impact

Impact	Sports participation preoperatively (n = 10 studies)			Sports participation postoperatively (n = 11 studies)		
	Sports (n)	Patients (n)	Average sports/ patient n (%)	Sports (n)	Patients (n)	Average sports/ patient n (%)
Low (e.g. cycling, swimming, golfing)	413	453	0.91 (47)	658	592	1.11 (58)
Intermediate (e.g. hiking, downhill skiing)	303	453	0.67 (35)	369	592	0.62 (32)
High (e.g. tennis, running, ball sports)	159	453	0.35 (18)	109	592	0.18 (10)
Total	875	453	1.93	1136	592	1.92

Return to Work

In total, 11 of 26 studies reported on the possibility of RTW after HTO (Table 1). Mean RTW varied from 41 to >100%, with >100% indicating that more patients were working postoperatively than preoperatively. For the studies with a low risk of bias, RTW rates were 72, 84, 93 and 94%. One study investigated a military population with a very high workload and found that 72% could RTW[42]. Another study investigated an agricultural population with a high workload and found that 86% could RTW[39]. Four studies reported on the timing of RTW, which varied from 9.7 to 22.1 weeks. One additional study reported that 89% of a homogeneous group of agricultural workers had returned to work after 8–12 months, but did not specify the exact timing[39]. Two studies found timing of RTW was significantly dependent on the workload, which was assessed using the REFA workload classification[25,43]. Duration of inability to work varied from 6 and 10 weeks for REFA grade 0 (lowest workload) to 17 and 22 weeks for REFA 4 (heaviest physical strain) ($p < 0.05$). In line with these findings, Faschingbauer et al. found that workers with the highest workload returned after 19.1 weeks and those with the lowest workload returned after 11.8 weeks, although this difference was not statistically significant[44]. In terms of working capacity at follow-up, 72–100% of patients returned to the same or a higher workload. Finally, one study investigating RTW after DFO found that 89% of patients could RTW[38]. The duration of inability to work was not mentioned.

Data could be pooled for seven studies, including two with a low risk of bias, which reported exact numbers of patients working pre- and postoperatively. Overall, 85% of patients could RTW (Table 5). In studies with a low risk of bias, 80% could RTW. Six studies described the duration of inability to work. On average, patients were unable to work for 16 weeks (Table 5). Two studies with a low risk of bias reported that patients were unable to work for an average of 19 weeks. This included the study by Saier et al., who found that, overall, patients were unable to work for 21 weeks[45]. Separate analysis showed that patients with a concomitant mental disorder could RTW after an average of 36 weeks compared with 16 weeks in the mentally healthy group.

Table 5 Pooled data for RTW and average duration of incapacity for work

Study (n = 7)	Number of working patients			Time to RTW		
	Preoperative (*n*)	Postoperative (*n*)	RTW (%)	Study (n = 6)	Patients (*n*)	Inability to work (weeks)
Dahl et al.[40]	43	38	88	Bode et al.[25]	40	13.5
De Carvalho et al.[38]	26	23	88	Faschingbauer et al.[44]	40	16.7
Faschingbauer et al.[44]	43	40	93	Hoell[a] (ow) et al.[34]	40	13.9
Korovessis et al.[39]	63	54	86	Hoell[a] (cw) et al.[34]	51	13.6
Noyes et al.[33]	23	34	148	Lerat et al.[55]	49	20
Saier et al.[45]	50	45	90	Saier et al.[45]	64	20.8
Waterman et al.[42]	181	130	72	Schröter et al.[43]	32	12.4
Total	429	364	85	Total	276	16.3

RTW return to work, *OW* opening-wedge, *CW* closing-wedge, *HTO* high tibial osteotomy
[a] Hoell et al. reported separate duration of inability to work after opening-wedge HTO and closing-wedge HTO.

Secondary Outcome Measures of Physical Activity

The Tegner score, Lysholm score, UCLA score and IKDC score were described as secondary outcome measures for physical activity. IKDC scores (0–100) were used in three studies. Gomoll et al. and Niemeyer et al. described median preoperative scores of 26 and 40 and median postoperative scores of 63 and 70, respectively[36,46]. Boussaton and Potel described a median postoperative IKDC score of 94 (range 86–99)[41]. The Lysholm score was described in 12 studies, with median preoperative scores ranging from 5 to 63 and median postoperative scores ranging from 63 to 91. The Tegner score was described in 11 studies, with median preoperative scores ranging from 3.1 to 6.5 and median postoperative scores ranging from 2.5 to 5.9. The UCLA score was described in one study, with a median preoperative score of 7.1 and postoperative score of 6.6[35].

Confounders

We scored whether studies mentioned possible confounders and whether analyses were adjusted for these confounders. Possible confounders that could influence RTS and/or RTW were mentioned in 25 of 26 studies, but only 15 studies adjusted for one or more confounders in the analysis. Age was mentioned as a possible confounder in 11 studies, and three studies adjusted for it. Minzlaff et al. found that younger patients reached a higher frequency of postoperative sports[47]. In contrast, Salzmann et al. and Saragaglia et al. found age had no influence on RTS[35,48]. BMI was mentioned as a possible confounder in four studies. Two studies adjusted for BMI but found no influence on RTS. Four studies mentioned sex as a confounder, and three studies adjusted for it, but found no effect on RTS. Three studies mentioned comorbidities as a possible confounder. Salzmann et al. adjusted for comorbidities using the American Society of Anesthesiologists classification, but found no correlation with RTS[48]. Saragaglia et al. specifically mentioned reasons for patients who could not RTS[35]. Of 12 patients, four had medical contraindications, three had severe intractability, and five indicated that the knee was solely responsible for the inability to RTS. Four studies mentioned concomitant procedures as a possible confounder. Salzmann et al. found no effect of concomitant procedures on RTS[48], whereas Waterman et al. found that concomitant procedures increased the risk of failure[42]. The influence of patient motivation was mentioned in four studies. Bonnin et al. found motivation to be strongly correlated to RTS[49], whereas Saragaglia et al. found no correlation[35]. The preoperative sports level was mentioned as a confounder in six studies. Nagel et al. found preoperative sports level to be the most predictive factor for RTS[50], whereas Saragaglia et al. found no correlation[35]. The influence of the surgeons' advice on RTS was mentioned in nine studies. Most surgeons in these studies advised their patients that RTS was not the goal of surgery and tried to moderate their patients' sporting ambitions. Faschingbauer et al. and Noyes et al. discouraged participation in high-impact activities such as soccer and tennis[33,44]. The rehabilitation protocol was mentioned in 19 of 26 studies, but the description was often very brief, only including information about the first phase of rehabilitation, concerning range of motion (ROM) and weight-bearing advice. Five studies described their RTS advice in detail. Three studies advised a return to activities of daily life and low-impact sports after 3 months and a return to more demanding activities and contact sports after 6–12 months[36,45,51]. Two studies allowed full RTS, including contact sports, after radiologically confirmed healing of the osteotomy[38,47]. Finally, three studies adjusted for the effect of workload on RTW: two of these found that higher workloads resulted in longer inability to work[25,43], but one study found no significant difference in RTW between high and low workloads[44]. Only one study compared RTW for different types of HTO; it found no significant difference in time to RTW between open- and closed-wedge HTO[34].

DISCUSSION

Our systematic review showed that a large percentage of patients were able to RTS activities and RTW after osteotomies around the knee. Concerning sports activities, 66 to >100%, with >100% indicating more patients participated in sports postoperatively than preoperatively, of patients could RTS. An overall trend was observed towards participation in lower-impact activities after surgery. The diversity in RTS percentages was mostly caused by the different definitions used for the preoperative reference point for sports participation. Remarkably, none of the included studies reported on the timing of RTS. Concerning RTW, 41 to >100% of patients could RTW and 72–100% of patients could return to the same or a higher workload. The duration of inability to work varied from 10 to 22 weeks.

Return to Sport

The meta-analysis showed that overall, 94% of patients could RTS, and 85% returned to their pre-symptomatic sports level after knee osteotomies. In a recent review on RTS and RTW after HTO, Ekhtiari et al. found that 87% could RTS[58]. However, the authors did not take into account the definition of preoperative sports participation, and our review showed that different definitions resulted in considerable variance in RTS percentages. Moreover, Ekhtiari et al.[58] only evaluated results of RTS and RTW after HTO, described in ten studies, including 250 patients, whereas we reviewed results after any osteotomy around the knee and found 16 studies, including 463 patients. Lastly, the indication for HTO was knee OA in almost all studies in their review. We observed that osteotomies around the knee are also increasingly performed for other indications, such as in addition to ligament reconstruction or articular cartilage restoration procedures. Such patients are often younger and thus more likely to wish to return to more demanding activities. For these patients in particular, it is imperative to know whether it is possible to RTS and RTW. In a review of RTS after KA, Witjes et al. found that 36–89% could RTS after total KA (TKA), and 74 to >100% could RTS following unicondylar KA (UKA)[6]. Postoperatively, patients undergoing TKA were engaged in an average of 1.0 sports, including 87% low-impact sports, 9% intermediate-impact sports, and 4% high-impact sports. Patients undergoing UKA were engaged in an average of 1.5 sports, including 77% low-impact sports, 19% intermediate-impact sports, and 4% high-impact sports. The present study demonstrates that patients participated in an average of 1.9 sports postoperatively, including 58% low-impact sports, 32% intermediate-impact sports, and 10% high-impact sports. Thus, on average, patients undergoing knee osteotomies returned to more sports than did patients undergoing KA. A shift to participation in lower-impact sports activities was observed in all three groups, but high-impact sports were performed more often after knee osteotomy than after KA. Thus, the possibility of returning to high-impact sports appears most likely after knee osteotomies and is also possible, though less likely, after UKA. In contrast, participation in high-impact sports after TKA is most unlikely. However, these findings could, at least in part, be explained by the generally younger age and less severe grades of knee OA in patients undergoing knee osteotomy compared with those undergoing KA.

Factors Influencing Return to Sport

The existing evidence on factors that influence RTS after knee osteotomy is ambiguous. Nagel et al. found that the most predictive factor for RTS after HTO was the patient's preoperative sporting level[50]. Patient motivation appears to be another important factor. Mancuso et al. found that only 30% of patients undergoing TKA expressed motivation to RTS, whereas Saragaglia et al. found that 71% of patients undergoing HTO were motivated to RTS, but that neither the motivation nor the pre-existent sport level was related to greater RTS[35,59]. In contrast, Bonnin et al. found a correlation between patient motivation and activity level, with motivated patients being more active postoperatively[49]. These contrasting findings may be explained by the nature of the practiced sports. Despite high motivation, a return to high-impact sports is more difficult than a return to low-impact sports. Comorbidities that could possibly hinder patients in their RTS were only described in 3 of 26 studies. One study found that 12 of 83 patients could not RTS because of comorbidities, and knee symptoms were solely responsible for the inability to RTS in five patients[35]. Thus, we cannot rule out that specific medical conditions unrelated to the knee surgery had a negative influence on the number of patients that could RTS and RTW in other studies. Our results confirm that, when assessing RTS, it is very important to use a clear definition of the preoperative sports level (e.g. preoperative, pre-symptomatic), as previously stated by Witjes et al.[6]. Remarkably, only 18 studies reported their definition, and only nine studies used the pre-symptomatic sports level to calculate RTS percentages. A return to pre-surgery sports level was possible in >100%, whereas a return to the pre-symptomatic level was possible in only 85%. We believe that the pre-symptomatic level is most relevant for young, active patients, since it is conceivable that this patient population in particular expects to return to the activities they performed before the onset of knee symptoms.

Finally, evidence on the return to professional or competitive levels of sports after knee osteotomies is sparse. A French study by Boussaton and Potel followed six professional rugby players who all successfully returned to play, with follow-up varying from 1 to 10 years[41]. Faschingbauer et al. included four competitive-level athletes: two football players, one rugby player, and one squash player[44]. Only one athlete, the rugby player, could return to competitive sport. In the study by Williams et al., two patients participated in (unspecified) competitive sports preoperatively, whereas four patients were participating in competitive sports at a mean follow-up of 3.8 years[56]. Lerat et al. found that two of ten patients could return to competitive boxing and tennis, respectively[55]. We found one other review describing two cases of National Football League players who successfully returned to play after HTO[26]. Still, the authors highlighted that, even in elite athletes, the goal of HTO is not resumption of competition but rather to allow daily and recreational-level activities. This consideration is in line with the surgeons' advice that was described in nine of the studies included in this review. However, even without taking into account the effect of possibly discouraging advice from surgeons, our results show that a reasonable number of patients are able to successfully return to high-impact sports activities. Therefore, we believe that a return to competitive sports should not be ruled out in advance. As indicated, native knee structures are spared in knee osteotomies, without any risk of wear to a prosthesis. Thus, when full consolidation of the osteotomy is achieved, a return to competitive sports may be attempted. However, this also depends on the original indication for the osteotomy. Expectations of RTS may need to be tempered based on the indication.

Return to Work

This review is the first to systematically assess the possibility of RTW after all types of knee osteotomies. We found that 364 of 429 (85%) patients could RTW and that the mean duration of their inability to work was 16.3 weeks. This is in line with the aforementioned review by Ekhtiari et al., who found 310 of 367 (85%) patients could RTW[58]. Based on existing studies, we cannot draw definite conclusions on the possibility of returning to the same or higher workloads. However, our findings do indicate that a RTW with high workloads (e.g. military service, work with heavy physical strain) is less likely than a RTW with low workloads.

Factors Influencing Return to Work

Our study is the first to describe factors influencing RTW after knee osteotomies. Such factors have been described before in patients undergoing KA and included a job with high physical demands on the knee, preoperative sick leave, and patient movement restrictions[60-62]. It seems reasonable that patients with physically demanding jobs need more time to RTW. Of the three studies we included that adjusted for workload, two found that higher workloads resulted in significantly longer inability to work[25,43], but one study did not find this association[44]. Unfortunately, data on preoperative sick leave were not available for any of the included studies. Thus, more studies with larger patient groups are needed to clarify the relationship between these factors and RTW after knee osteotomy. Finally, the influence of movement restrictions could be partly compared between studies using the weight-bearing advice, which may influence the possibility of RTW. Immediate weight-bearing can allow for an earlier return to activities, including work. Recently, Lansdaal et al. showed that immediate full weight-bearing compared with delayed full weight-bearing (2 months) after HTO with TomoFix plate fixation was safe and did not compromise functional outcome[63]. The use of angle-stable fixation plates, such as the TomoFix plate, offers superior initial stability compared with other plates, and immediate weight-bearing is possible with this type of plate fixation[64]. Of six studies reporting on time to RTW, three used the TomoFix plate, one used the Association for the Study of Internal Fixation (AO) L-plate, one used the Puddu plate and/or staples, and one used an unspecified plate and/or staples. Only Saier et al. and Faschingbauer et al. reported the use of an early weight-bearing protocol after 2 weeks, and both studies used the TomoFix plate for fixation[44,45]. Interestingly, the average time to RTW in the study by Saier et al. was the longest of all included studies (21 weeks)[45], whereas Faschingbauer et al. reported an average of 17 weeks[44]. The other studies reported 6–8 weeks of partial weight-bearing and found an inability to work of 12–20 weeks. Based on this evidence, we therefore cannot confirm or reject the hypothesis that using plates that allow early weight-bearing results in earlier RTW. Saier et al. attributed their findings of a late RTW to the presence of mental disorder in the included patients, because separate analysis showed that patients with mental disorder took considerably longer to RTW than mentally healthy patients (36 vs. 16 weeks, respectively, on average)[45]. This emphasizes the importance of recognizing another important confounder, namely mental disorders, a known risk factor for worse outcome after knee surgery[65].

Strengths and Limitations

One strength of the present systematic review is that we included all osteotomies around the knee and studies of all indications for osteotomies. Waterman et al. observed that concomitant chondral restoration, meniscal and ligamentous procedures were performed in nearly half of 181 HTOs in a young military population[42]. We believe that the use of osteotomies as an adjunct to reconstructive knee procedures in young, highly active patients will continue to increase. Therefore, it is important to be able to counsel these patients on the possibility of resuming high-demand activities, thus, we also included studies concerning these other osteotomy indications. A limitation common to any systematic review is the risk of overlooking papers. However, we tried to overcome this with our extensive search strategy, which was conducted by an experienced clinical librarian (JD). Furthermore, we imposed no language restrictions and included French and Italian articles. A specific limitation to our systematic review is that the included studies showed a broad heterogeneity in terms of study design, study population, outcome measures, and overall quality. Thus, while this review presents the best available evidence on RTS and RTW after knee osteotomy, our results should be interpreted with caution. For example, preoperative or pre-symptomatic sports levels and work participation data were mostly collected postoperatively, which makes these findings prone to recall bias. Furthermore, many different secondary outcome measures for physical activity were used (e.g. Tegner score, Lysholm score, UCLA score), hampering comparisons of physical activity between studies. In addition, only a few studies corrected for confounding. For example, only 10 of 26 studies reported the mean BMI. This appears to be an important confounder since BMI >27.5 kg/m^2 has been associated with worse outcomes, including worse activity levels, after knee osteotomies[66]. This implies that confounders that were not accounted for in the included studies may have influenced our findings. Future prospective studies should identify important confounders such as physical and mental comorbidities, preoperative sports levels and work status, patients' motivation, and surgeon's advice, and should correct for these confounders in the analysis. Also, based on our extensive evaluation of the risk of bias, we found that studies with a low risk of bias reported lower percentages of RTS and RTW. This implies that future studies should carefully consider potential sources of bias and aim to account for these sources in the study design to find the most reliable percentages of RTS and RTW.

CONCLUSION

The majority of patients undergoing knee osteotomy return to sports activities and work. For RTS, we observed a trend towards participation in lower-impact sports activities, similar to RTS after KA. Patients undergoing knee osteotomy returned to high-impact activities more often than did those undergoing KA. For RTW, it appears that a return to the same or a higher workload is possible. This valuable information will aid both the orthopaedic surgeon and the patient in the preoperative decision-making process, and is especially interesting in the treatment of the younger, active, and employed OA population. The systematic comparison of current literature is hampered by the heterogeneity of patient populations, operative techniques, and an overall lack of accounting for possible confounding factors. Lastly, this review confirms the importance of using the pre-symptomatic level as a starting point when analysing percentages of RTS and RTW.

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Table 1 Return to sports & work after knee osteotomy: data extracted from studies included in the review (n = 26)[a]

Study details, design, population [language]	Operation type (+ fixation implant)	Rehabilitation protocol	Outcome measures	Preoperative activity + definition	Postoperative activity	RTS + time to RTS	RTW + time to RTW	Confounding factors
Study: Ampollini et al.[52], 1998, Italy [Italian] Design: retrospective case series; FU NS Population: pts with chronic anterior laxity and varus malalignment (n=7); age range 24-35, sex 7 M (100%); BMI NS; Co NS	LCW HTO + ACL reconstruction Fixation: plate 5; staples 2	Knee brace for 60 days, CPM from postoperative d3	Sports participation n (%)	0 (0) Definition of pre-op: <1 year before surgery	7 (100)	>100% Time to RTS: Unknown	Unknown	Mentioned, not adjusted for: surgeon's advice (RTS is not the goal); pre-injury sports level
Bode et al.[25], 2015, Germany Design: retrospective cohort study; FU: 5.0 ± 0.2 years Population: pts with cartilage defect medial femoral condyle and varus malalignment >2° (n=40); age 37.6 ± 7.5; sex NS; BMI 25.4 ± 3.4; Co NS	MOW HTO + ACI Fixation: TomoFix	CPM for 6 weeks, up to 4 h/day. Mobilization on postoperative d1. Limited weight bearing for 6 weeks	Lysholm Workload: REFA work (physical strain, n (%) - 0 (without) - 1 (small) - 2 (moderate) - 3-4 (hard, most heavy)	54.4 ± 18.9 - - - - Definition of pre-op: unknown	76.2 ± 19.8 (p<0.01) 11 9 5 14	Unknown	% RTW: Unknown Time to RTW: 94.5 ± 77.0 days REFA 1: 68.1 ± 61.4 days REFA 4: 155.0 ± 111.0 days (p = 0.023)	Adjusted for in analysis: BMI (>35 not included), workload Mentioned, not adjusted for: age
Study: Bonnin et al.[49], 2013, France Design: retrospective multicentre (four centres) cohort study; FU 4.2 ± 0.9 years Population: pts with medial compartment OA and varus malalignment (n=139);	LCW HTO (n=88) MOW HTO (n=51) Fixation: plate 114, blade plate + screws 18, staples 7	NS	Sports participation n, (%): - Stationary cycling - Road cycling - Stretching - Swimming - Golfing	 - - -	 38 58 54	29 (20.8%) more active, 62 (44.6%) same activity level 45 (33%) less active than before surgery.	Unknown	Adjusted for in analysis: age, motivation. Mentioned, not adjusted for: reasons for no RTS

OA and varus malalignment (n=139); age 59.1 (range 24–80); sex 98 M (71%), 41 F (29%); BMI 27.2 ± 4.1; Co: medical limitation (respiratory, cardiac or neurologic): 6			- Sailing - Strength exercise - Dancing - Gymnastics - Hiking - Gardening - C-C skiing - DH skiing - Tennis - Running > 500m Mean Weiss activity score - Light - Intermediate - Strenuous	- - - - - - - - - - - - - - Definition of pre-op: before surgery	6 22 10 29 60 71 14 35 2 6 5.3 ± 1.2 5.9 5.5 5.1	Time to RTS: Unknown		
Study: Boss et al.[51], 1995, Switzerland Design: retrospective cohort study; FU 6.3 years (range 2.6–13.8) Population: pts with ACL deficiency, existing cartilaginous lesions medial compartment ± medial meniscus lesion (n=20), and varus malalignment (n=27); age 36 (range 19–55); sex 22 M (82%), 5 F (18%); BMI NS; Co NS	ACL reconstruction (BPTB +/- LAD (n=13)) + HTO (24 LCW, 3 MOW) Fixation: staples, AO-T-plates, semi tubular plate with long screw in ventral tibial cortex	Dorsal cast and removable circular splint. Immediate passive ROM, early mobilization. Full weight bearing. At 3 months cycling and jogging allowed, at 6-9 months more	Activity level	Unknown Definition of pre-op: pre-trauma & pre-surgery	55% higher at FU than preoperatively 15% lower at FU than preoperatively	94%; 85% returned to same or higher level Time to RTS: unknown	89% had returned to same profession at FU Time to RTW: unknown	Mentioned, not adjusted for: concomitant surgery

		demanding sports						
Study: Boussaton et al.[41], 2007, France [French] Design: retrospective case series; FU NS (range 1–10 years) Population: professional rugby players requiring HTO (n=6); age NS; sex 6 M (100%); BMI NS; Co NS	Valgising HTO (n=4) and varising HTO (n=2) Fixation NS	NS	IKDC	Unknown Definition of pre-op: pretraumatic	94 (range 86 – 99)	100% (6/6) Time to RTS: unknown	Unknown	NS
Study: Cotic et al.[53], 2015, Germany Design: prospective cohort study; FU: 2 years Population: pts with medial compartment OA and varus malalignment or medial compartment overload combined with localized chondral defects requiring cartilage repair (n=28); age 45 (± 11); sex 19 M (70%), 9 F (30%); BMI 25 ± 3; Co NS	(Biplanar) MOW HTO Fixation: second generation peek-carbon composite plate Concomitant procedures: medial meniscectomy: 5; microfracturing: 1; OATS: 6 ACL reconstruction: 1	Active and passive FROM as tolerated directly or after 6 weeks (in microfracture and OATS pts). 20-kg partial weight bearing until 6 weeks, then full weight bearing was allowed	Lysholm (n=27) Tegner (n=27) Sports participation, *n* (%): - Overall - Windsurfing - Sailing - Dancing - Martial arts - Basketball - Soccer - Bowling - Badminton - Table tennis - Tennis singles - Golf - Hunting - Ice skating - Snowboarding - C-C skiing - Downhill skiing - Aqua fit	51 (40 – 62) 5 (3 – 6) 24 1 1 4 1 2 2 1 3 2 3 1 2 1 1 7 5 0	83 (73 – 94) ($p < 0.001$) 4 (3 – 5) (n.s.) 27 1 2 4 1 1 0 1 0 2 0 2 1 1 0 6 8 1	>100% Time to RTS: unknown RTS (%) >100 100 >100 100 100 50 0 100 0 100 0 >100 50 100 0 86 >100 >100	Unknown	Mentioned, not adjusted for: fixation type, timing of implant removal

			- Gymnastics - Aerobics - Fitness training - Swimming - Mountain biking - Cycling - Climbing - Hiking - Inline skating - Jogging - Nordic walking	4 1 9 13 6 19 3 10 2 6 5 Definition of pre-op: regular participation in year before surgery	5 0 15 14 7 24 3 12 3 7 9	>100 0 >100 >100 >100 >100 100 >100 >100 >100 >100		
Study: Dahl et al.[40], 2015, Sweden Design: prospective cohort study; FU 10 years Population: pts with unicompartmental knee OA treated with hemicallotasis HTO technique (medial OA 40; lateral OA 5) (n=45); age 55 (range 35–64); sex 31 M (69%), 14 F (31%); BMI 29 ± 4.5; Co NS	HTO by hemicallotasis technique Fixation: external fixator	Free mobilization allowed. Full weight bearing. PT prescribed individually and related to needs of patient	Level of physical activity, *n* (%) (lifetime/pre-op): - 6: competitive sports - 5: recreational sports - 4: golf, dancing, hiking, water aerobics - 3: heavy yard / household work - 2: light yard/household work - 1: minimal household work, sewing, card games	 19 / 0 9 / 1 10 / 9 7 / 33 0 / 2 0 / 0	 0 3 21 6 13 1	63% RTS (%) 0 33 >100 86 >100 -	At 2 y: 84% At 10 y: 49%	Mentioned, not adjusted for: BMI, expectations, pts converted to TKA were excluded from FU, retirement

			- 0: no household work, TV/reading only Working pts, *n* (%): - Working - Retired - Unemployed - Sick leave	0 / 0 43 2 0 0 Definition of pre-op: lifetime & pre-op	1 21 23 0 1	- Time to RTS: unknown		
Study: De Carvalho et al.[38], 2012, Brazil Design: cross-sectional cohort study; FU 4 years (range 1.7–9.5) Population: pts with lateral compartment OA and valgus malalignment (n=26); age 48.6 (range 21–65); sex 8 M (31%), 18 F (69%); BMI NS (<35 kg/m^2); Co NS	LCW DFO Fixation: Dynamic condylar screw (Synthes)	FROM as tolerated without weight bearing. Partial weight bearing after 6 weeks and full 8 – 12 weeks. RTS after healing of osteotomy and recovery of muscle strength	Sports participation, *n* (%): - Routine physical activity - Soccer - Volleyball Tegner Lysholm	15 3 1 3 (2 – 7) 53.1 ± 16.2 (24 – 95) Definition of pre-op: unknown	14 3 0 3 (1 – 7) (n.s.) 77.3 ± 16.7 (29 – 100) (p<0.001)	89% RTS (%) 93 100 0 Time to RTS: unknown	88.5% resumed normal work duties at pre-op functional level Time to RTW: unknown	Mentioned, not adjusted for: age, limited FU, pre-op sports level, surgical technique
Study: Dejour et al.[54], 1994, France Design: retrospective cohort study; FU 3.6 years (range 1–11)	ACL reconstruction (BPTB ± LET	Immediate ROM as tolerated. Non-weight	Sporting level (pre-injury/pre-surgery, *n* (%)):			66% RTS (%)	unknown	Adjusted for in analysis: no differences in RTS between

Population: pts with symptomatic chronic ACL deficiency + acquired varus malalignment (n=44); age 29 (range 18–42); sex 27 M (63%), 16 F (37%); BMI NS; Co NS	(n=34)) + HTO (LCW n=37; MOW n=7) Fixation: two staples	bearing for 8 weeks	- Pivotal contact (e.g. soccer) - Pivotal non-contact (e.g. tennis) - Non-pivotal non-contact (e.g. cycling)	30 / 17 8 / 4 3 / 4 Definition of pre-op: both pre-injury and pre-surgery	7 10 10	23 / 41 >100 >100 Time to RTS: unknown		pts with poor outcome and pts with good outcome
Study: Faschingbauer et al.[44], 2015, Germany Design: cross-sectional cohort study; FU 1.8 years ± 0.8 Population: pts with medial compartment OA and varus malalignment (n=43); age 42 ± 11.2; sex 32 M (74%), 11 F (26%); BMI 26.9 ± 3.6; Co NS; concomitant procedures: 13 (OATS 6; partial meniscectomy 4; microfracturing 3)	MOW HTO Fixation: TomoFix	20 kg partial weight-bearing for 2 weeks, swiftly increased from week 2 until full weight-bearing. Daily PT was recommende d	General sports participation (at least 1 sport) Sports activities *n* (%): - Cycling - Hiking - Swimming - Fitness - Downhill skiing - Nordic walking - Jogging - Soccer - Gymnastics - Inline skating Tegner Lysholm	39/43 (90.7%) 33 19 18 8 10 8 8 8 5 6 3.78 ± 1.9 Unknown	36/43 (83.7%) 25 16 17 10 5 6 4 2 4 2 3.7 ± 1.4 (n.s.) 68.7 ± 23.9	92% (no inactive pts started new activities post-op) RTS (%) 76 84 94 >100 50 75 50 25 80 33 Time to RTS: unknown	94% returned to pre-op workload Time to RTW: 16.7 ± 15.6 weeks Group I (high work intensity, n=13): 19.1 ± 9.1 weeks Group II (moderate, n=12): 20 ± 17.8 weeks Group III (low, n=15): 11.8 ± 7.8 weeks	Adjusted for in analysis: analgesics use, completion of rehabilitation, cessation of partial weight bearing, workload Mentioned, not adjusted for: avoidance of potentially harmful activities, limited FU, surgeon's advice

				Definition of pre-op: pre-symptomatic			(p = 0.325) No pre- and postoperative changes among groups	
Study: Gomoll et al.[36], 2009, USA Design: retrospective study; FU 2 years (range 1–4.2) Population: pts with ipsilateral chondral defects and meniscal deficiency (n=7); age 32 (range 18–43); sex 5 M (71%), 2 F (29%); BMI NS; Co NS	Meniscus allograft transplantation + cartilage repair + osteotomy: HTO 5, DFO 2 Fixation: NS	Hinged knee brace with CPM for 6 hours per day for 6 weeks. Non-weight bearing 6 weeks. ADL activities allowed after 3 months, return to non-contact sports after 4-5 months. No restrictions after 12 months	Lysholm (mean) IKDC	34 26 Definition of pre-op: unknown (presumably pre-injury)	77 ($p<0.01$) 63 ($p<0.01$)	100%, 6 to full activities without restrictions, 1 with mild symptoms while playing basketball Time to RTS: unknown	Unknown	Mentioned, not adjusted for: expectation management by surgeon
Study: Hoell et al.[34], 2005, Germany Design: retrospective cohort study; FU 1.9 years (range 0.7–2.8) Population: pts with medial compartment OA and varus malalignment treated with MOW HTO [(n=40); age 46.4 ± 8; sex 25 M (63%), 15 F (37%); BMI 30 ± 5.2] or LCW HTO [(n=51); age 52.1 ± 8.4; sex 36 M (70%), 15 F	MOW HTO 40; LCW HTO 51 Fixation: MOW: Puddu plate; LCW: staples	Limited ROM (0-0-90°) first 6 weeks	Lysholm (range) - MOW - LCW Tegner (range) - MOW - LCW	 46 (25 – 65) 42 (19 – 63) 3.2 (1.5 – 5) 3.1 (1 – 5.2)	 68 (45 – 92) ($p<0.05$) 63 (38 – 90) ($p<0.05$) 4.3 (2.6 – 6) ($p<0.05$) 3.9 (2.5 – 5.5) ($p<0.05$)	Unknown Time to RTS: unknown	RTW: unknown Time to RTW: MOW: 13.9 weeks LCW: 13.6 weeks (p = n.s.)	Adjusted for in analysis: type of osteotomy Mentioned, not adjusted for: fixation type (Puddu plate with pain at implant site), rehabilitation

(30%); BMI 29 ± 4.2]; Co: no pts with rheumatic disease				Definition of pre-op: unknown				
Study: Isolauri et al.[37], 1983, Finland Design: retrospective cohort study; FU 3 years (range 1–5) Population: pts with unicompartmental knee OA and malalignment (n=50: varus 32, valgus 18); age at operation 58 (range 33–77); sex 15 M (30%), 35 F (70%); BMI NS; Co: n=26 (RA 1; HT 11; cardiac 8; diabetes 3; hyperthyroid 2; epilepsy 1)	HTO: LCW 32, MCW 18 Fixation: Charnley's compression device 16, plaster 34 (8 weeks)	Mobilisation on crutches postoperative d1 Full weight bearing allowed after 3 – 4 weeks	-	-	-	Unknown Time to RTS: unknown	41% Time to RTW: 5.5 months (2.5–11 months) Working capacity at FU: return to previous work 10 of 12 (83%) Trained for new occupation 2 of 12 (17%) Disabled on account of knee OA 13 (26%) Disabled on account other disease 4 (8%) Pension 21 (42%)	Adjusted for in analysis: obtained correction Mentioned, not adjusted for: co, reasons other than HTO for no RTW

Study: Korovessis et al.[39], 1999, Greece Design: prospective; FU 11 years (range 10–12) Population: pts with medial compartment OA and varus malalignment who were employed in agriculture. Group I: n=35; age 60 (range 49–74); sex 7 M (20%), 28 F (80%); BMI NS; Co NS. Group II: n=28; age 65 (range 50–79); sex 7 M (25%), 21 F (75%); BMI NS; Co NS	Group I: Two-level "gap" osteotomy (Mittelmeier) Group II: LCW HTO Fixation: gap osteotomy: non-locking plate; LCW: AO buttress plate	Partial weight bearing for 6 – 12 weeks	-	- Definition of pre-op: pre-surgery	-	NS	89% (in both groups) Time to RTW: 8 – 12 months	Mentioned, not adjusted for: age, patient motivation ("agricultural workers have to work until they are 80 years old")
Study: Lerat et al.[55], 1993, France [French] Design: retrospective case series; FU 4 years (range 4–11) Population: pts with chronic ACL deficiency associated with medial OA and varus malalignment (n=49); age 37 (range 25–58); sex 39 M (80%), 10 F (20%); BMI NS; Co NS	Valgising HTO + ACL reconstruction Fixation: plate 20, staples 31	Removable splint for 4 – 6 weeks. Early mobilization with CPM. Weight bearing allowed after 2 months	Sports participation (pre-injury/pre-surgery, *n* (%)): - Competition - Boxing - Tennis - Recreational sport	n=28 10 / 5 NS NS 15 / 14 Definition of pre-op: pre-injury and pre-surgery	n=28 2 1 1 10	48% / 63% RTS (%) 20 / 40 NS NS 67 / 71 Time to RTS: unknown	Unknown Time to RTW: 5.1 months ± (range 3 – 18)	Mentioned, not adjusted for: surgeon's advice
Study: Minzlaff et al.[47], 2016, Germany Design: cross-sectional; FU 6.9 years (range 2.5–9.8) Population: pts with focal osteochondral defects of medial condyle and varus malalignment	LCW HTO 16; MOW HTO 14 Fixation: LCW: non-locking L-plate; MOW: Tomofix	CPM for 6 – 8 weeks, ROM not restricted. 6 weeks non-weight bearing, increased	Tegner Sports participation, *n* (%): - Overall - Oarsmanship - Horseback riding	5 (2 – 7) 30 1 1	5 (4 – 7) 23 1 1	77% RTS (%) 77 100 100	Unknown	Adjusted for in analysis: age, defect size, number of previous surgeries Mentioned, not adjusted for:

(n=30); age 31 (range 19–39); sex NS; BMI 25 (range 21–32); Co NS; concomitant procedures: OATS 30		with 20kg/week. PT for 6 – 8 weeks. RTS (contact sports) allowed after osteotomy healing	- Martial arts - Volleyball - Basketball - Handball - Soccer - Badminton - Table tennis - Tennis singles - Ice hockey - Snowboarding - C-C skiing - Downhill skiing - Gymnastics - Fitness training - Swimming - Mountain biking - Cycling - Climbing - Hiking - Inline skating - Jogging - Nordic walking	0 1 1 0 7 1 1 0 1 3 3 5 0 9 10 5 15 1 3 3 8 2 Definition of pre-op: lifetime & 1 year pre-surgery	2 2 0 1 6 1 2 1 0 4 4 8 2 10 11 9 17 0 8 2 7 3	>100 >100 0 >100 86 100 >100 >100 0 >100 >100 >100 >100 >100 >100 >100 >100 0 >100 67 88 >100 Time to RTS: unknown		donor-site morbidity
Study: Nagel et al.[50], 1996, USA Design: retrospective; FU 8 years (range 2–14) Population: pts with medial compartmental OA and varus malalignment (n=34 [37 knees]). Group 1 (n=12): preoperative Tegner ≤4.	LCW HTO Fixation: above-the-knee cast 28, blade-plate 8	NS	Sports participation, *n* (%): - Overall - Tennis - Downhill + C-C skiing - Jogging - Cycling	- 15 11 14 30	25 13 9 10 26	RTS (%) - 87 82 71 87	Unknown 26/34 regularly performed manual labour (painting, laying tile, panelling,	Adjusted for in analysis: pre-op sports level (most predictive for RTS) Mentioned, not adjusted for: sex, surgeon's advice

Group 2 (n=22): preoperative Tegner ≥5. Age 49 (range 28–60); sex: 34 M (100%); BMI NS; Co NS			Tegner (range) - Group I (n=12) - Group II (n=22)	 3.2 (2 – 4) 6.5 (5 – 8) Definition of pre-op: unknown (presumably pre-surgery)	 2.8 (1 – 4) 5.9 (2 – 8)	Time to RTS: unknown	carpentry, gardening, constructio n work) Time to RTW: unknown	
Study: Niemeyer et al.[46], 2008, Germany Design: prospective; FU 2 years Population: pts with medial compartment OA and varus malalignment (n=43); age 47.3 ± 10.3 (range NS); sex: 37 M (86%) 6 F (14%); BMI 27.2 ± 3.5; Co NS; concomitant procedures: n=37 (ACL reconstruction 1; microfracturing 24; partial meniscectomy 17; ACI 7)	MOW HTO Fixation: TomoFix	Pts were mobilized on postoperative d1. Weight bearing limited to 15 kg for 6 weeks after which full weight bearing was allowed in all cases	Pre-disease sports activity level, *n* (%) - 6 months - 12 months - 24 months Lysholm IKDC (subjective) IKDC (objective) *n* (%) - Normal - Nearly normal - Abnormal - Severely abnormal	 - - - 5 40 (NS) 4 (9) 16 (37) 15 (35) 8 (18) Definition of pre-op: pre-symptomatic	 13 (30) 25 (58) 29 (68) 78 ± 20 (p<0.01) 70 (NS) (p<0.01) 19 (44) 10 (23) 12 (28) 2 (5)	68% regained predisease level of activity at 24 months FU Time to RTS: unknown	Unknown	Adjusted for in analysis: smoking Mentioned, not adjusted for: additional surgery, fixation type, pre-op sports level
Study: Noyes et al.[33], 2000, USA Design: prospective case series; FU 4.5 years (range 2–12)	LCW HTO Fixation: L-shaped internal plate	Long-leg brace for 8 weeks. Immediate ROM (0°-	Sports participation, *n* (%): - Overall	 14	 27	 >100%	>100%	Mentioned, not adjusted for: surgeon's advice, non-homogenous

Population: pts with ACL deficiency and partial or complete lateral ligament deficiency and varus malalignment. Double varus: n=23; age 30 (range 19–47); sex 21 M (91%), 2 F (9%); BMI NS. Triple varus: n=18; age 28 (range 16–46); sex 11 M (61%), 7 F (39%); BMI NS. Co NS		90°). Toe-touch weight bearing for 3 weeks, gradually increased to full by wk 8-10. Quadriceps muscle isometric exercises, straight leg raises, patellar mobilization, and EMS	- Jumping, pivoting, cutting - Running, twisting, turning - Low impact (swimming, biking) - No sports Employment, *n* (%) - Overall - Light - Moderate - Very heavy - Student /homemaker - Disabled (because of knee condition)	2 9 3 27 23 11 9 3 9 9 Definition of pre-op: pre-surgery	3 4 24 10 34 20 10 4 4 3	>100% 44% >100% 37% Time to RTS: unknown	Time to RTW: unknown RTW (%) >100 >100 >100 >100 - 33	population, staged surgery for complex cases
Study: Saier et al.[45], 2015, Germany Design: prospective case series; FU 2 years Population: pts aged <65 with medial compartment OA and varus malalignment (n=64); age 45.5 (range 20–63); sex 46 M (74%), 18 F (26%); BMI 26.6 (range 19–35); Co NS	MOW HTO (biplanar) Fixation: TomoFix plate, Peek power plate	Immediate FROM. Partial weight bearing for 2 weeks, increased by 20kg/wk until full weight bearing. RTS allowed after 3 months and contact sports after osseous consolidation	-	- Definition of pre-op: pre-surgery	-	Unknown	93% (45/50). 90% without symptoms; 3% with impairment; 7% did not RTW due to knee symptoms Time to RTW: 5.2 months	Adjusted for in analysis: psychological distress Mentioned, not adjusted for: fixation type, surgeon's advice

							(range 1.5 – 24)	
Study: Salzmann et al.[48], 2009, Germany Design: cross-sectional; FU 3 years (range 1.2–7) Population: pts aged <65 with medial compartment OA and varus malalignment (n=65); age 41.2 (range 19–65); sex 51 M (78%), 14 F (22%); BMI 21 (range 20–34); Co NS; concomitant procedures: n=9 (partial meniscectomy 6, OATS 2, notchplasty 1)	MOW HTO (biplanar) Fixation: TomoFix plate	Partial weight bearing (15 kg) for 4 weeks. Weight bearing gradually increased from week 4 – 6 and full weight bearing after 6 – 8 weeks	Sports activity (lifetime/pre-operative, *n* (%)): - Overall - Cycling - Downhill skiing - Swimming - Hiking - Fitness - Mountain biking - C-C skiing - Tennis singles - Volleyball - Inline skating Tegner (range) Lysholm (range)	 62 / 57 47 / 43 35 / 18 33 / 42 29 / 17 27 / 13 19 / 13 19 / 7 16 / 3 15 / 3 15 / 8 4.9 (1 – 10) 42 (7 – 90) Definition of pre-op: during lifetime and pre-surgery	 59 46 18 30 20 17 14 5 2 3 6 4.3 (2 – 9) (*p*<0.05) 70 (22 – 95) (*p*<0.01)	95% RTS (%) 95 / >100 99 / >100 51 / 100 92 / 71 68 / >100 63 / >100 70 / >100 28 / 71 13 / 67 22 / 100 39 / 75 Time to RTS: unknown	Unknown	Adjusted for in analysis: age, ASA, BMI, concomitant procedures, correction angle, sex, KL score, satisfaction (None of these factors were correlated with sports participation)
Study: Saragaglia et al.[35], 2014, France Design: retrospective; FU 5.8 years (range 5–9) Population: pts with medial compartment OA and varus malalignment (n=83); age 50.4	MOW HTO 62; MOW HTO + LCW DFO (double osteotomy) 21 Fixation NS	NS	Sports participation, *n (%)*: - Overall - Cycling - Power walking - Downhill skiing - Running - Hiking	 66 28 22 22 20 12	 71 26 26 14 17 6	>100% RTS (%) >100 93 >100 64 85 50	Unknown	Adjusted for in analysis: age, BMI, sex, type of osteotomy, motivation, pre-existent sports level Mentioned, not adjusted for: co,

(range 32–67); sex 56 M (68%), 27 F (32%); BMI 27.5 ± 4.7. Previous surgery: medial meniscectomy 23, ACL reconstruction 10; Co: 16% medical conditions that could hinder RTS			- Swimming - Tennis - Football - C-C skiing - Ski touring - Gymnastics - Gardening - Climbing - Windsurfing - Mountain bike - Bodybuilding - Golf - Handball - Bowls - Hunting - Squash - Diving - Volleyball - Rugby - Basketball Lysholm (range) Tegner (range) UCLA (range)	9 5 4 4 3 3 2 2 2 2 1 1 1 1 1 1 1 1 1 1 63 (30 – 100) 4.5 (range NS) 7.1 (range NS) Definition of pre-op: pre-symptomatic	13 5 1 1 3 2 3 2 2 1 2 1 1 1 1 1 1 0 1 0 91 (55 – 100) (*p*<0.001) 4.1 (range NS) (*p* = 0.07) 6.6 (range NS) (*p* = 0.09)	>100 100 25 25 100 67 >100 100 100 50 >100 100 100 100 100 100 100 0 100 0 66 (80%) returned to same sporting level as before onset of OA. Time to RTS: unknown		effect of double-osteotomy, reasons for non-RTS
Study: Schröter et al.[43], 2013, Germany Design: retrospective; FU 6.4 ± 1.6 years (range NS)	MOW HTO Fixation: LC-DCP plate	No brace or cast. 20-kg partial weight bearing for 6 weeks, full after 6 – 8	Lysholm (± SD) Tegner (range)	62.5 (± 17.5) 3 (1 – 5)	81.7 (± 12.7) (*p*<0.01) 4 (1 – 8) (*p* = NS)	Unknown	Unknown Time to RTW: 87 days (14 – 450)	Adjusted for in analysis: workload Mentioned, not adjusted for:

Population: pts with medial compartment OA and varus malalignment who were employed at time of surgery (n=32); age 47 ± 9; sex 22 M (69%), 10 F (31%); BMI 28.6 ± 4.7; Co NS		weeks. Active PT started after removal of drains	REFA work (physical strain, *n* (%)) - 0 (without) - 1 (small) - 2 (moderate) - 3 (hard) - 4 (most heavily)	 7 (22) 11 (34) 8 (25) 5 (16) 1 (3)	 8 (25) 11 (34) 9 (28) 3 (9) 1 (3)		Time to RTW for each REFA category: 0 = 42 days (14 – 150) 1 = 90 days (40 – 180) 2 = 120 days (28 – 450) 3 = 66 days (60 – 300) 4 = 120 days (120 – 120) 3 (9%) pts changed employment to occupation with lower workload	fixation type, rehabilitation protocol, surgeon's advice
Study: Waterman et al.[42], 2015, USA Design: retrospective; FU 4.0 years (range 2–8) Population: active US duty service members undergoing HTO for coronal plane malalignment and/or intraarticular pathology (n=181 [202 HTOs]); age 35.7 (range 15–55); sex 169 M (93%), 12 F	MOW HTO Fixation: plate fixation 171; external/ring fixation 12; unspecified 19	NS	Combat deployment record, *n* (%)	34 (19) Definition of pre-op: pre-surgery	15 (8.3)	Unknown	72% returned to military duty. 43% without limitations. 8.3% successfully completed postoperative combat deployment	Adjusted for in analysis: age, complications, concomitant procedures, sex, smoking Mentioned, not adjusted for: selected (military) population,

(7%); BMI NS; Co NS. Concomitant procedures: n=87 (meniscal 48, chondral 40, ligamentous 48)							. 41% had minor permanent activity limitations	surgeon's advice
Study: Williams et al.[56], 2003, USA Design: retrospective; FU 3.8 years (range 2.0–8.8) Population: pts with chronic ACL deficiency, medial compartment OA and varus malalignment (n=25); age 35 (range 26–46); sex 18 M (72%) 7 F (28%); BMI NS; Co NS	LCW HTO 12; LCW HTO + ACL reconstruction 13 Fixation: two staples	Hinged knee brace. Non-weight bearing for minimum 4 weeks	Sports participation, *n* (%): - Overall - Competitive sports - Recreational sports - Unable to participate in sports activities Lysholm (range) - Group 1 - Group 2 Tegner (range) - Group 1 - Group 2	 13 2 12 11 46.8 (19 – 64) 47.0 (14 – 73) 3.8 (1 – 7) 3.6 (1 – 7) Definition of pre-op: immediately prior to surgery	 25 4 19 2 76.3 (57 – 100) ($p<0.05$) 80.9 (56 – 95) ($p<0.05$) 4.9 (3 – 7) ($p<0.02$) 4.7 (3 – 8) ($p<0.02$)	RTS (%) >100 >100 >100 -	Unknown	Adjusted for in analysis: concomitant procedures (ACL reconstruction), correlation, Tegner/Lysholm and RTS Mentioned, not adjusted for: fixation type, patient motivation, pre-op sports level, persistence of ACL insufficiency in group 1, selection bias, surgeon's advice
Study: Yim et al.[57], 2013, South Korea	MOW HTO	ROM exercises, patellar	Tegner	3.1 ± 1.1	2.5 ± 1.2 (p = NS)	78%	unknown	Mentioned, not adjusted for: age, selected

Design: cross-sectional; FU 3.6 years (range 3–4) Population: pts with medial compartment OA and varus malalignment (n=58); age 58.3 (range 43–65); sex 7 M (12%), 51 F (88%); BMI NS; Co NS	Fixation: two Aescula wedge plates	mobilization, and straight-leg raises from postoperative d1. Partial weight bearing after 6 weeks, full weight bearing with a crutch after 8–12 weeks	Lysholm Participation in 1 or more low-impact activities, n: - 0 activities - ≥1 activities	62.4 ± 9.5 8 50 Definition of pre-op: pre-surgery	89.6 ± 8.7 (p = NS) 19 39	Time to RTS: unknown		population (rural areas)

ACI autologous chondrocyte implantation, *ACL* anterior cruciate ligament, *ADL* activities of daily living, *AO* Arbeitsgemeinschaft für Osteosynthesefragen, *ASA* American Society of Anesthesiologists, *BMI* body mass index, *BPTB* bone patellar tendon bone, *C-C* cross-country, *Co* co-morbidities, *CPM* continuous passive motion, *d* day, *DFO* distal femoral osteotomy, *DH* downhill, *EMS* electronic muscle stimulation, *F* female, *FROM* free range of motion, *FU* follow-up, *HT* hypertension, *HTO* high tibial osteotomy, *IKDC* International Knee Documentation Committee, *KL* Kellgren-Lawrence, *LAD* ligament augmentation device, *LC-DCP* limited-contact dynamic compression plate, *LCW* lateral closing wedge, *LET* lateral extra-articular tenodesis, *M* male, *MOW* medial opening wedge, *NS* not stated, *n.s.* not significant, *OA* osteoarthritis, *OATS* osteochondral autograft transplant system, *preop* preoperative, *PT* physiotherapy, *pts* patients, *RA* rheumatoid arthritis, *REFA* Reichsausschuss für Arbeitszeitermittlung, *ROM* range of motion, *RTS* return to sports, *RTW* return to work, *SD* standard deviation, *TKA* total knee arthroplasty, *UCLA* University of California, Los Angeles

[a] Data are mean ± SD except otherwise indicated; age is presented in years unless otherwise indicated; BMI is presented in kg/m^2

CHAPTER 2

Eight Respectively Nine out of Ten Patients Return to Sport and Work After Distal Femoral Osteotomy

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ABSTRACT

Purpose Distal femoral osteotomy (DFO) is a well-accepted procedure for the treatment of femoral deformities and associated symptoms including osteoarthritis, especially in younger and physically active patients in whom knee arthroplasty is undesirable. Still, there is an apparent need for evidence on relevant patient outcomes, including return to sport (RTS) and work (RTW), to further justify the use of knee osteotomy instead of surgical alternatives. Therefore, the purpose of the present study was to investigate the extent and timing of patients' RTS and RTW after DFO.

Methods This monocentre, retrospective cohort study included consecutive DFO patients, operated between 2012 and 2015. Out of 126 eligible patients (18–70 years, 63% female), all patients responded, and 100 patients completed the questionnaire. Median follow-up was 3.4 years (range 1.5–5.2). The predominant indication for surgery was symptomatic unicompartmental osteoarthritis and valgus or varus leg alignment caused by a femoral deformity. The primary outcome measure was the percentage of RTS and RTW. Secondary outcome measures included time to RTS/RTW, sports level and frequency, the median pre-symptomatic and postoperative Tegner activity score (1–10, higher is more active) and the postoperative Lysholm score (0–100, higher is better).

Results Out of 84 patients participating in sports preoperatively, 65 patients (77%) returned to sport postoperatively. Forty-six patients (71%) returned to sports within 6 months. Postoperative participation in high-impact sports was possible though less frequent compared to preoperative participation. Out of 80 patients working preoperatively, 73 (91%) returned to work postoperatively, of whom 59 patients (77%) returned within 6 months. The median pre-symptomatic Tegner activity score [4.0 (range 0–10)] was significantly higher ($p < 0.01$) than the reported Tegner score at follow-up [3.0 (range 0–10)]. The mean Lysholm score at follow-up was 68 (± 22). No significant differences were found between the osteoarthritis- and non-osteoarthritis group.

Conclusion Eight out of ten patients return to sport and nine out of ten patients return to work after DFO. These are clinically relevant findings, because they further justify DFO as a surgical alternative to KA in young, active knee OA patients who wish to return to high activity levels.

INTRODUCTION

Knee osteoarthritis (OA) is increasingly observed in active patients who are still of working age[1]. This population represents a challenge, because knee replacement is undesirable, given the three- to fivefold increased risk of revision surgery in young and active patients, compared to patients above the age of 55–65[2]. Furthermore, meeting younger patients' expectations is difficult, because their expectations tend to be higher than what a knee arthroplasty (KA) can deliver[3,4]. Therefore, knee osteotomy has regained interest from surgeons who are looking for joint preserving alternatives to KA, resulting in a considerable increase in knee osteotomy surgery in the last decade[5,6]. In cases of early-stage unicompartmental knee OA with a femoral deformity, distal femoral osteotomy (DFO) is considered the preferred treatment[7]. DFO is also a well-accepted procedure for the treatment of symptomatic unicompartmental overload and congenital malformations, especially in younger and physically active patients[7-11].

Yet, there is an apparent need for robust evidence on relevant patient outcomes, including return to sport (RTS) and return to work (RTW), to further justify the use of knee osteotomy instead of surgical alternatives[8,12]. Systematic reviews on RTS and RTW after knee osteotomy showed that up to 85% of patients can RTS and RTW after high tibial osteotomy (HTO)[13,14]. However, data on RTS and RTW after DFO are sparse. One study on varising DFO for lateral compartment OA, found that 23 of 26 patients returned to work, and 14 of 15 patients returned to their preoperative sports activities[15]. Another study, including 13 young athletes treated with varising DFO for symptomatic lateral compartment overload, found that all patients returned to sport at 2 years follow-up[16]. However, both studies described a small number of patients selected based on strict inclusion criteria, thus limiting generalizability. Furthermore, no studies on RTS and RTW have been performed in patients with DFOs other than varus-producing osteotomies. Finally, timing of return to sport and work after DFO has not been described previously. Both the extent and timing of RTS and RTW represent valuable information to the patient and the orthopaedic surgeon, that could be used to guide preoperative patient counselling, shared decision making and expectation management[17].

Therefore, the purpose of the present study was to investigate the extent and timing of patients' return to sport and work after DFO in a large cohort with different indications for distal femoral corrections. This is clinically relevant information, that may be used when counselling young, active patients to discuss their expectations regarding postoperative sport and work ability after DFO. If a return to sports and work is indeed possible after DFO, this would further justify the use of DFOs in this population. Our hypothesis was that most patients return to sport and work, including high-impact activities, after DFO.

MATERIALS AND METHODS

A monocentre cross-sectional study was performed in consecutive DFO patients operated on between 2012 and 2015. Eligible patients were between 18 and 70 years of age at follow-up. Patients had to understand the Dutch language and were required to be mentally able to complete the questionnaire. Patients who were treated with DFO bilaterally were asked to complete the questionnaire for the most recent operation. Eligible patients received a questionnaire by postal mail, followed by a maximum of two telephone reminders.

Patient characteristics

Patients' age, BMI (kg/m^2) and education level were asked. In addition, patients were asked if they had experienced postoperative complications and whether they had been operated on the same leg again following DFO (e.g. revision surgery or knee arthroplasty). The ASA classification, degree of correction and additional information on possible revision surgery and hardware removal were collected from the electronic medical record.

Participants

Out of 143 consecutive DFOs, 126 were eligible for inclusion and these patients were sent a questionnaire. All patients responded and 100 patients completed the questionnaire at a median follow-up of 3.5 years (range 1.4–5.2). One additional patient was excluded after completing the questionnaire, because she suffered from achondroplasia and had never worked or performed sports in her life. Figure 1 presents the in- and exclusion flow chart for this study. The predominant indication for surgery was symptomatic unicompartmental osteoarthritis. In addition, patients with a valgus or varus leg alignment caused by a femoral deformity without the presence of OA and patients with symptomatic rotational deformities of the femur were included. Finally, patients with a flexion contracture were treated with an extending DFO. Out of a total of 99 patients, 29 patients with a multiplane deformity or a concomitant tibial deformity were treated with combined osteotomies of the femur and tibia.

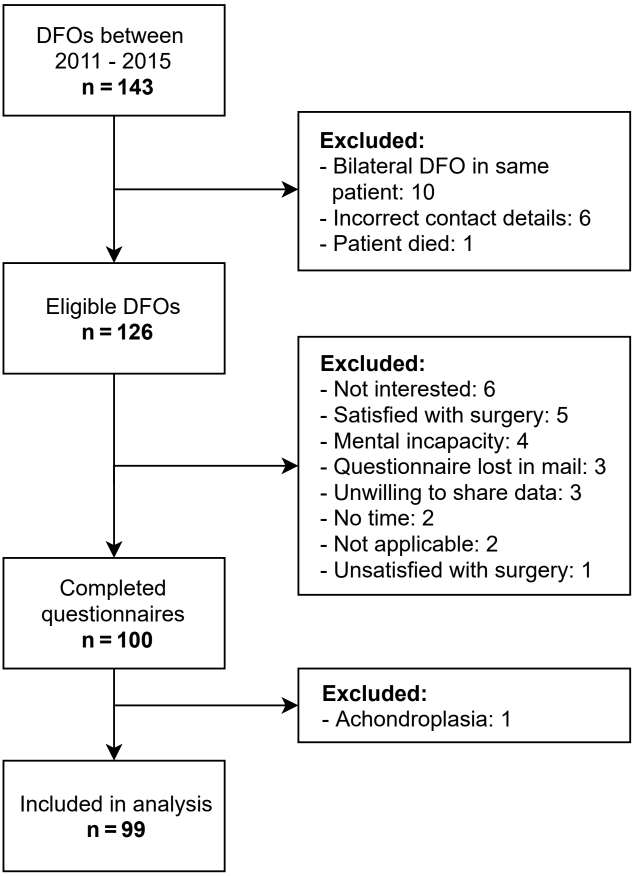

Fig. 1 Inclusion flowchart

Surgical technique and rehabilitation

Surgery was performed by one of three dedicated knee osteotomy surgeons with 5–15 years of experience with DFO. The DFO frontal plane and transverse plane techniques have been described in previous publications[9,10], and all techniques including the sagittal plane technique are illustrated in Fig. 2. For valgus malalignment, patients underwent a biplanar medial closing wedge osteotomy or a biplanar lateral opening wedge osteotomy. For varus malalignment, patients underwent a biplanar lateral closing wedge osteotomy. In case of additional valgus or varus malalignment of the tibia, a combined DFO and HTO were performed.

Patients with rotational malalignment of the femur were treated with a single plane, de-rotation transverse DFO. Patients with an additional rotational malalignment of the tibia were also treated with a de-rotation transverse proximal tibial osteotomy. Finally, in case of a flexion contracture, patients were treated with a single plane extension DFO. Prior to surgery, a detailed planning was performed for each patient. Degrees of correction in frontal and sagittal plane were converted to millimetres of wedge to be resected, as measured on the calibrated radiographs. In the OR, callipers and rulers were used to define the wedge in the bone with K-wires under fluoroscopic guidance. Transverse plane corrections were calculated from standardized CT-scans. Intra-operatively, a tracker specifically designed for rotational measurements is used, together with K-wires defining the angle of rotation in the bone or to measure the angle of correction. Plate fixation in all patients was performed with angle stable plates (TomoFix, Synthes GmbH, Solothurn, Switzerland). Postoperatively, physiotherapy guided immediate range of motion exercises and muscle strengthening was started and all patients were restricted to partial weight bearing for 6 weeks. Thromboembolic prophylaxis, i.e. Enoxaparin 40 mg, was prescribed once daily for 6 weeks. After 6 weeks, knee radiographs were obtained to verify the degree of correction and to check for hardware complications. Progressive weight bearing was allowed thereafter, up to full weight bearing at 3 months. At 3 months postoperative, knee radiographs and full-length standing radiographs were obtained to verify bone healing and the correction of deformity.

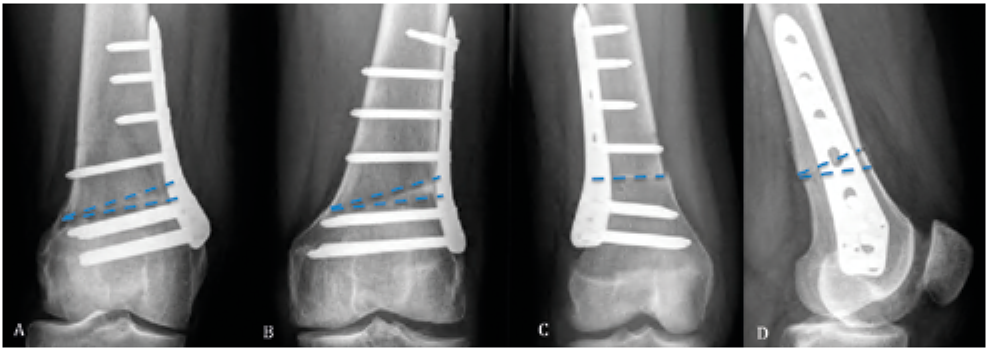

Fig. 2 Postoperative anteroposterior/lateral radiographs of distal femoral osteotomies (DFOs) with projected osteotomy cuts (striped lines). **A** Right knee after medial closing wedge DFO, **B** Left knee after lateral closing wedge DFO, **C** Right knee after de-rotation DFO, **D** Left knee after anterior closing wedge DFO

Sport outcome measures

The primary outcome measure was the percentage of patients that returned to sport postoperatively. Secondary outcome measures included the timing of RTS, the frequency, duration and type of performed sport activities pre- and postoperatively. No validated questionnaire exists to assess RTS in knee osteotomy patients. Therefore, a questionnaire was developed, based on the sports questionnaire described by Naal et al. in 2007, to investigate RTS after hip resurfacing arthroplasty and unicompartmental knee arthroplasty (UKA)[18,19]. This questionnaire has been used in several other studies investigating RTS after knee surgery, including studies in knee osteotomy patients[20,21]. The questionnaire ascertains patients' preoperative and postoperative engagement in 20 sports, e.g. cycling, jogging, golf and tennis. For the present study, 14 sports were added to the questionnaire (Supplementary material 1). Preoperative sports participation was defined as both pre-symptomatically, i.e. before the onset of restricting knee symptoms, and 1 year preoperatively. Postoperative sports participation was defined as 1 year postoperatively and at final follow-up. For each selected sport, patients reported at which of those four time- points they had participated in that sport. For each timepoint, the highest level of participation (recreative, competitive or professional) was asked. Next, sports frequency (0–7 times per week), duration (hours per week) and timing of RTS (weeks) were asked. To assess the level of impact, sports activities were rated as low-, intermediate- or high-impact according to the classification by Vail et al.[22]. In addition, patients were asked to rate their sports ability at follow-up, compared to the best sports ability in their lifetime with the following five answering categories: much worse; worse; unchanged; improved; much improved. Finally, the Tegner activity score and the Lysholm score, which have been recently validated in Dutch[23], were collected. Patient was asked to report their pre-symptomatic Tegner score and their Tegner score at follow-up. The Lysholm score was only completed for the situation at follow-up[24].

Work outcome measures

The primary work outcome measure was the percentage of patients that returned to work postoperatively. The secondary outcome measure was the timing of RTW. First, patients were asked if they worked before the onset of restricting knee symptoms, and within 3 months preoperatively. Job title was recorded and classified as light, medium or heavy by two occupational experts, who independently scored all jobs based on work-related physical demands on the knee[25,26]. The hours per week that patients worked 3 months preoperatively, 1 year postoperatively and at follow-up were also asked. In addition, time to RTW and changes in work load (lower; unchanged; higher) were asked. If patients did not RTW, reasons for no RTW were asked. Finally, the validated WORQ questionnaire was used to assess the impact of DFO on work-related activities[27,28]. The WORQ consists of 13 knee-burdensome activities (e.g. kneeling, lifting/carrying, climbing stairs). Patients grade the difficulty they experience when performing each activity on a five-point Likert scale, with 0 meaning no difficulty and 4 meaning extreme difficulty/unable to perform. Patients were asked to retrospectively grade the difficulty at three timepoints: 3 months preoperatively, 1 year postoperatively and at final follow-up. Institutional Review Board approval was obtained from the local medical ethical review board (Academic Medical Center Amsterdam, reference number W17_382 #17.448) prior to initiation of this study. All patients provided written informed consent.

Statistical analysis

Demographic data, pre- and postoperative sport participation and work status were analysed using descriptive statistics. In addition, timing of RTS and RTW, and frequency and duration of sports participation were analysed with descriptive statistics. RTS was calculated by selecting all patients that participated in one or more sports preoperatively and calculating which percentage of these patients could RTS 1 year postoperatively and/or at final FU. The unpaired T test was used to compare pre-symptomatic and postoperative Tegner scores. The WORQ scores at three timepoints were dichotomized to determine how many patients experienced severe difficulty with a work-related knee-demanding activity. "Severe difficulty" and "extreme difficulty/unable to perform" were classified as "severe difficulty". "Moderate difficulty," "mild difficulty" and "no difficulty" were classified as "no severe difficulty". In addition to the primary analyses for the total group, subgroup analyses for RTS and RTW were performed for the OA patients and the non-OA patients using the Chi-square test. A *p*-value of $p < 0.05$ was considered significant. All statistical analyses were performed with SPSS for Windows (Version 24.0. Armonk, NY: IBM Corp.).

RESULTS

Table 1 presents the baseline characteristics of the total group, and of the OA- and non-OA subgroups. No intra-operative complications were encountered. There were four postoperative complications that required revision surgery: one case of a broken plate, one case of a broken and protruding screw, one case of delayed union and one case of non-union. Table 2 presents the operation type and degree of correction for the included patients.

Table 1 Baseline characteristics of total group and of the OA- and non-OA subgroups

Outcome measure	Total group (n = 99)	OA group (n = 64)	Non-OA group (n = 35)
Mean age at surgery, years (SD)	41.2 (14.2)	48.5 (8.7)	28.1 (12.9)
Median follow-up, years (range)	3.4 (1.4 – 5.2)	3.5 (1.4–5.2)	3.4 (1.5–5.2)
Sex, female (%)	62 (63)	39 (61)	23 (66)
Mean BMI, kg/m^2 (SD)	27.3 (4.6)	28.4 (4.1)	25.2 (4.9)
Side, right (%)	54 (55)	40 (63)	14 (40)
ASA classification, n (%)			
I	67 (68)	41 (64)	26 (74)
II	31 (31)	22 (35)	9 (26)
III	1 (1)	1 (2)	–
Type of femoral deformity			
Varus		18 (28)	7 (20)
Valgus		46 (72)	12 (34)
Rotational		–	13 (37)
Extension		–	3 (9)
Revision osteotomy, yes (%)	4 (4)	3 (5)	1 (3)
Hardware removal, yes (%)	65 (66)	37 (59)	28 (80)
Timing of hardware removal, years (SD)	1.0 (0.8)	1.1 (0.8)	0.9 (0.6)

ASA American Society of Anaesthesiologists, *BMI* body mass index, *OA* osteoarthritis

Table 2 Operation type and degree of correction

Operation type	Patients (n (%))	Degree of correction (mean ± SD)
Medial cwDFO	42 (43%)	7.9° ± 2.9°
Lateral cwDFO	14 (14%)	6.5° ± 2.2°
Lateral owDFO	5 (5%)	7.0° ± 3.6°
Lateral cwDFO + medial owHTO	9 (9%)	6.3° ± 2.8° + 6.7° ± 1.6°
Medial cwDFO + medial cwTKO	13 (13%)	7.9° ± 4.0° + 7.5° ± 2.7°
FDO[a]	6 (6%)	18.3° ± 11.8°
FDO + TDO[a]	7 (7%)	13.9° ± 3.5° + 16.5° ± 2.3°
Extending DFO	3 (3%)	8.5° ± 5.7°

cw closing wedge, *DFO* distal femoral osteotomy, *FDO* femoral de-rotation osteotomy, *HTO* high tibial osteotomy, *ow* opening wedge, *TDO* tibial de-rotation osteotomy
[a] Degrees of rotational correction are presented.

Return to sport

Out of 84 patients participating in one or more sports pre-operatively, 65 patients (77%) returned to sport postoperatively. Time to RTS was ≤ 6 months in 71% of patients. In addition, four patients (4%) started participating in one or more sports postoperatively. For the OA group, 44 out of 54 patients (82%) could RTS compared to 21 out of 30 patients (70%) for the non-OA group (n.s.). Figure 3 presents the level of sports participation at four timepoints for the total group, showing a shift over time from a competitive/professional level to a recreational level. Compared to pre-symptomatically, sports frequency was lower 1 year pre- and postoperatively (Supplementary material 2). At final follow-up, frequency had increased again, but did not reach the pre-symptomatic level. A shift was found from high- to intermediate- and low-impact sports (Supplementary material 2). Sports ability at final follow-up compared to best lifetime sports ability was worse or much worse in 55 patients (60%), unchanged in 19 patients (20%) and improved or much improved in 19 patients (20%). The median Tegner score decreased from 4.0 (range 0–10) pre-symptomatically to 3.0 (range 0–10) at final follow-up ($p < 0.01$). The mean Lysholm score at final follow-up was 68 (± 22). In total, 42% of patients reported a Lysholm score of < 65 points (poor), 28% a score of 65–83 (fair), 23% a score of 84–94 (good) and 7% a score of > 94 (excellent).

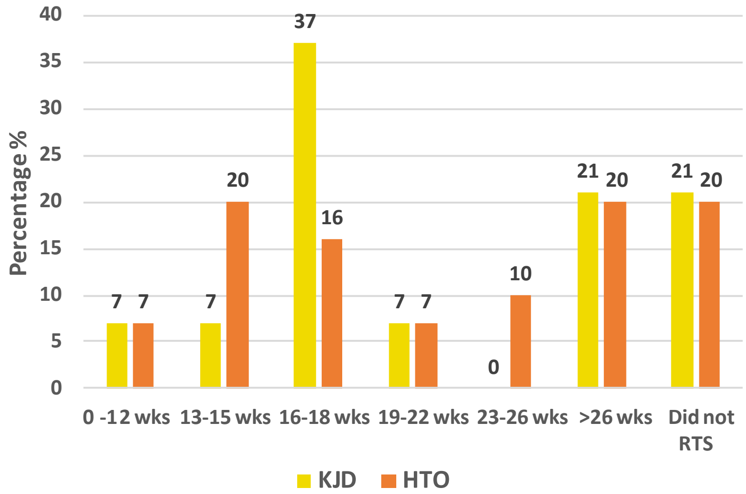

Fig. 3 Level of sports participation (no participation, recreational or competitive/professional sports participation) of the total group at four timepoints.

Return to work

Before the onset of restricting knee symptoms, 80 patients (81%) were working, and 77 of them (77%) were still working 3 months preoperatively. Postoperatively, 73 out of 80 patients (91%) could RTW of whom 59 patients (81%) returned within 6 months. In addition, three patients started working postoperatively. In the OA group, 51 out of 54 patients (94%) could RTW, compared to 22 out of 26 patients (85%) in the non-OA group (n.s.) (Fig. 4). On average, patients worked an equal number of hours 1 year post-operatively compared to preoperatively and worked slightly more hours at final follow-up (Table 3). Table 4 presents the pre-symptomatic and preoperative workload, and postoperative changes in workload. Out of seven patients that did not RTW, four patients did not return due to knee complaints and three patients did not return due to physical complaints unrelated to their knee. Finally, Fig. 5 presents the WORQ scores at three timepoints. Three months preoperatively, > 50% of patients experienced severe difficulty with kneeling, crouching, clambering and walking on rough terrain. Postoperatively, an improvement was observed for all activities. Walking on rough terrain and taking the stairs showed the largest improvement, while patients experienced most difficulty with kneeling and crouching.

Table 3 Number of working hours of the total group at three time points

	1 year pre-operatively (n (%))	1 year post-operatively (n (%))	At final follow-up (n (%))
0–8 h/wk	13 (16)	12 (16)	8 (11)
9–16 h/wk	10 (13)	12 (16)	10 (13)
17–24 h/wk	9 (11)	11 (14)	9 (12)
25–32 h/wk	12 (15)	13 (17)	15 (20)
33–40 h/wk	21 (27)	16 (21)	20 (27)
>40 h/wk	14 (18)	12 (16)	13 (17)

h hours, *wk* week

Table 4 Preoperative knee-demanding workload and postoperative changes in workload

Workload	Pre-symptomatically (%)	Preoperatively (%)	Change in workload	1 year postoperatively (%)
Light	66	73	Lighter	14
Intermediate	25	24	Equal	79
High	9	3	Higher	7

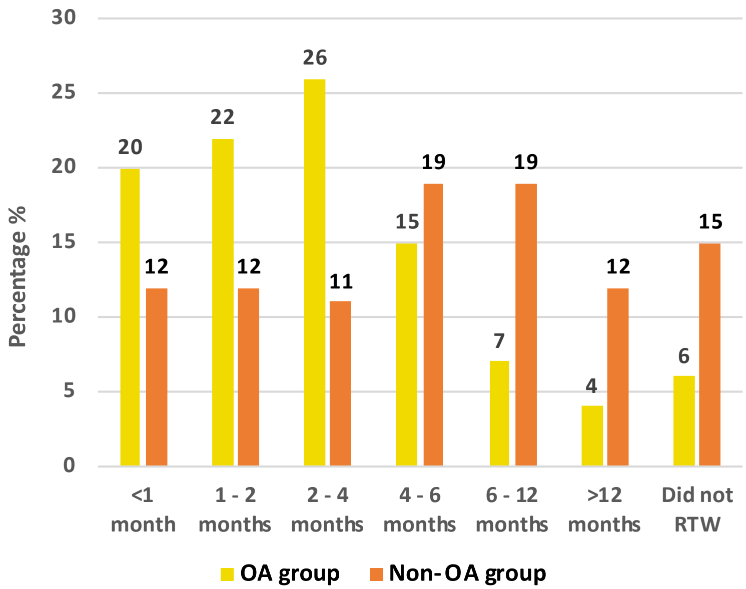

Fig. 4 Timing of return to work for the OA group and the non-OA group.

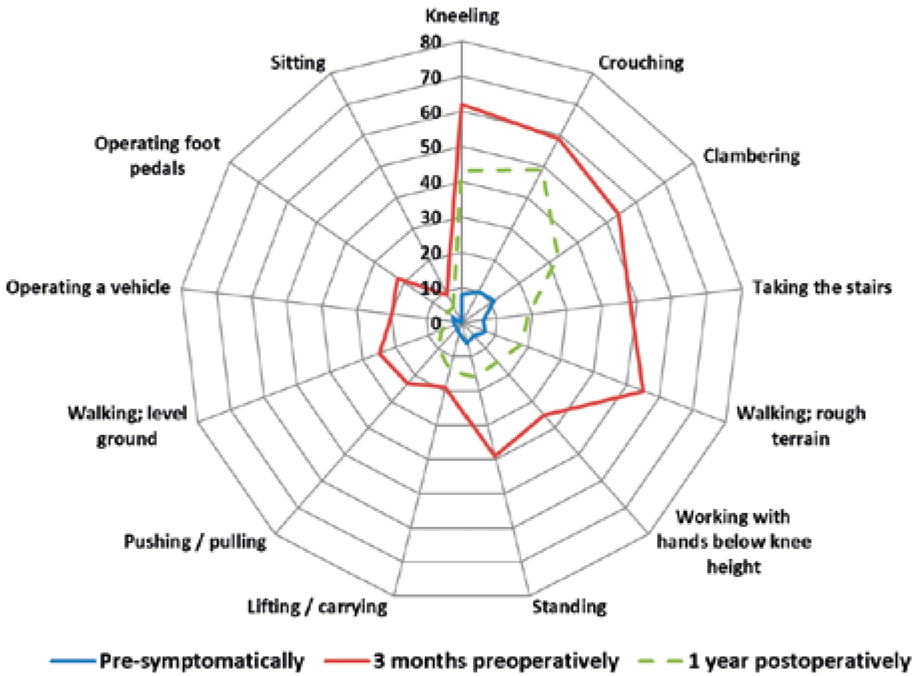

Fig. 5 Reported difficulty with work-related tasks of the total group at three time points. The percentage of patients that experienced severe difficulty with each of the 13 activities is depicted at three timepoints.

DISCUSSION

The most important findings of the present study were that 77% of patients could RTS after DFO, of whom 71% returned within 6 months. Furthermore, 91% of patients could RTW, of whom 81% returned within 6 months. There was no statistically significant difference in RTS and RTW between the subgroups of OA patients and non-OA patients.

The present study is the first to assess sports participation pre-symptomatically, 1 year pre- and postoperatively and at final follow-up, allowing for a good comparison of the effect of DFO on sports ability over time. Based on previous research[14,29], a return to the pre-symptomatic sports level was considered unlikely for most patients. This was confirmed by the reported sports ability at final follow-up, which was worse or much worse in 60% of patients compared to their best lifetime sports ability. Still, 45% performed sports ≥ 2 times/week and 41% performed sports for ≥ 3h/week. Finally, 45% of all sports activities performed at follow-up were intermediate- or high-impact activities. Compared to HTO, DFO patients showed a lower participation in high-impact activities (10 vs. 6%) and higher participation in intermediate-impact activities (32 vs. 39%)[14]. Nevertheless, participation in intermediate- and high-impact sports was considerably higher than after TKA (11%) and UKA (23%)[30]. This might be explained by more liberal surgeons' advice as well as higher functional benefits after DFO compared to KA, given the fact that native knee structures are preserved[8].

In addition, the present study is the first to report time to RTS after DFO. Half of the patients returned within 15 weeks and 71% returned within 6 months. Thus, 29% of patients took longer than 6 months to RTS. In TKA, average time to RTS was 13 weeks, compared to 12 weeks in UKA[30]. Therefore, DFO appears to show a functional benefit from retaining native knee kinematics, allowing demanding functional loading that would otherwise jeopardize the survival of a KA[8,11]. In contrast, time to RTS might be somewhat longer after DFO due to the extended rehabilitation following knee osteotomy[7].

Regarding RTW, almost all patients (91%) returned to work, which is high compared to reported numbers for surgical alternatives. Average RTW in HTO patients is 85%[14], and varies between 70 and 89% in TKA patients[31–33]. Yet, it must be noted that the mean age in our cohort was comparable to studies in HTO patients, and lower compared to studies in TKA patients. Furthermore, our study is the first to report time to RTW after DFO and found that 71% returned within 6 months. This is in line with findings in HTO patients, where the mean time to RTW was 16 weeks[14]. Given the higher mean age of the OA subgroup (49 vs. 28 years) and the presence of debilitating knee OA, it is remarkable that more patients appeared to return to work and time to RTW appeared shorter compared to the non-OA group. A possible explanation is that bone healing and functional recovery are faster after DFO for unicompartmental OA, compared to de-rotation osteotomies for rotational malalignment and combined femoral and tibial osteotomies, which were mainly performed in the non-OA group[7,9,34]. Concerning knee-demanding work activities, as anticipated, preoperatively patients experienced most difficulty with kneeling, crouching, clambering, walking on rough terrain and taking the stairs. One year postoperatively, the number of patients experiencing severe difficulties had decreased markedly for all work-related activities, except for crouching. These findings are consistent with those in TKA patients, who experienced severe difficulty with kneeling, crouching, clambering and taking the stairs preoperatively[32]. However, at 2–3 years follow-up, the total percentage of KA patients experiencing difficulties was higher for all activities, except for crouching, compared to DFO[32,35]. These findings indicate that DFO may provide equal or better work-related functional outcomes compared to KA.

Given the limited number of studies on RTS and RTW after DFO, a comparison with previous literature is difficult. De Carvalho et al. found that, after varising DFO for unicompartmental OA, 14 out of 15 patients (93%) returned to their preoperative activity level and 23 out of 26 patients (89%) returned to work[15]. The authors found a median Tegner score of 3.0 (range 1–7) both pre- and postoperatively, compared to a median Tegner score of 4.0 (range 0–10) pre-symptomatically and 3.0 (range 0–10) postoperatively in the present cohort. Thus, RTS was slightly higher in De Carvalho's cohort, while the Tegner score was higher in the present study. This difference cannot be explained by age distribution, which was similar in both groups, or surgical indication, since subgroup analysis of the OA group in the present study showed similar findings. Thus, no clear reason could be identified for the difference between both studies. Another study investigated RTS in 13 young athletes participating in high-impact sports ≥ 4 times per week. All athletes returned to their prior level, which is a promising finding, indicating that even a return to high levels of athletic activity is possible after DFO[16].

Finally, finding the optimal treatment strategy for the increasing number of young patients with "old knees", who tend to have expectations that exceed the improvements a knee arthroplasty can deliver[3,4], remains challenging. According to the algorithm proposed by Arnold et al., the highest priority in any affected knee should be a balanced mechanical leg axis[3]. Due to the high variety of indications and broad age range in our study population, our results are likely more generalizable to the total DFO population than previously reported results in young athletes and lateral OA patients[15,16]. Consequently, these findings can be of use for shared decision making in a broader DFO population. The general view arising from current limited literature is that RTS and RTW after DFO is possible and might even be higher compared to surgical alternatives such as TKA and UKA.

An important limitation of the present study is the retrospective design, which makes our findings prone to recall bias. Future prospective studies are needed to control for this aspect and to further elaborate on the fulfilment of patients' expectations after DFO. In addition, no validated questionnaire exists to ascertain participation in sport and work. To improve comparability, a sports questionnaire was used that has been previously described in patients undergoing TKA, UKA and HTO[18,19,21], and the validated Tegner and Lysholm score were added. For the work-related outcomes, the validated WORQ questionnaire was used to increase reliability and validity of our findings[27,28].

CONCLUSION

In conclusion, almost eight out of ten patients return to sport and nine out of ten patients return to work after DFO. These are clinically relevant findings that further justify DFO as a surgical alternative to KA in young, active knee OA patients who wish to return to high activity levels.

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CHAPTER 3

Return to Sport and Work after Randomization for Knee Distraction versus High Tibial Osteotomy: Is There a Difference?

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ABSTRACT

Knee joint distraction (KJD) is a novel technique for relatively young knee osteoarthritis (OA) patients. With KJD, an external distraction device creates temporary total absence of contact between cartilage surfaces, which results in pain relief and possibly limits the progression of knee OA. Recently, KJD showed similar clinical outcomes compared with high tibial osteotomy (HTO). Yet, no comparative data exist regarding return to sport (RTS) and return to work (RTW) after KJD. Therefore, our aim was to compare RTS and RTW between KJD and HTO. We performed a cross-sectional follow-up study in patients <65 years who previously participated in a randomized controlled trial comparing KJD and HTO. Out of 62 eligible patients, 55 patients responded and 51 completed the questionnaire (16 KJDs and 35 HTOs) at 5-year follow-up. The primary outcome measures were the percentages of RTS and RTW. Secondary outcome measures included time to RTS/RTW, and pre- and postoperative Tegner's (higher is more active), and Work Osteoarthritis or Joint-Replacement Questionnaire (WORQ) scores (higher is better work ability). Patients' baseline characteristics did not differ. In total 1 year after KJD, 79% returned to sport versus 80% after HTO (not significant [n.s.]). RTS <6 months was 73 and 75%, respectively (n.s.). RTW 1 year after KJD was 94 versus 97% after HTO (n.s.), and 91 versus 87% <6 months (n.s.). The median Tegner's score decreased from 5.0 to 3.5 after KJD, and from 5.0 to 3.0 after HTO (n.s.). The mean WORQ score improvement was higher after HTO (16 ± 16) than after KJD (6 ± 13; $p = 0.04$). Thus, no differences were found for sport and work participation between KJD and HTO in our small, though first ever, cohort. Overall, these findings may support further investigation into KJD as a possible joint-preserving option for challenging "young" knee OA patients.

INTRODUCTION

Demand for knee arthroplasty (KA) is rising worldwide, especially in younger patients. If this trend continues, by 2035 up to 50% of KAs will be performed in patients younger than 65 years of age[1–3]. Younger knee osteoarthritis (OA) patients are generally more active, often still working, and therefore frequently have high demands and expectations from their surgery[4,5]. Also, KA patients 50 to 65 years of age have a significantly increased risk of revision surgery, compared with older populations (>65 years), with one study reporting a lifetime revision risk of one in three in patients aged 50 to 55 years[6,7]. Also, higher rates of dissatisfaction have been reported in younger patients[8], and up to 50% of younger patients reported residual symptoms and limitations after contemporary total KA[9]. Hence, performing KA in this younger active population is unappealing to many surgeons, and as a treatment not a guarantee for satisfaction and return to desired activities for patients. Consequently, KA is often postponed in younger patients with severe functional limitations, who now find themselves trapped inside the so-called "treatment gap"[10,11].

To address this gap, the global interest for joint-sparing alternatives has significantly increased. Cartilage regeneration techniques are progressively studied, but still lack the scientific basis to justify broad implementation of these techniques in clinical practice[12–14]. However, osteochondral allograft transplantation techniques can successfully restore joint function in young (up to 55 years of age) and active patients with large focal or multifocal articular cartilage lesions[15–17]. High tibial osteotomy (HTO) has also been increasingly advocated to treat this younger patient population[18,19] and thus expected to rise in the coming years. The pooled 10-year HTO survivorship, using KA as an endpoint, was 92% for opening-wedge HTO and 85% for closing wedge HTO[20]. Also, rates of return to sport (RTS) of 82 to 85% and return to work (RTW) of 85 to 95% have been reported after HTO[21–23].

Knee joint distraction (KJD) is a less well known but promising alternative joint-sparing treatment option in relatively young OA patients with severe complaints. With KJD, an external distraction device creates a temporary load reduction between focal areas of cartilage surfaces in the knee[24]. Intema et al. showed that KJD treatment resulted in radiographic improvement of joint space width (JSW) and increased cartilage thickness on MRI, indicative of tissue structure modification that may have beneficial effects on patients' knee pain and symptoms[25]. A preserved treatment effect up to 5 years has been described with increased minimum JSW at 5-year post-treatment compared with pretreatment[26]. In addition, a randomized controlled trial (RCT) comparing KJD with HTO, for patients with medial compartment OA who were eligible for HTO, reported similar improvements for both groups in patient-reported clinical outcomes including the knee injury and osteoarthritis outcome score (KOOS), Western Ontario and McMaster Universities Osteoarthritis Index, VAS pain scores, and EQ-5D[27,28]. The most important difference regarding morbidity was the high incidence of pin tract infections in the KJD group (59%) compared with 5% of wound infections in the HTO group[27]. While the authors discussed the possibility of undertaking knee-demanding activities after KJD, including recreational sports, they did not report actual RTS and RTW rates.

Therefore, our aim was to compare RTS and RTW rates, including time to RTS and RTW, between these KJD and HTO patients who participated in the RCT. We hypothesized that KJD may lead to similar outcomes regarding participation in sport and work, and similar self-reported physical activity and work ability, compared with HTO.

METHODS

Study Design and Patient Selection

We performed a survey among patients that were included in a RCT between 2011 and 2013, comparing KJD and HTO[27]. All patients of the RCT were eligible for inclusion in the present study, since they were <65 years of age at inclusion and thus of working age. The inclusion criteria for the original RCT comparing KJD and HTO were medial tibiofemoral OA considered for HTO, normal range of motion (≥120 degrees of knee flexion), body mass index <35 kg/m^2 and normal stability. An overview of the inclusion and exclusion criteria of the RCT can be found online (Supplementary Table 1 [available in online version]). Of the included sample of 69 patients (23 KJDs and 46 HTOs), two KJD patients were excluded due to inoperability, one HTO patient was diagnosed with multiple sclerosis and could not complete follow-up, and four patients (two KJDs and two HTOs) declared that they did not want to participate in follow-up studies (Fig. 1). An online questionnaire was developed using an electronic data management system (Castor EDC, www.castoredc.com). The remaining patients received an invitation by email between September and October 2017, followed by a maximum of two email reminders. Institutional review board approval was obtained from the local medical ethical review board (reference number 17–538/C) prior to initiation of this study. The study was performed in accordance with the ethical principles from the Declaration of Helsinki, and all patients gave written informed consent.

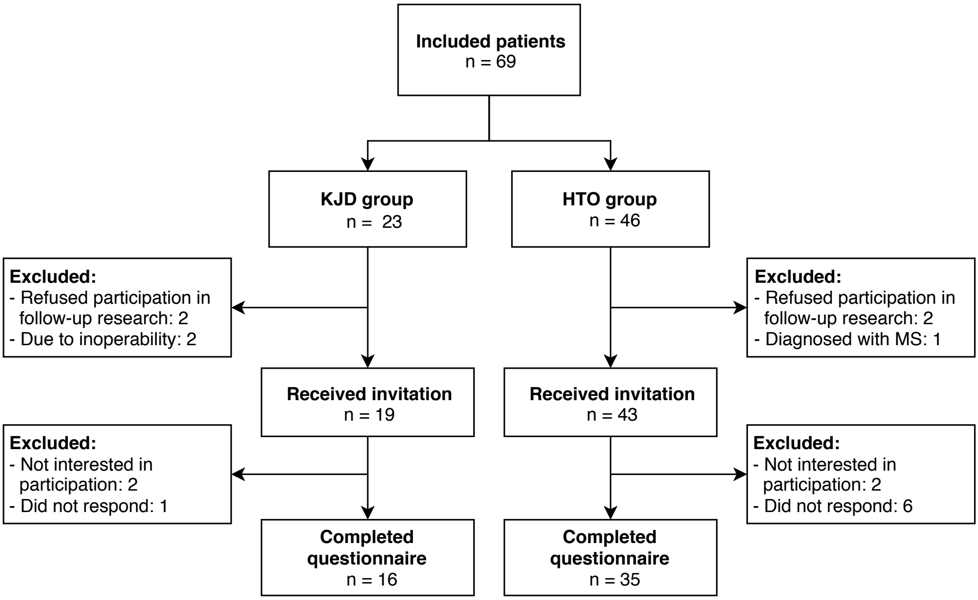


Fig. 1 Inclusion flowchart
HTO, high tibial osteotomy; KJD, knee joint distraction; MS, multiple sclerosis

Surgical Techniques and Postoperative Rehabilitation

A detailed description of surgical techniques can be found in previous publications[24,27,28]. All HTO patients underwent a bi-planar and medial opening-wedge osteotomy[29] by one of three experienced surgeons. Preoperatively, the desired correction was determined on full leg standing radiographs using the Miniaci method[30]. For fixation, the TomoFix plate and screws (DePuy Synthes, Switzerland) or Synthes Locking Compression Plate (DePuy Synthes, Switzerland) were used (Fig. 2A). Postoperatively, patients were allowed partial weight-bearing (up to 20 kg) for 6 weeks, followed by gradual full weight-bearing. Plate removal was routinely performed in all patients within 2 years. For KJD, an external distraction device was used: two dynamic monotubes (Triax, Stryker, 45 kg spring with 2.5 mm displacement) were fixated to eight bone pins (Fig. 2B). The tubes were distracted 2 mm intraoperatively, followed by 1 mm of distraction per day up to a total of 5 mm of joint distraction. Weight-bearing radiographs were taken on day 4 to check the amount of distraction. When adequate distraction was obtained, patients were discharged and allowed full weight-bearing with crutches. Radiographic evaluation and pin tract inspection were performed after 3 weeks. The frame and pins were surgically removed after 6 weeks, followed by gradual increase to full weight-bearing in 6 weeks. Both HTO and KJD patients were prescribed subcutaneous low molecular weight heparin for 6 and 9 weeks, respectively. All patients were referred to regular outpatient physical therapy.

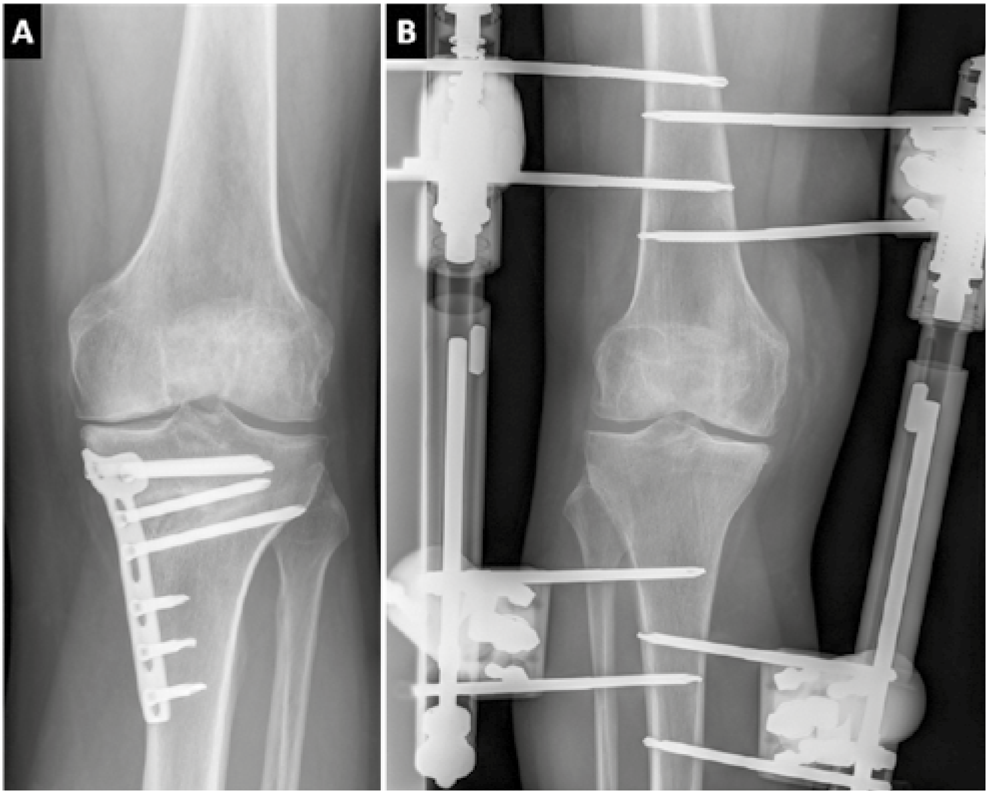


Fig. 2 Examples of postoperative radiographs, **A** left knee treated with high tibial osteotomy, **B** right knee treated with knee joint distraction.

Sport and Work Outcome Measures

Our primary outcome measures were the RTS and RTW rates after HTO and KJD at 6 and 12 months. Secondary outcome measures included time to RTS and RTW, the frequency, duration and type of performed sports, experienced difficulty performing work-related knee demanding activities, and physical requirements of the jobs performed. Patients were asked to retrospectively report sports participation at four time points (presymptomatically, 1 year preoperatively, 1 year postoperatively, and at final follow-up). RTS was defined as a patient participating in one or more sports preoperatively (presymptomatically or 1 year preoperatively), who resumed participation in one or more sports postoperatively (1 year postoperatively or final follow-up). Also, sports ability at follow-up, compared with the patient's best sports ability in their lifetime, was asked ("much worse," "worse," "unchanged," "improved," and "much improved"). To assess the level of impact, sports activities were rated as low-, intermediate-, or high-impact according to the classification by Vail et al.[31]. Finally, the validated Tegner's activity scale (0–10; higher is more physically active) and Lysholm's score (0–100; higher is better function) were collected[32]. To assess experienced difficulty with work-related knee demanding activities, the 13-item validated "Work Osteoarthritis or Joint-Replacement Questionnaire" (WORQ) questionnaire was used[33]. Patients grade the difficulty that they experience when performing different activities on a 5-point Likert scale, with 4 indicating "no difficulty" and 0 indicating "extreme difficulty/unable to perform". Patients were asked to retrospectively grade the difficulty at three time points: presymptomatically, 3 months preoperatively, and 1 year postoperatively. The sum of the item scores can be converted to a 0 to 100 score, where 0 represents the worst and 100 the best possible score[33]. A score of 71 or more is classified as being satisfied with their work ability with respect to the knee, while a score of 50 or less is considered as being unsatisfied. In addition, job titles were classified as light, medium, or heavy workload by two occupational experts, who independently scored all jobs based on work-related physical demands of the knee[34,35]. A more detailed description of the questionnaire can be found in a previous publication[36].

Statistical Analysis

A sample size calculation was performed for the primary RCT[24]. For the present study, a convenience sample was used, aiming for a response rate >80%. Demographic data, and pre- and postoperative sport and work participation were analysed using descriptive statistics. Also, descriptive statistics were used to analyse time to RTS and RTW, frequency, and duration of sports participation. RTS rate was calculated by selecting all patients that participated in one or more sports either presymptomatically, preoperatively or both, and calculating which percentage of these patients could RTS at 6 months and 1 year postoperatively. Given the 6-week delay in return to normal activities due to the distraction device, differences between KJD and HTO in RTS and RTW rates were analysed at 2, 4, and 6 months, and at 1-year follow-up, using the Chi-square test. To test for differences in sports participation (level, frequency, hours/week) and work participation (hours/week, workload) between groups, the Fisher's exact test was used. The Wilcoxon signed-rank test was used to compare presymptomatic and postoperative Tegner's scores within groups. To test for differences between the KJD and HTO group, the Mann–Whitney U test was used for the ΔTegner's score (postoperative minus presymptomatic score) and the unpaired t-test was used for the postoperative Lysholm's score. The change in mean total WORQ scores from preoperative to final follow-up was compared using the unpaired t-test. Next, the scores of all WORQ items at the three time points were dichotomized to determine how many patients experienced severe difficulty with a work-related knee-demanding activity. "Severe difficulty" and "extreme difficulty/unable to perform" were classified as "severe difficulty". "Moderate difficulty", "mild difficulty", and "no difficulty" were classified as "no severe difficulty". A *p*-value of $p < 0.05$ was considered significant. All statistical analyses were performed with SPSS for Windows (Version 24.0. Armonk, NY: IBM Corp.).

RESULTS

Out of 62 eligible patients, 55 patients responded (89%) and 51 patients completed the questionnaire (82%). Two KJD patients and two HTO patients declared that they were not interested in participation. Baseline characteristics of the respondents are presented in Table 1.

Table 1 Baseline characteristics of the knee joint distraction group and high tibial osteotomy group

Outcome measure	**KJD (n = 16)**	**HTO (n = 35)**	***p*-value**
Mean follow-up, y (SD)	5.1 (0.7)	5.0 (0.6)	n.s.
Mean age at surgery, y (SD)	50.5 (4.8)	49.6 (6.9)	n.s.
Sex, female (%)	3 (19)	15 (43)	n.s.
Mean BMI, kg/m² (SD)	27.1 (3.2)	27.2 (3.4)	n.s.
Side, right (%)	10 (63)	18 (51)	n.s.
OA grade (Kellgren-Lawrence)			n.s.
0	0 (0)	1 (3)	
I	4 (25)	5 (14)	
II	3 (19)	10 (29)	
III	8 (50)	16 (46)	
IV	1 (6)	3 (9)	
Tibiofemoral axis, degrees (SD)	6.1 (2.1)	6.2 (2.4)	n.s.
Previous surgery, yes (%)			
ACL reconstruction	2 (13)	2 (6)	
Fixation OD lesion	0 (0)	1 (3)	
Knee arthroscopy Lateral release + tibial tuberosity transposition Open medial meniscectomy	11 (69) 0 (0) 0 (0)	26 (74) 1 (3) 2 (6)	

ACL, anterior cruciate ligament; BMI, body mass index; HTO, high tibial osteotomy; KJD, knee joint distraction; n.s., not significant; OA, osteoarthritis; OD, osteochondritis dissecans; SD, standard deviation

Sport-Related Outcomes

Out of 51 respondents, 44 patients had participated in one or more sports at some time point preoperatively (Table 2). In the KJD group, 11 out of 14 patients (79%) returned to one or more sports, compared with 24 out of 30 patients (80%) in the HTO group. For the KJD and HTO group, the number of patients that returned to sport within 4 months was 18 and 33%, respectively (n.s.) and within 6 months 73% and 75%, respectively (Fig. 3). No significant differences were found between both groups for sports frequency (times and hours per week) at any of the reported time points (Table 3). A shift from participation in high- and intermediate-impact sports to participation in intermediate- and low-impact sports was reported in both groups (Table 3; Supplementary Table 2 [available in online version]). Compared with the patient's best sports ability in their lifetime, all KJD patients (100%) reported worse or much worse sports ability at final follow-up, compared with worse or much worse in 25 HTO patients (83%), unchanged in one HTO patient (3%) and improved or much improved in four HTO patients (13%; n.s.). In the KJD group, the median Tegner's score decreased from 5.0 (interquartile range [IQR]: 4.0–5.0) presymptomatically to 3.5 (IQR: 3.0–4.0) 1 year postoperatively ($p = 0.02$). In the HTO group, the median Tegner's score decreased from 5.0 (IQR: 4.0–7.0) presymptomatically to 3.0 (IQR: 2.0–4.0) 1 year postoperatively ($p < 0.001$). The median ΔTegner's score was –1.0 (IQR: –2.0 to 0) in the KJD group, compared with –1.0 (IQR: –3.0 to 0) in the HTO group (n.s.). The mean Lysholm's score at follow-up was 67 (± 10) in the KJD group compared with 65 (± 23) in the HTO group (n.s.).

Table 2 Sport participation in one or more sports at each time point

	KJD (n = 14)	**HTO (n = 30)**	***p*-value**
Presymptomatic, *n* (%)	14 (100)	30 (100)	
- Recreational	3 (21)	10 (33)	1.00
- Competitive/professional	11 (79)	20 (67)	
1 year preoperative, *n* (%)	12 (86)	26 (87)	
- Recreational	10 (83)	21 (81)	1.00
- Competitive/professional	2 (17)	5 (19)	
1 year postoperative, *n* (%)	9 (64)	20 (67)	
- Recreational	9 (100)	17 (85)	0.91
- Competitive/professional	–	3 (15)	
Final follow-up, *n* (%)	10 (71)	22 (73)	
- Recreational	10 (100)	19 (86)	1.00
- Competitive/professional	–	3 (14)	

HTO, high tibial osteotomy; KJD, knee joint distractionHTO, high tibial osteotomy; KJD, knee joint distraction

Table 3 Sports frequency, level of impact and time to RTS for the KJD group and HTO group at four time points

	Presymptomatic n (%)		**1 year pre-operative n (%)**		**1 year post-operative n (%)**		**At final follow-up n (%)**	
	KJD (n = 14)	**HTO** (n = 30)	**KJD** (n = 14)	**HTO** (n = 30)	**KJD** (n = 14)	**HTO** (n = 30)	**KJD** (n = 14)	**HTO** (n = 30)
Sports frequency, times/wk[a]								
No participation	–	–	2 (14)	4 (13)	5 (36)	9 (30)	4 (29)	8 (27)
≤1	1 (7)	4 (13)	1 (7)	9 (30)	2 (14)	11 (37)	3 (22)	11 (37)
2	1 (7)	6 (20)	6 (43)	8 (27)	5 (36)	4 (13)	3 (22)	7 (23)
3	5 (36)	8 (27)	4 (29)	6 (20)	2 (14)	2 (7)	2 (14)	2 (7)
≥4	7 (50)	12 (40)	1 (7)	3 (10)	–	4 (13)	2 (14)	2 (7)
Sports participation, h/wk[a]								
No participation	–	–	2 (14)	4 (13)	5 (36)	9 (30)	4 (29)	8 (27)
0–2	3 (22)	3 (10)	5 (36)	11 (37)	4 (29)	9 (30)	4 (29)	11 (37)
3–4	2 (14)	6 (20)	4 (29)	4 (13)	3 (21)	8 (27)	2 (14)	7 (23)
5–6	2 (14)	10 (33)	2 (14)	11 (37)	2 (14)	4 (13)	3 (21)	2 (7)
>6	7 (50)	11 (37)	1 (7)	-	-	-	1 (7)	2 (7)
Level of impact								
Low	38 (37)	67 (34)	23 (58)	41 (47)	21 (66)	42 (55)	25 (66)	43 (61)
Intermediate	28 (28)	81 (41)	11 (27)	33 (38)	9 (28)	31 (41)	12 (32)	23 (32)
High	35 (35)	49 (25)	6 (15)	13 (15)	2 (6)	3 (4)	1 (3)	5 (7)
Total sports	101	197	40	87	32	76	38	71

[a] Due to rounding sum score can be >100%
h, hour; HTO, high tibial osteotomy; KJD, knee joint distraction; wk, week

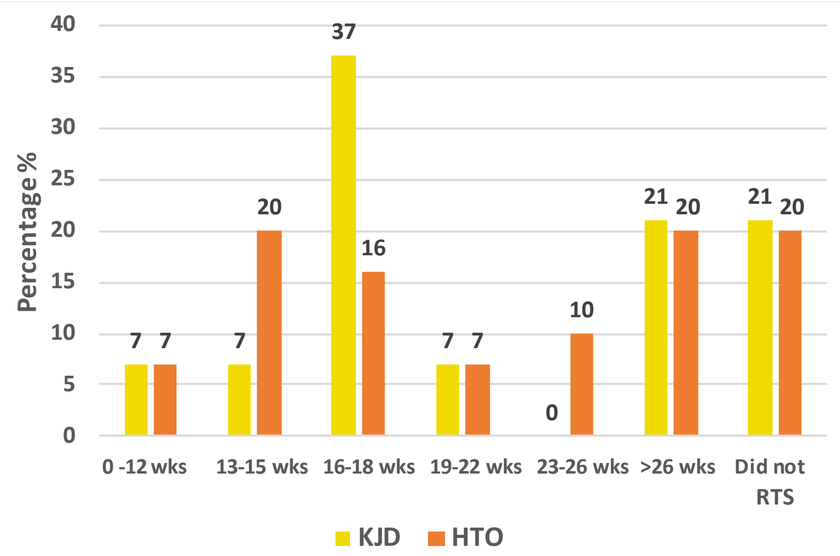


Fig. 3 Time to return to sport for the knee joint distraction group and high tibial osteotomy group.

Work-Related Outcomes

In the KJD group, 16 patients (100%) were working before the onset of restricting knee symptoms, and 3 months preoperatively 15 patients (94%) were still working. In the HTO group, 32 out of 35 patients (91%) were working before the onset of knee symptoms, and 3 months preoperatively 29 patients (83%) were still working. Postoperatively, 15 out of 16 KJD patients (94%) returned to work, compared with 31 out of 32 HTO patients (97%; n.s.). The RTW rate within 2 months was 27% in the KJD group and 45% in the HTO group (n.s.), the RTW rate within 4 months was 53% in the KJD group and 72% in the HTO group (n.s.), and the RTW rate within 6 months was 91% in the KJD group and 87% in the HTO group (Fig. 4; n.s.). None of the KJD patients and one HTO patient reported knee complaints as the reason for no RTW. The presymptomatic workload, preoperative workload, and changes in postoperative workload did not significantly differ between both groups (Table 4). The number of working hours also did not significantly differ between both groups 3 months preoperatively, 1 year postoperatively, and at final follow-up (Supplementary Table 3 [available in online version]). The improvement (Δ) in mean WORQ scores from preoperatively to postoperatively was higher in the HTO group (16 ± 16) than in the KJD group (6 ± 13; $p = 0.04$). For the KJD group, most patients experienced severe difficulty with kneeling (44%), clambering (38%), and walking on rough terrain preoperatively (38%) (Fig. 5a). The largest postoperative improvements were reported for walking on rough terrain (–25% reporting extreme difficulty), clambering (–19%), and kneeling (–19%) (Fig. 5a). For the HTO group, ≥50% of patients experienced severe difficulty with kneeling, crouching, clambering, and taking the stairs 3 months preoperatively (Fig. 5b). The largest postoperative improvements were reported for taking the stairs (–38%), clambering (–32%), and kneeling (–29%) (Fig. 5b).

Table 4 Pre-symptomatic and preoperative workload, and postoperative changes in workload, for the HTO group and KJD group

Workload	Pre-symptomatic HTO (%)	Pre-symptomatic KJD (%)	Pre-operative HTO (%)	Pre-operative KJD (%)	Postoperative change in workload	HTO (%)	KJD (%)
Light	62	44	66	47	Lighter	–	7
Intermediate	19	19	17	13	Equal	91	93
High	19	37	17	40	Higher	9	–
p-value	0.36		0.25			0.19	

HTO, high tibial osteotomy; KJD, knee joint distraction

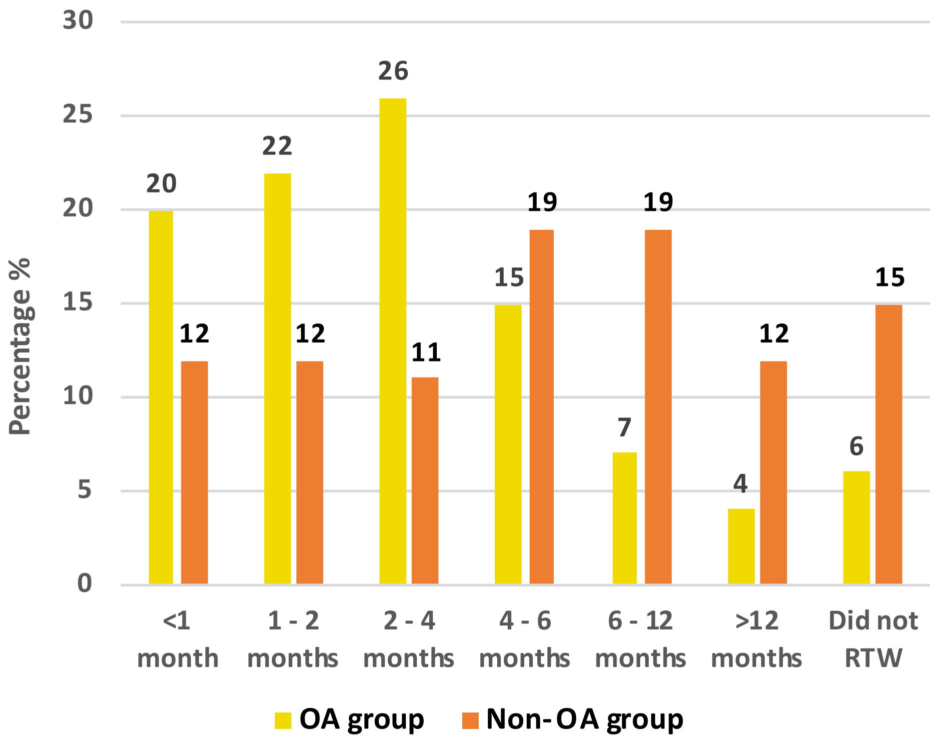


Fig. 4 Time to return to work for the knee joint distraction group and high tibial osteotomy group.

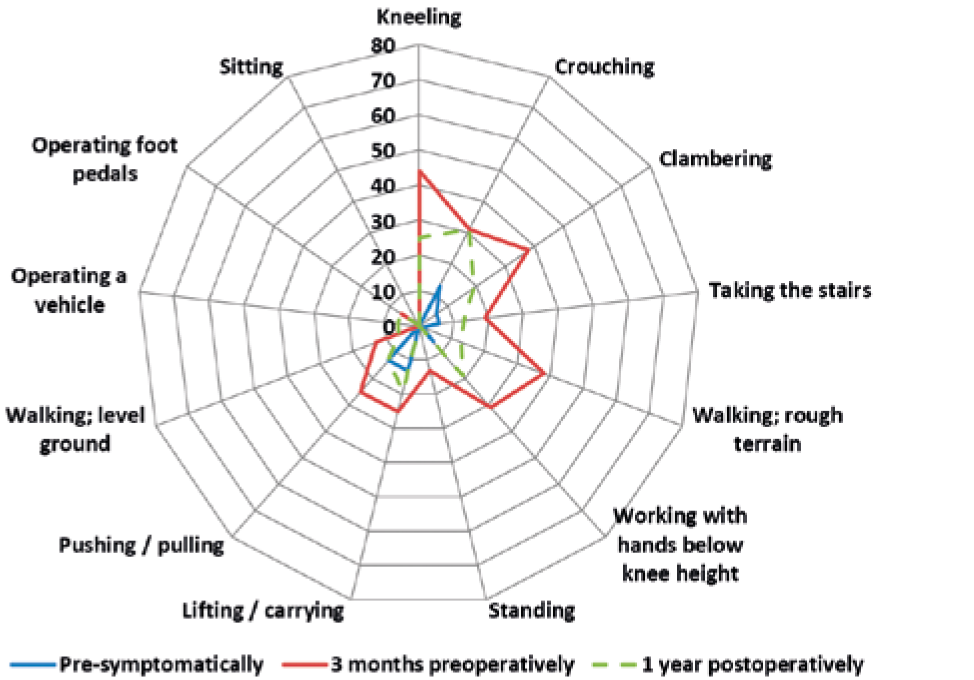
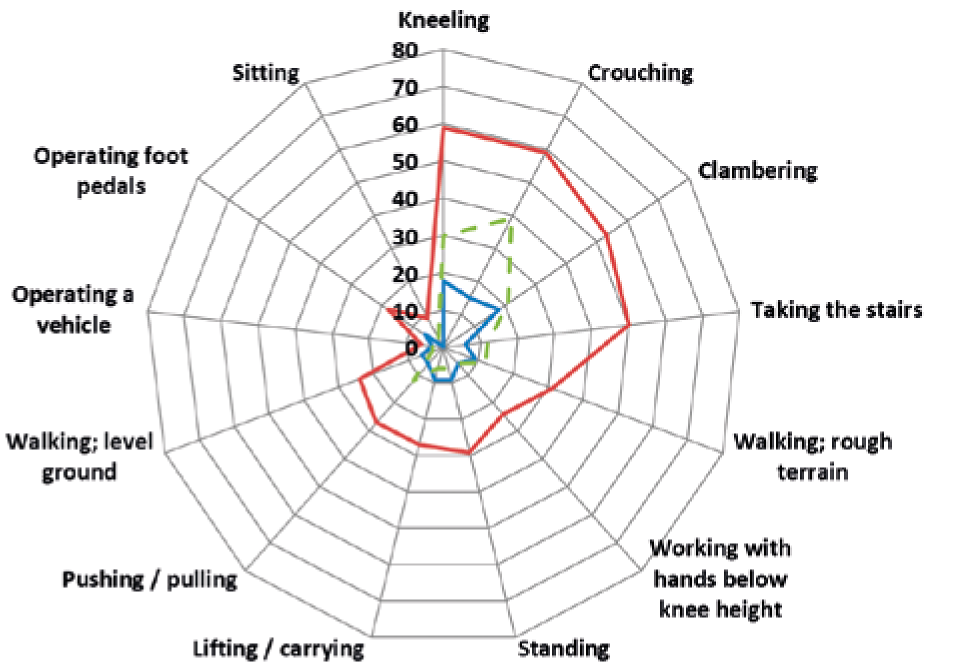


Fig. 5 A, B Reported difficulty with 13 work-related activities for the knee joint distraction group **A** and high tibial osteotomy group **B** at three time points. The percentage of patients that experienced severe difficulty is depicted for each task.



DISCUSSION

The present survey among patients who previously participated in a RCT comparing KJD with HTO showed similar sport- and work-related outcomes for both groups. The RTS rate was 79% in the KJD group, compared with 80% in the HTO group. The RTW rate was 94% in the KJD group compared with 97% in the HTO group. Overall, 7 out of 10 patients returned to sports within 6 months and 9 out of 10 patients returned to work within 6 months. Time to RTS and RTW did not differ between both groups. The improvement in mean WORQ score from pre- to postoperative was slightly higher in the HTO group. Thus, our initial findings, the first RTS/RTW data in KJD patients may support the hypothesis that KJD might result in comparable postoperative sport and work participation, compared with HTO, although larger cohorts are clearly warranted to verify this hypothesis.

No data exist on RTS after KJD, but the present RTS rates of 79% after KJD and 80% after HTO are in line with the RTS rate of 85% after HTO that was found in a meta-analysis[21]. Although the overall time to RTS did not differ, we did observe a trend of more HTO patients returning within 4 months (33 vs. 18%), which was likely not statistically significant due to the small sample size. A possible explanation for the lower percentage of KJD patients that RTS ≤4 months is the distraction device[26]. Interestingly, no KJD patients reported improved sports ability at follow-up compared with 13% of HTO patients. Still, the median Tegner's score was 3.5 in the KJD group compared with 3.0 in the HTO group, which could indicate somewhat higher mean postoperative activity levels for the KJD group. For both groups, the postoperative Tegner's scores were lower than the reported presymptomatic Tegner's scores. Eleven previous studies on HTO reported median postoperative Tegner's scores ranging from 2.5 to 5.9, where the latter was found in a specific population (athletes)[21].

Next, participation in low-, intermediate-, and high-impact sports did not differ either. Here, we observed the same trend of lower postoperative participation in intermediate- and high-impact sports that was described previously after distal femoral osteotomy, HTO and KA[22,36,37]. Lastly, sports participation in terms of level, times per week, and hours per week showed similar trends between both groups, namely postoperative participation at a lower level and less frequently. This decline is also in line with previous findings after HTO and KA[21,37]. Still, at final follow-up patients reported sports participation levels and frequencies comparable to 1 year postoperatively, indicating a sustained treatment effect over 5 years. Thus, our initial findings appear to be in line with previous studies on RTS after joint-sparing surgery for knee OA.

The reported RTW rates for KJD and HTO (94 and 97%, respectively) were higher than expected, since a systematic review found a pooled estimate of 85% RTW after HTO[21]. For KJD, this was the first study to report RTW, hampering comparison with existing literature. Still, 94% RTW is an encouraging finding, possibly facilitated by maintaining the native knee joint, as well as removing all external material after 6 weeks, compared with plate removal after 1 to 2 years in the HTO group. Again, larger cohort studies are mandatory to verify RTW rates after KJD. Next, time to RTW did not differ overall, although 53% of KJD patients returned after ≤4 months compared with 72% in the HTO group. As stated, this difference might be explained by the 6-week period of knee immobilization for KJD, which limits rehabilitation and thus slows the RTW activities. RTW outcomes should be further analysed in adequately powered studies, since slower RTW after KJD may be clinically meaningful to the patient, and also has a negative societal impact given the financial consequences of slower RTW.

Next, the improvement in WORQ scores was significantly higher in the HTO group (16 vs. 6 points), compared with KJD. While Kievit et al. reported a difference of 13 points for the WORQ to be clinically meaningful to the patient[33], a difference of 10 points in favour of HTO may certainly indicate a better postoperative ability to perform knee-demanding activities, compared with KJD. Additionally, the mean WORQ score of 73 in the HTO group was above the satisfaction threshold of 71[33], while the mean score of 69 in the KJD group was slightly below this threshold. In comparison, Kievit et al. reported mean WORQ scores of 71 after total knee arthroplasty (TKA) and 77 after unicompartmental knee arthroplasty (UKA)[38]. As expected, kneeling and crouching presented most difficulty for both groups postoperatively. Yet, both groups appeared to experience less postoperative difficulty with these activities compared with TKA and UKA patients[38], although this comparison is hampered by the difference in mean age (50 years in our cohort vs. 60 years in the KA cohort). Thus, regarding work-related outcome measures, HTO showed better outcomes than KJD in the present study.

Although KJD has shown promise in the treatment of knee OA, the current scientific basis remains small and literature on long-term outcomes is lacking[39]. Therefore, patient counselling should include these existing uncertainties, and the fact that TKA showed an overall better response in clinical outcome parameters at 2 years, including the total KOOS, VAS pain, and EQ-5D, compared with KJD in the only RCT to date[28]. Yet, 15 out of 18 patients in the KJD group, who were initially indicated for TKA, had still not undergone TKA at 5-year follow-up[26]. Based on these findings, the authors concluded that KJD should not be considered a TKA replacement but rather a new treatment option to possibly postpone primary TKA[26,28]. Regarding sport and work participation, a significantly increased revision risk has been reported in younger and active TKA patients[6,7]. Clearly, maintaining the native knee joint decreases the future risk of prosthesis wear and associated revision procedures if KA is eventually performed. Thus, for patients with invalidating knee OA who wish to RTS and work activities, KJD may become a viable treatment option and a possible alternative to HTO. Yet, much work remains to be done to provide a broader scientific basis for KJD.

In the only RCT to date, KJD and HTO showed similar clinical outcomes[27,28]. However, 13 KJD patients (59%) developed pin tract infections, the most frequent complication after KJD[27]. Nine patients were treated with oral antibiotics, while three patients were administered intravenous antibiotics and two patients required surgical debridement. In contrast, only two HTO patients (4%) developed wound infections and were treated with oral and intravenous antibiotics, respectively. Also, KJD patients experienced more discomfort with activities of daily living the first postoperative weeks due to the distraction device[40]. While KJD patients require standard surgical removal of the distraction device 6 weeks postoperatively, up to 71% of HTO patients require hardware removal, that is, a new operation with its associated risks due to hardware irritation[41]. Obviously, all the above should be discussed with the patient when considering KJD and HTO as treatment options for invalidating knee OA.

The most important limitation of the present study is the small group size for KJD, which limited statistical power for comparisons between the HTO and KJD group. However, this was expected given that only 103 KJD cases have been described in prospective studies worldwide[39]. Therefore, our findings may be considered a general indication of the expected RTS and RTW after KJD, and no definite conclusions can be drawn yet. Another limitation is our retrospective design. Preferably, future prospective studies on KJD should include sport and work outcome measures to control for this limitation. Finally, the small group size also complicates the generalizability and thus external validity of the present findings. Especially for KJD, distinct eligibility criteria as well as long-term outcome data clearly need to be established prior to broader implementation of this novel technique.

CONCLUSION

In the present first albeit small cohort study, KJD in patients indicated for HTO resulted in comparable postoperative participation in sport and work, compared with HTO. Overall time to RTS and RTW did not differ in our cohort, and HTO patients were slightly more satisfied with their performance of knee-demanding activities. These findings should be confirmed in larger cohort studies to further define the role of KJD in the treatment algorithm for the challenging population of “young” knee OA patients.

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PART II

PREDICTING PATIENT RELEVANT OUTCOMES FOR SPORT AND WORK

CHAPTER 4

Not Physical Activity, but Patient Beliefs and Expectations are Associated With Return to Work After Total Knee Arthroplasty

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ABSTRACT

Background After total knee arthroplasty (TKA), 17%-60% of the patients do not or only partially return to work (RTW). Reasons for no or partial RTW remain unclear, warranting further research. Physical activity (PA) has proven beneficial effects on work participation. Therefore, we hypothesized that preoperative PA is associated with RTW after TKA.

Methods Working TKA patients participating in an ongoing prospective cohort study were included. Preoperatively and 1 year postoperatively, patients were asked to define their work status and PA level according to the Dutch Recommendation for Health-Enhancing PA and the Fitnorm. Multivariate logistic regression analysis was performed to assess the effect of PA on RTW, taking into account established prognostic factors for RTW among TKA patients.

Results Of 283 eligible patients, 266 (93%) completed the questionnaires sufficiently. Preoperatively, 141 patients (54%) performed moderate PA for ≥5 d/wk and 42 (16%) performed intense PA for ≥3 d/wk. Concerning RTW, 178 patients (67%) reported full RTW, 59 patients (22%) partial RTW, and 29 patients (11%) no RTW. Preoperative PA was not associated with RTW. Patients who reported that their knee symptoms were not or only partially work-related had lower odds of no RTW (odds ratio 0.37, 95% confidence interval 0.17-0.81). Also, for each additional week patients expected to be absent from work, the likelihood of no RTW increased (odds ratio 1.11, 95% confidence interval 1.03-1.18).

Conclusion No association between preoperative PA and RTW after TKA was found. Patient beliefs and preoperative expectations did influence RTW and should be addressed to further improve RTW after TKA.

INTRODUCTION

In the Netherlands, an expected 57,900 patients will undergo total knee arthroplasty (TKA) in 2030[1]. The greatest increase in TKA is seen in patients who are of working age. Already, the number of TKA patients below 65 years of age tripled between 1995 and 2003 in the Netherlands, and this number is expected to rise further[1]. Similar trends of increasing numbers of TKA patients below 65 years of age have been identified in the United States and the United Kingdom[2,3]. For the United States, it is estimated that by 2030, up to 62% of TKAs will be performed in patients below 65 years of age[2], and for the United Kingdom, this estimation is 50% by 2035[3]. This growing TKA population of working age is dependent on their job to generate income, and thus considers return to their own work as one of the most important outcomes of surgery[4]. Although many patients do successfully return to work (RTW), a reported 17%-60% of patients do not or only partially RTW after TKA[5–7].

To improve RTW rates, analysis of factors influencing RTW after TKA is essential. However, the remarkable conclusion of a systematic review by Kuijer et al. in 2009[8] was that there was an almost complete lack of literature on prognostic factors for RTW after TKA. A second systematic review in 2014 identified only 3 studies that reported on determinants of work status after TKA[9]. Factors associated with a faster RTW included female sex, age <50 years, self-employment, better mental and physical health scores, less comorbidity, and a handicap accessible workplace[7,9,10]. A slower RTW was found in patients with lower preoperative pain levels, with more physically demanding jobs and in those receiving workers' compensation[9,10]. More recently, these determinants were confirmed in several clinical studies[5,11–13], as well as in a systematic review which identified 11 studies investigating 33 beneficial and limiting factors for RTW after TKA[14].

Although the abovementioned studies have identified several factors that influence RTW after TKA, these factors only partially explain why patients do not RTW after TKA, with a maximum explained variance of 50%, warranting further research[5]. None of the previous studies investigated the influence of preoperative physical activity (PA) on RTW. Evidence from a prospective cohort study, including 1228 workers, and a recent systematic review suggested that PA reduced sickness absence[15,16]. Workers with higher levels of PA were generally less likely to be absent from work because of sickness[15,17]. Also, Bernaards et al.[18] found that strenuous leisure time PA might prevent long-term absenteeism in a working population. These findings seem to indicate that PA has a beneficial influence on work participation.

Based on the abovementioned findings, we formulated the hypothesis that preoperative PA is associated with RTW after knee arthroplasty. If, apart from current knee function and sociodemographic and work characteristics, preoperative PA is indeed an independent determinant of RTW, health care professionals could try to improve PA before and after surgery to further optimize RTW after TKA.

MATERIALS AND METHODS

Study Design and Patient Selection

This study is based on TKA patients of working age participating in an on-going prospective longitudinal cohort study, the Longitudinal Leiden Orthopaedics Outcomes of Osteo-Arthritis Study (LOAS, Trial ID NTR3348), which aims to include all patients undergoing TKA at 6 regional hospitals and 1 university hospital in the Netherlands. Recruitment of patients in the LOAS has previously been described[19]. Patients were required to have a mental status allowing them to complete questionnaires, and had to understand the Dutch language. Patients with rheumatoid arthritis, a tumour, (hemi)paresis, or amputation of the leg, and patients undergoing a hemiarthroplasty or revision THA or TKA were excluded. All patients provided written informed consent. For the present study, a selection was made from this prospective cohort. Eligible patients were below 70 years of age and provided information on their work status and levels of PA preoperatively and 1 year postoperatively. In case of incomplete or unclear provision of data on working hours or postoperative work status, the primary investigator (AH) performed a telephone interview between January and March 2017. Of the 1211 TKA patients who completed both questionnaires, 928 patients (76%) did not work preoperatively, and 283 patients (24%) were working preoperatively and provided information on their RTW postoperatively. These patients were included in the present analysis (Fig. 1).

The study protocol was reviewed and approved by the local hospital review board (registration number P.12.047), associated with the regional Medical Research Ethics Committee.

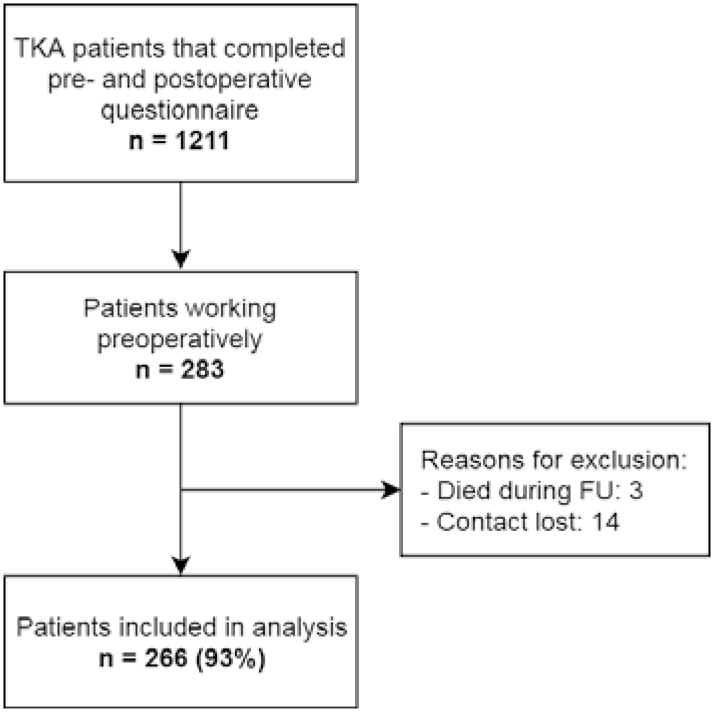

Fig. 1 Flowchart for patient inclusion and exclusion.
FU, follow-up; TKA, total knee arthroplasty

General Patient Characteristics

The following patient characteristics were collected: sex, age (years), and body mass index (BMI; kg/m^2). The presence of musculoskeletal and/or non-musculoskeletal comorbidities was asked.

Work Status

Preoperatively, all patients were asked to indicate whether they had a paid job (yes/no). The following aspects of the patients' preoperative working situation were recorded: number of hours worked per week; self-employed or salaried; absenteeism from work because of knee complaints (yes/no); and the presence of work adaptions (yes/no), with yes including at least one of the following: change of tasks; performing fewer tasks; changes in working hours; other work-related adaptations or devices. Job title was recorded and classified as light, medium, or heavy, in terms of its physical demands on the knee, by 2 occupational experts who independently scored all jobs based on work-related physical demands. The scoring system was derived from the evidence-based exposure criteria for the work relatedness of hip and knee osteoarthritis developed by the Netherlands Center for Occupational Diseases[20]. Postoperatively, all patients were asked whether they were currently working (yes/no). If yes, they were asked to report their current number of working hours per week. Based on the difference in preoperative and postoperative working hours, RTW was classified as: full return (no difference in, or higher postoperative working hours); partial return (working fewer hours post-operatively); or no RTW (complete work disability, pension, full-time sick leave, or out of work). The patients' preoperative expectations on RTW were examined using one item of the Hospital for Special Surgery Hip Replacement and Knee Replacement Expectations Surveys[21], formulated as: "the expectation regarding being able to have a paid job". The 5-point Likert scale was dichotomized into "back to normal" or "less than back to normal". Also, the expected number of postoperative working hours and expected timing of RTW (weeks) were asked.

Physical Activity

Preoperatively and at follow-up, all patients were asked to define their level of PA, using the Dutch Recommendation for Health-Enhancing PA (NNGB), which is based on recommendations by the American College of Sports Medicine[22]. For adults (aged 18-54 years), the recommendation is: at least half an hour of moderately intensive PA (4-6.5 metabolic equivalent of task, walking [5 km/h] or cycling [16 km/h] briskly), on at least 5 days a week. For persons over 55 years of age, the recommendation is: at least half an hour of moderately intensive PA (3-5 metabolic equivalent of task, walking [4 km/h], or cycling [10 km/h]) on at least 5 days a week. Patients were asked if they met the NNGB (yes/no). Also, patients were asked if they met the Fitnorm: at least 20 minutes of heavy intensive PA at least 3 times a week (yes/no)[22]. In addition, the self-reported number of hours patients participated in sport and leisure time activities were also taken into account.

Knee Function

To assess knee function, the Knee injury and Osteoarthritis Outcome Score (KOOS) was administered preoperatively and 1 year postoperatively. The KOOS includes subscales on symptoms, pain, activities of daily living, quality of life, and a subscale on sports activities (i.e. squatting, running, jumping, twisting/pivoting, kneeling)[23].

Statistical Analysis

Patient demographics, preoperative and postoperative working status, overall health status, and joint function were analysed with descriptive statistics for 3 separate groups: full RTW, partial RTW, and no RTW (Table 1). For each of the KOOS subscales, mean changes in scores between preoperative and 1 year postoperative were calculated, including the 95% confidence interval (CI). Because of the expected low number of patients not returning to work, RTW was divided into 2 categories: full RTW and partial/no RTW. First, associations between preoperative PA and postoperative work status were analysed with univariate regression analyses. Also, the association between preoperative sick leave and KOOS scores, and their association with preoperative PA, were analysed with univariate regression analysis. Next, logistic regression was performed to ascertain the effects of preoperative PA and other prognostic factors on the likelihood that patients did not fully RTW at 12 months. Three logistic regression models were created. Model 1 analysed the effect of PA on RTW, including the NNGB, the Fitnorm, and the number of hours participated in sport and leisure time activities. Model 2 analysed the effect of known prognostic factors for no RTW among TKA patients, based on literature and the univariate analysis. Model 3 analysed the combined effect of PA and known risk factors on RTW. Age, sex, and BMI were included as covariates in all the 3 models. A p-value < 0.05 was considered significant and 95% CIs were calculated. All statistical analyses were performed with SPSS for Windows (version 24.0; IBM Corp, Armonk, NY).

Table 1 Preoperative patient and work characteristics of working patients undergoing total knee arthroplasty (Total group) and specified per RTW category (yes/partial/no)

	Total group (n = 266)	**Full RTW (n = 178)**	**Partial RTW (n = 59)**	**No RTW (n = 29)**
Sex, female (%)	149 (56%)	98 (55%)	30 (51%)	21 (72%)
Mean age, y (SD)	58.3 (6.0)	58.0 (6.1)	59.1 (5.5)	58.3 (6.6)
18-45 [n (%)]	5 (2%)	3 (2%)	1 (2%)	1 (3%)
46-55 [n (%)]	71 (27%)	48 (27%)	15 (25%)	8 (28%)
>55 [n (%)]	190 (71%)	127 (71%)	43 (73%)	20 (69%)
BMI, kg/m^2 (SD)	29.6 (4.2)	29.5 (4.1)	29.1 (4.4)	30.9 (4.5)
Musculoskeletal comorbidities, yes	86 (48%)	62 (47%)	17 (50%)	7 (47%)
Non-musculoskeletal comorbidities, yes	161 (61%)	104 (65%)	35 (70%)	22 (79%)
Physical workload				
Light work	140 (54%)	97 (56%)	31 (52%)	12 (43%)
Medium work	71 (27%)	45 (26%)	14 (24%)	12 (43%)
Heavy work	48 (19%)	30 (17%)	14 (24%)	4 (14%)
Working hours [median (IQR)]	30 (20-40)	30 (20-40)	36 (21-40)	24 (19-35)
Sick leave, yes	74 (28%)	38 (22%)	24 (41%)	12 (44%)
Work adaptations, yes	83 (33%)	54 (32%)	21 (40%)	8 (30%)
Work status, %				
Employed	228 (87%)	152 (87%)	50 (85%)	26 (90%)
Self-employed	34 (13%)	22 (13%)	9 (15%)	3 (10%)

Self-reported work-relatedness of symptoms				
Not related	11 (5%)	9 (5%)	1 (2%)	1 (4%)
Partially related	108 (45%)	86 (52%)	17 (34%)	5 (23%)
Strongly related	119 (50%)	71 (43%)	32 (64%)	16 (73%)
Expected working hours postoperatively, h [median (IQR)]	30 (20-40)	30 (20-40)	32 (20-40)	25 (18-40)
Expected timing of RTW, wk [median (IQR)]	8 (6-12)	8 (5-10)	12 (7-15)	10 (8-12)
Expectations concerning working ability, back to presymptomatic state	172 (69%)	117 (70%)	41 (72%)	14 (52%)
Meeting preoperative NNGB, yes (%)	141 (54%)	91 (53%)	32 (55%)	18 (62%)
Meeting preoperative Fitnorm, yes (%)	42 (16%)	28 (16%)	10 (17%)	4 (14%)
Leisure/sport activities, h/wk [median (IQR)]	3 (0-6)	4 (2-6)	2 (0-5)	4 (0-9)
Expectations concerning sports ability, back to presymptomatic state	89 (35%)	57 (33%)	23 (40%)	9 (32%)
KOOS scores, mean (SD)				
Symptoms	42 (13)	43 (13)	41 (12)	35 (13)
Pain	35 (17)	35 (18)	36 (17)	28 (15)
ADL	42 (18)	43 (18)	43 (16)	35 (15)
Sport	9 (12)	10 (13)	7 (10)	3 (8)
Quality of life	34 (10)	34 (9)	34 (11)	32 (10)

All values are n (%) unless stated otherwise. Numbers of patients and percentages may vary slightly due to missing data points.
ADL, Activities of Daily Living; IQR, interquartile range; KOOS, Knee Injury and Osteoarthritis Outcome Score; NNGB, Dutch Recommendation for Health-Enhancing Physical Activity; RTW, return to work; SD, standard deviation

RESULTS

Patients

Of 283 patients working preoperatively, 3 patients died during follow-up (not related to TKA) and 14 patients did not complete the questionnaire sufficiently and could not be reached by telephone. Thus, 266 patients with a mean age of 58.3 years (SD ± 6.0) could be included in the analysis (response rate 93%). Table 1 presents the baseline characteristics for all included patients.

Associations Between Preoperative PA and Baseline Characteristics

Preoperatively, 141 patients (54%) met the NNGB and 42 patients (16%) met the Fitnorm (Table 1). Patients performed sport or leisure activities for a median of 3 hours per week (range 0-6). Patients' age and BMI were not associated with meeting the NNGB or the Fitnorm. Furthermore, none of the preoperative KOOS subscales were associated with meeting the NNGB or Fitnorm. Finally, complying to the NNGB preoperatively was not associated with preoperative sick leave. However, patients complying to the Fitnorm preoperatively were less likely to report preoperative sick leave ($p = 0.02$).

Return to Work

One year after TKA, of 266 patients, 178 patients (67%) had fully returned to work, 59 patients (22%) had partially returned to work, and 29 patients (11%) had not returned to work. Patients returned to work (fully or partially) at a median of 3 months (interquartile range [IQR] 2-5). Patients who were self-employed (n = 34) returned to work significantly faster (2 months, IQR 1-3) than employed patients (3 months, IQR 2-5, $p < 0.001$). For the patients who partially returned to work (n = 59), the median decrease in working hours was 8 h/wk (range 1-50).

Table 2 presents the results of univariate analysis of variables associated with RTW. Preoperative sick leave was a significant predictor of no RTW (odds ratio [OR] 2.63, 95% CI 1.51-4.61). Also, patients who believed that their knee symptoms were not related to their work were more likely to RTW (OR 0.38, 95% CI 0.21-0.69). Patients who did RTW expected to be absent from work significantly shorter than the patients who did not RTW (median 8 vs 12 weeks, OR 1.12, 95% CI 1.06-1.18). Finally, a trend was present for the number of hours that patients participated in sports and leisure time activities ($p = 0.067$).

Table 3 presents the results of the 3 multivariate logistic regression models analysing the effect of PA, known risk factors for no RTW, and a combination of these 2, respectively, on the likelihood of no RTW. Model 1 was statistically significant ($p < 0.01$), explained 1% (Nagelkerke R^2) of the variance in RTW and correctly classified 71% of cases. Lower levels of preoperative PA did not result in higher odds for no RTW (Table 3). Model 2 was statistically significant ($p < 0.01$), explained 16% (Nagelkerke R^2) of the variance in RTW and correctly classified 71% of cases. Odds for no RTW were significantly lower for patients who reported partial work-relatedness of their knee symptoms (OR 0.35 95% CI 0.16-0.75). Also, for each additional week patients expected to be absent from work, the likelihood of no RTW increased (OR 1.10, 95% CI 1.03-1.17; Table 3). Model 3 was statistically significant ($p < 0.01$), explained 17% (Nagelkerke R^2) of the variance in RTW and correctly classified 71% of cases. Model 3 confirmed that preoperative PA had no effect on RTW (Table 3). Odds for no full RTW were significantly lower for patients who reported partial work-relatedness of their knee symptoms (OR 0.37 95% CI 0.17-0.81). Also, for each additional week patients expected to be absent from work, the likelihood of no RTW increased (OR 1.11, 95% CI 1.03-1.18).

Table 2 Univariate analysis of factors associated with RTW (full vs. partial/no RTW) after total knee arthroplasty, including odds ratios with 95% CI

	TKA patients working preoperatively (n = 266)			
	Full RTW (n = 178)	**Partial or no RTW** (n = 88)	*p*-value[a]	OR (95% CI)[b]
Sex, female (%)	98 (55%)	51 (58%)	.65	1.13 (0.67–1.89)
Mean age, y (SD)	58.0 (6.1)	58.8 (5.9)	.31	1.02 (0.98–1.07)
18-45 [n (%)]	3 (2%)	2 (2%)		
46-55 [n (%)]	48 (27%)	23 (26%)		
>55 [n (%)]	127 (71%)	63 (72%)		
BMI, categories, n (%)			.99	
18.5-25 (normal)	20 (11%)	10 (11%)		1
25.1-30 (overweight)	84 (47%)	41 (47%)		0.98 (0.42–2.28)
>30 (obese)	74 (42%)	37 (42%)		1.00 (0.43–2.35)
Musculoskeletal comorbidities, yes (%)	62 (47%)	24 (49%)	.81	1.08 (0.56–2.09)
Non-musculoskeletal comorbidities, yes (%)	104 (65%)	57 (73%)	.19	1.49 (0.82–2.70)
Physical workload			.57	
Light work	97 (56%)	43 (49%)		1
Medium work	45 (26%)	26 (30%)		1.30 (0.71–2.38)
Heavy work	30 (17%)	18 (21%)		1.35 (0.68–2.69)
Preoperative sick leave, yes	38 (22%)	36 (42%)	**<.005**	**2.63 (1.51–4.61)**
Preoperative work adaptations, yes	54 (32%)	29 (36%)	.50	1.21 (0.69–2.12)
Work status, %			.82	1.09 (0.51–2.32)
Employed	152 (87%)	76 (85%)		
Self-employed	22 (13%)	12 (14%)		
S**elf-reported work-relatedness of symptoms**				
Not related	9 (5%)	2 (3%)	**<.01**	**0.38 (0.21–0.69)**
Partially related	86 (52%)	22 (30%)		0.33 (0.07–1.59)
Strongly related	71 (43%)	48 (67%)		1
Expected working hours postoperatively, h [median (IQR)]	30 (20–40)	32 (20–40)	.89	1.00 (0.98–1.02)
Expected timing of RTW, wk [median (IQR)]	8 (5–10)	12 (8–15)	**<.001**	**1.12 (1.06–1.18)**

Expectations concerning working ability, back to presymptomatic state	117 (70%)	55 (66%)	.46	1.23 (0.71–2.16)
Meeting preoperative NNGB, yes (%)	91 (53%)	50 (58%)	.46	0.82 (0.49–1.38)
Meeting preoperative Fitnorm, yes (%)	28 (16%)	14 (16%)	.99	1.01 (0.50–2.03)
Preoperative sport/leisure participation, h [median (IQR)]	4 (2-6)	2 (0-6)	.89	1.00 (0.94–1.05)
Expectations concerning sports ability, back to presymptomatic state	57 (33%)	32 (38%)	.48	0.82 (0.48–1.41)
KOOS change scores, mean (95% CI)				
Symptoms	11 (8–14)	15 (11–18)	.22	-
Pain	48 (44–52)	50 (45–55)	.78	-
ADL	40 (36–43)	41 (37–46)	.69	-
Sport	37 (33–42)	37 (30–44)	.59	-
Quality of life	18 (15–21)	17 (13–21)	.61	-

Numbers of patients and percentages may vary slightly due to missing data points. The significance of the bold values is mentioned in the table (<0.005; <0.01; <0.001).
ADL, Activities of Daily Living; BMI, body mass index; CI, confidence interval; IQR, interquartile range; KOOS, Knee Injury and Osteoarthritis Outcome Score; NNGB, Dutch Recommendation for Health-Enhancing Physical Activity; OR, odds ratio; RTW, return to work; SD, standard deviation; TKA, total knee arthroplasty
[a] Univariate analysis, significance was assumed at $p < 0.05$ (bold).
[b] Odds ratios (with 95% confidence intervals) for partial or no RTW are presented. In cases of more than 2 options, the reference category is presented as 1.

Table 3 The effect of PA (Model 1), known prognostic factors (Model 2), and the combination of PA and known prognostic factors (Model 3) on the odds for no full RTW in total knee arthroplasty patients

Model #	Predictors for no RTW	Reference	OR	95% CI
Model 1	Age, y	-	1.01	0.96–1.07
	BMI, kg/m²	-	1.00	0.93–1.09
	Sex, female	Male	1.25	0.64–2.45
	Meeting preoperative NNGB, no	Yes	0.78	0.40–1.50
	Meeting preoperative Fitnorm, no	Yes	1.23	0.50–3.02
	Preoperative sport/leisure participation	-	1.00	0.94–1.06
Model 2	Age, y	-	0.64	0.26–1.53
	BMI, kg/m²	-	1.04	0.97–1.11
	Sex, female	Male	1.32	0.64–2.73
	Preoperative sick leave, yes	No	1.22	0.51–2.90

	Self-reported work-relatedness of knee symptoms	Highly related	1	
		Partially related	**0.35**	**0.16–0.75**
		Not related	0.48	0.09–2.72[a]
	Physical workload	Light	1	
		Medium	0.75	0.33–1.69
		High	0.51	0.17–1.53
	Expected timing of RTW, wk	-	**1.10**	**1.03-1.17**
Model 3	Age, y	-	1.04	0.97–1.11
	BMI, kg/m²	-	0.97	0.89–1.06
	Sex, female	Male	1.37	0.65–2.87
	Meeting preoperative NNGB, no	Yes	0.80	0.39–1.66
	Meeting preoperative Fitnorm, no	Yes	0.69	0.28–1.70
	Preoperative sick leave, yes	No	1.18	0.49–2.83
	Self-reported work-relatedness of knee symptoms	Highly related	1	
		Partially related	**0.37**	**0.17-0.81**
		Not related	0.62	0.11–3.58[a]
	Physical workload	Light	1	
		Medium	0.74	0.32–1.71
		High	0.47	0.15–1.43
	Expected timing of RTW, wk	-	**1.11**	**1.03-1.18**

Odds ratios with 95% confidence intervals for partial or no RTW are presented. Values in bold are significant ($p < 0.05$).
- = No reference category for continuous variables in the model
BMI, body mass index; CI, confidence interval; NNGB, Dutch Recommendation for Health-Enhancing Physical Activity; OR, odds ratio; PA, physical activity; RTW, return to work.
[a] Not enough power to detect a significant difference due to small sample size (n = 11).

DISCUSSION

The aim of the present prospective cohort study was to investigate if preoperative PA is associated with RTW after TKA. Our most important finding is that preoperative PA was not associated with full RTW in our TKA population within 1 year postoperatively. Two other modifiable factors, namely self-reported work-relatedness of knee symptoms and the expected timing of RTW, were associated with RTW. Thus, our hypothesis that preoperative PA levels would be associated with RTW after TKA could not be confirmed. No previous studies have investigated the association between preoperative PA and RTW among TKA patients, complicating the comparison between our results and existing literature. Yet, several studies have investigated the effect of PA on comparable outcomes, such as sickness absence and employment status. In a representative sample of the Dutch working population, vigorous PA for at least 3 times a week had a positive effect on sick leave[24]. More recently, a systematic review on the impact of PA on sickness absence found several studies that suggest that PA interventions reduce sickness absence[16]. In addition, insufficient PA was associated with sick leave in a Dutch working population (OR 1.12, 95% CI 1.03-1.21)[25]. Finally, in a systematic review and meta-analysis, workers with lack of PA were found to be at an increased risk of disability pension and unemployment[26]. Yet, in our TKA population, meeting the NNGB preoperatively was not associated with preoperative sick leave nor full RTW. In contrast, meeting the Fitnorm was associated with less preoperative sick leave, but not with full RTW. It is possible that patients on sick leave are still able to meet the NNGB because of the relatively low PA requirements, but cannot participate in strenuous PA and therefore do not meet the Fitnorm. In addition, our study is the first to prospectively investigate the association between PA and work participation in TKA patients after surgery. This hampers the comparison with the abovementioned reviews, which included mostly observational studies and did not investigate the effect of a clinical intervention such as TKA. Finally, the NNGB and Fitnorm were self-reported by our patients. It is likely that this resulted in an overestimation of the actual PA, particularly in patients who are not physically active[27]. Thus, it is possible that we could not detect an association between PA and RTW because patients who did not or only partially RTW overestimated their PA. Another explanation might be that we combined patients who partially returned to work and patients who did not RTW, whereas the other studies only investigated complete absence from work (because of sick leave or unemployment). It is possible that PA differs between partial and no RTW, but our sample size was insufficient to study these groups separately.

Concerning other factors that predict RTW after TKA, prospective studies including multivariate analysis to identify TKA-specific prognostic factors associated with RTW are limited[5,7,10,12,13]. The present study includes the largest prospective cohort investigating RTW after TKA. Univariate analysis did show that preoperative sick leave was a strong predictor of no RTW, which is in line with previous studies[5,11,13]. Interestingly, sick leave was no significant predictor in the multivariate models. A possible explanation is that significant prognostic factors such as work-relatedness of knee symptoms and expected timing of RTW are also associated with sick leave. Self-reported work-relatedness of knee symptoms was associated with no full RTW in our population, indicating that patients who reported that their knee complaints were caused by their work are less likely to RTW. This is in line with the study by Kuijer et al.[5], who found an OR for no RTW of 5.3 (90% CI 2.0-14.1). In addition, we found that patients who did not or partially RTW already expected to be absent from work longer than patients who did RTW (12 vs 8 weeks, $p < 0.001$). The regression model showed an OR of 1.11 (95% CI 1.03-1.18) for no full RTW for each additional week patients expected to be absent from work. This is in line with data from a recent systematic review, which identified "a sense of urgency about RTW" as an acceleration factor for RTW[14]. These findings confirm that patient beliefs about the work-related cause of their knee complaints and preoperative expectations regarding timely RTW play an important role in the process of fully returning to work after TKA[10]. Timely referral to an occupational physician for an independent evaluation of the work-relatedness of knee symptoms and for timely work-directed care may improve RTW of these patients[5].

The association between physical workload and RTW remains disputable. Physical workload was not associated with RTW in our study. Other studies have reported conflicting findings, with some authors finding an association between medium or heavy physical workload and faster RTW[7,12,28], and others reporting high physical workload as a limiting factor for RTW[5,11]. As stated by Pahlplatz et al.[14], part of the explanation for this discrepancy lies in the definitions of physical workload that were used. In the studies by Leichtenberg et al., Kuijer et al., and the present study, the same methodology was used to classify physical workload. Leichtenberg et al. found no association, but their study sample was very small (n = 56)[13]. Kuijer et al. (n = 167) found that patients with a medium physical workload were at risk for no RTW compared with patients with a light physical workload (OR 3.3, 90% CI 1.2-8.9)[5]. However, in the present study (n = 263), we could not confirm this association. Workload appears to influence RTW after TKA, but having a high physically demanding job does not necessarily result in lower RTW. Thus, patients with high physical job demands should not be discouraged to RTW after TKA.

The present study describes RTW in the largest prospective cohort of working TKA patients. However, a limitation of the present study, as well as of previous studies on TKA-specific factors associated with RTW, is the low absolute number of patients not returning to work after TKA. In previous studies with cohorts of 56-261 patients, no RTW percentages ranged from 11%-60%[5,7,10,12,13] and partial RTW percentages ranged from 7%-19%[5,13]. In the present study with 266 patients, no RTW was 11% and partial RTW was 22%. A small sample size may limit the statistical power of a multivariate model. To address this, we combined the group of patients who reported a partial RTW with the group who reported no RTW (cf. Leichtenberg et al)[13]. However, for future studies, it would be preferable to include more patients to analyse the groups of full RTW, partial RTW, and no RTW separately.

Another limitation is the fact that our questionnaire did not enable us to investigate the exact reasons for no RTW. It is possible that some patients deliberately did not RTW, for example, because they decided to retire after surgery. Yet, patients' intention to RTW was reflected by the expected number of postoperative working hours. The median expected number of 30 hours with an IQR of 20-40 hours showed that 75% of patients expected to work for at least 20 hours postoperatively. In a comparable study, Kuijer et al. did report reasons for no

RTW and found that of 46 patients not returning, 17% did not RTW because of their TKA, 15% because of other physical complaints, and 57% reported that they had "retired" (not further specified)[5]. To further clarify exact reasons for no RTW after TKA, future studies should explicitly ask patients for their reasons for no RTW. Also, future studies should aim to collect more reliable measures of PA to avoid bias because of an overestimation in self-reported PA. Finally, in cases of incomplete RTW data, telephone interviews were performed, collecting data retrospectively. Thus, a small part of our data may be prone to recall bias. Finally, even though our hypothesis could not be proven, TKA patients should not be discouraged to be physically active before surgery. Evidence that PA is effective in primary and secondary prevention of chronic diseases (e.g. cardiovascular disease, diabetes, obesity, osteoporosis) and premature death is irrefutable[29]. Also, exercise therapy is one of the proven effective conservative treatment modalities for knee osteoarthritis[30]. Thus, patients of working age might be able to postpone their TKA while improving their work ability. Still, in TKA patients, other modifiable factors appear to be stronger predictors of RTW, such as patient beliefs and expectations.

CONCLUSION

The present study is the first to investigate the effect of preoperative PA on full RTW after TKA. Our results did not show an association between PA and full RTW, whereas self-reported work-relatedness of knee symptoms and the expected timing of RTW were associated with no full RTW. Nevertheless, PA should never be discouraged in patients with knee osteoarthritis, given the many positive effects of PA on general health.

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CHAPTER 5

Prognostic Factors for Return to Sport After High Tibial Osteotomy: A Directed Acyclic Graph Approach

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ABSTRACT

Background High tibial osteotomy (HTO) is increasingly used in young and physically active patients with knee osteoarthritis. These patients have high expectations, including return to sport (RTS). By retaining native knee structures, a return to highly knee-demanding activities seems possible. However, evidence on patient-related outcomes, including RTS, is sparse. Also, time to RTS has never been described. Furthermore, prognostic factors for RTS after HTO have never been investigated. These data may further justify HTO as a surgical alternative to knee arthroplasty.

Purpose To investigate the extent and timing of RTS after HTO in the largest cohort investigated for RTS to date and to identify prognostic factors for successful RTS.

Study Design Case-control study; Level of evidence, 3.

Methods Consecutive patients with HTO, operated on between 2012 and 2015, received a questionnaire. First, pre- and postoperative sports participation questions were asked. Also, time to RTS, sports level and frequency, impact level, the presymptomatic and postoperative Tegner activity score (1-10; higher is more active), and the postoperative Lysholm score (0-100; higher is better) were collected. Finally, prognostic factors for RTS were analysed using a logistic regression model. Covariates were selected based on univariate analysis and a directed acyclic graph.

Results We included 340 eligible patients of whom 294 sufficiently completed the questionnaire. The mean follow-up was 3.7 years (± 1.0 years). Out of 256 patients participating in sports preoperatively, 210 patients (82%) returned to sport postoperatively, of whom 158 (75%) returned within 6 months. We observed a shift to participation in lower-impact activities, although 44% of reported sports activities at final follow-up were intermediate- or high-impact sports. The median Tegner score decreased from 5.0 (interquartile range [IQR], 4.0-6.0) presymptomatically to 4.0 (IQR, 3.0-4.0) at follow-up ($p < 0.001$). The mean Lysholm score at follow-up was 68 (SD ± 22). No significant differences were found between patients with varus or valgus osteoarthritis. The strongest prognostic factor for RTS was continued sports participation in the year before surgery (odds ratio, 2.81; 95% CI, 1.37-5.76).

Conclusion More than 8 of 10 patients returned to sport after HTO. Continued preoperative sports participation was associated with a successful RTS. Future studies need to identify additional prognostic factors.

INTRODUCTION

A growing number of patients less than 60 years of age suffer from debilitating knee osteoarthritis (OA), due to the obesity epidemic and prolonged participation in high-impact sports and work activities[1,2]. Clinicians refer to these patients as falling into a ''treatment gap''[3,4], since knee arthroplasty (KA) at a young age is considered undesirable by patients as well as clinicians[5]. In the search for treatment alternatives to KA in young and active patients, use of high tibial osteotomy (HTO) has regained considerable interest in recent years[6,7].

It is known that younger patients with OA have significantly higher expectations from their knee surgery, including a return to high-impact sports and work activities[3,8]. However, participation in such activities after KA results in a 3- to 5-fold increased risk of revision surgery[5]. In contrast, HTO retains native knee structures, thus eliminating the risk of prosthesis wear. Furthermore, retention of the natural joint surfaces and ligaments offers the potential for more normal kinematic function[6]. Previous studies have shown that HTO compared favourably with KA in terms of postoperative range of motion[9] and knee kinematics[10]. Consequently, a successful return to highly knee-demanding activities, including sports, may be expected.

Yet, specific studies on the possibility of obtaining such ambitious goals remain sparse. Recent systematic reviews found that 85% of patients can return to sport (RTS) after HTO[11,12]. However, the included studies mainly reported on small patient cohorts and showed several methodological flaws. Hence, a lack of robust evidence from large HTO cohorts on relevant patient outcomes, including RTS, still exists[13,14]. Additionally, prognostic factors for a successful RTS have never been described. Identifying such factors could improve preoperative counselling and shared decision making, which is essential in obtaining satisfying results in the challenging young knee OA population[15]. Therefore, the aim of the present study was to investigate the extent and timing of RTS after HTO in the largest cohort to date and to identify prognostic factors for a successful RTS. We hypothesized that HTO, by retaining native knee structures and providing more natural knee kinematics, would allow for high rates of RTS.

METHODS

Study Design and Patient Selection

We performed a monocentre cross-sectional study in consecutive patients with HTO operated on between 2012 and 2015. HTOs were identified based on the surgical code in the database of electronic patient records. Eligibility criteria included age between 18 and 70 years at follow-up, good understanding of the Dutch language, and sufficient ability to complete the questionnaire. Patients who had been treated with HTO bilaterally were asked to complete the questionnaire for the most recent operation. We excluded patients who were operated on for other indications than OA. An online questionnaire was developed using an electronic data management system (Castor EDC, www.castoredc.com). Eligible patients received an invitation by email between May and July 2017, followed by a maximum of 2 telephone reminders. Institutional review board approval was obtained from the local medical ethical review board (reference no. W17_382 #17.448). All patients provided written informed consent.

Patient Characteristics

Patients' age, body mass index (BMI) (kg/m^2), and education level were obtained. Also, patients were asked if they had experienced postoperative complications and whether the same leg had been operated on again after HTO, for example, revision surgery or KA. The American Society of Anesthesiologists classification, degree of correction, and additional information on possible revision surgery and hardware removal were collected from the electronic medical record.

Surgical Technique and Rehabilitation

Surgery was performed by 1 of 3 dedicated knee osteotomy surgeons (one of whom was R.J.v.H.). The HTO frontal plane and transverse plane techniques have been described in previous publications[7,16]. Figure 1 illustrates both HTO types that were performed. For varus malalignment, patients underwent a biplanar medial opening wedge HTO. For valgus malalignment, patients underwent a biplanar medial closing wedge HTO. Before surgery, detailed planning was performed for each patient. Degrees of correction in the frontal and sagittal plane were converted to millimetres of wedge to be created or resected, as measured on the calibrated radiographs. In the operating room, callipers and rulers were used to define the wedge in the bone with K-wires (DePuy Synthes) under fluoroscopic guidance. Plate fixation in all patients was performed with angular stable plates (TomoFix; Synthes GmbH). Postoperatively, physical therapy-guided immediate range of motion exercises and muscle strengthening was started. All patients were restricted to partial weightbearing for 6 weeks. Thromboembolic prophylaxis, that is, 40 mg enoxoparin, was prescribed once daily for 6 weeks. After 6 weeks, knee radiographs were obtained to verify bone healing and stability of fixation. Full weightbearing was allowed thereafter, provided that bone healing and stability of fixation were sufficient. At 3 months postoperatively, knee radiographs and, if deemed necessary, full length standing radiographs were obtained to verify bone healing and the correction of deformity, respectively.

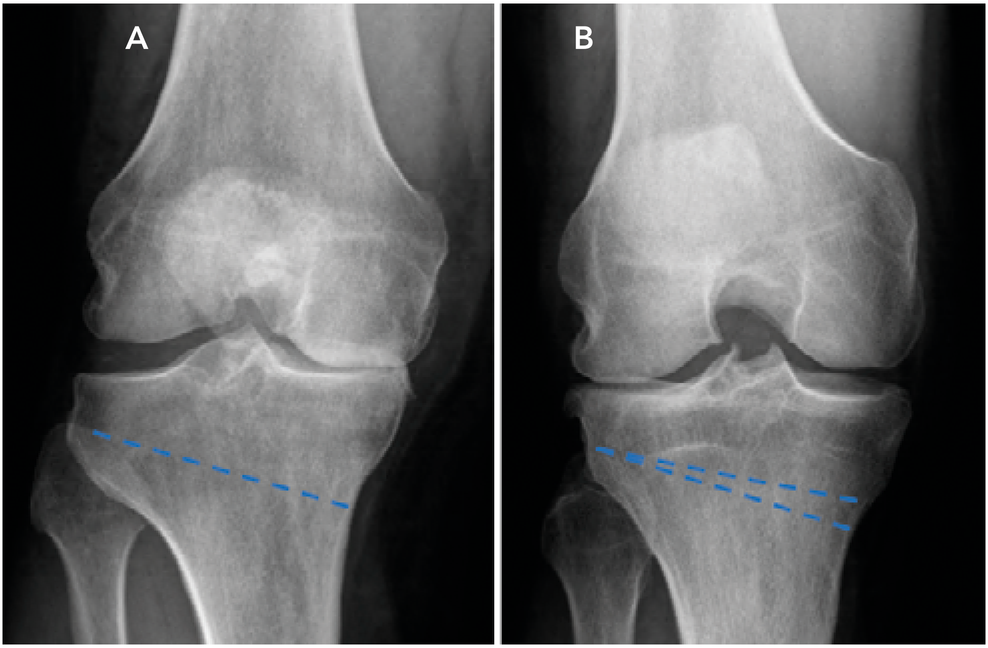

Fig. 1 Preoperative anteroposterior radiographs of high tibial osteotomies (HTOs) with projected osteotomy cuts (striped lines). **A** Right knee before medial opening wedge HTO. **B** Right knee before medial closing wedge HTO.

Sport Outcome Measures

The primary outcome measure was the percentage of patients that returned to sport postoperatively. Secondary outcome measures included the timing of RTS and the frequency, duration, and type of performed sports activities pre- and postoperatively. The validated Tegner activity scale (0-10; higher is more physically active) and Lysholm score (0-100; higher is better function) were collected[17]. Since no validated questionnaire exists to assess RTS in patients with knee osteotomy, we adapted the sports questionnaire described by Naal et al.[18], which has been used in several studies investigating RTS after knee surgery, including knee osteotomy[19,20]. A detailed description of the questionnaire can be found in a previous publication[21]. The first question was whether patients had participated in 1 or more sports in their lifetime. If this was not the case, all subsequent sports questions were automatically skipped. Preoperative sports participation was defined as both presymptomatically, that is, before the onset of restricting knee symptoms, and 1 year preoperatively. Postoperative sports participation was defined as 1 year postoperatively and at final follow-up. For each time point, the highest level of participation (recreative, competitive, professional) was asked. Next, sports frequency (0-7 times per week), duration (hours per week), and timing of RTS (weeks) were asked. To assess the level of impact, sports activities were rated as low, intermediate, or high impact according to the classification by Vail et al.[22]. Finally, patients were asked to rate their sports ability at follow-up, compared with the best sports ability in their lifetime (much worse, worse, unchanged, improved, much improved).

Statistical Analysis

Patient data and pre- and postoperative sports participation were analysed using descriptive statistics. RTS percentage was calculated by selecting patients who participated in 1 or more sports presymptomatically, preoperatively, or both, and calculating the percentage of these patients performing 1 or more sports 1 year postoperatively, at final follow-up, or both. Also, timing of RTS and frequency and duration of sports participation were analysed using descriptive statistics. Primary analyses were performed for the total group. Next, subgroup analyses on RTS were performed for the varus and valgus OA subgroups. To investigate prognostic factors for RTS, a logistic regression model was used. First, univariate analysis was performed to assess baseline differences between patients who did RTS and patients who did not RTS. Next, variable selection was based on a causal path diagram that was created using the directed acyclic graph (DAG) approach[23]. Covariates were selected based on recent literature on HTO[12], known prognostic factors for functional outcome in patients with KA[1,24], and hypothesized relationships. With the DAG approach, an a priori model of the postulated relationships between the exposure (HTO), outcome variable of interest (RTS), and covariates is established[23]. This leads to theoretically and expert-based adjustment and the most parsimonious model being chosen, without the risk of overadjustment and associated reduction of statistical power that could occur otherwise. In the DAG (Figure 2), arrows represent direct causal effects of 1 factor on another. For example, smoking increases the risk of perioperative complications, which in turn negatively influences recovery and thereby RTS. Based on the assumptions described in the diagram, the adjustment set required to estimate the effect of covariates on RTS after HTO included the variables BMI, wedge size, and sports participation 1 year preoperatively. By adjusting for these factors, the effect of all the described covariates in Figure 2 on RTS was investigated. The DAG was created using DAGitty version 2.3[25]. A p-value < 0.05 was considered significant. Odds ratios (ORs) and 95% CIs were calculated. All statistical analyses were performed with SPSS for Windows (version 24.0; IBM Corp).

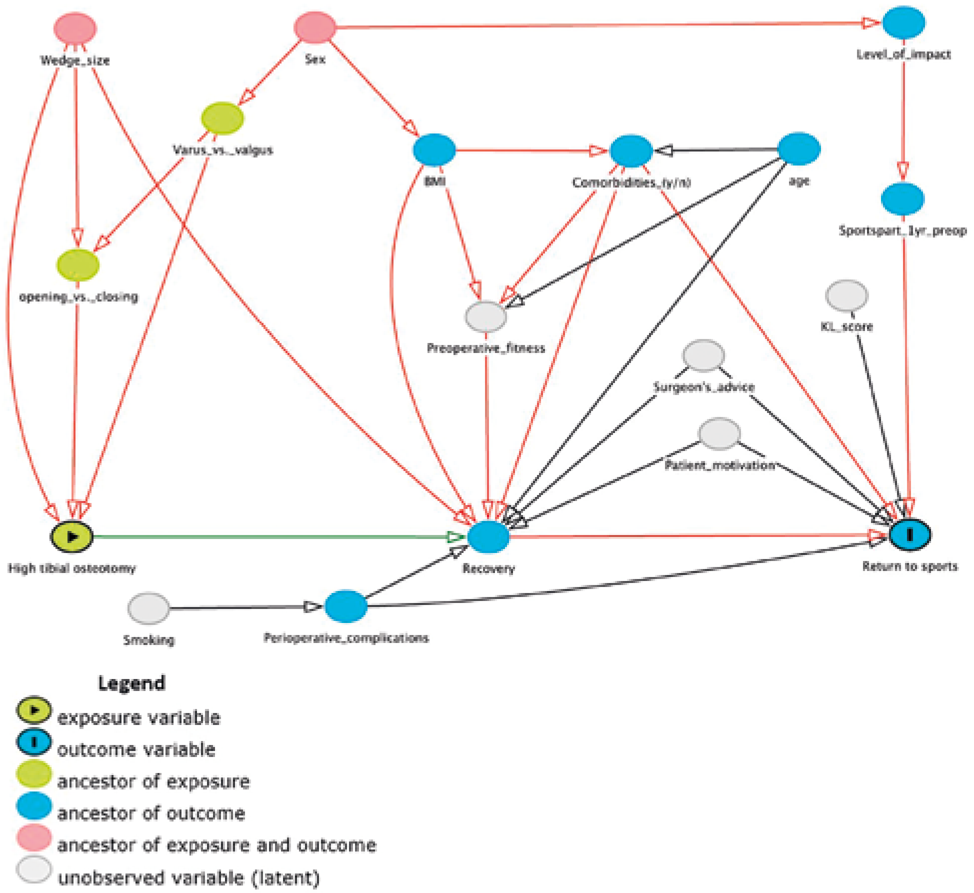

Fig. 2 Directed acyclic graph representing the causal assumptions used for covariate selection.

RESULTS

Participants

Out of 482 consecutive HTOs that were identified in the electronic patient database, 340 HTO patients were deemed eligible for participation (Figure 3). At a mean follow-up of 3.7 years (± 1.0 years), all 340 patients responded, of whom 301 patients completed the questionnaire and 294 could be included in the final analysis. The indication for surgery was unicompartmental OA and varus (n = 235) or valgus (n = 59) knee alignment caused by a tibial deformity. In 1 patient with varus OA, a lateral opening wedge HTO was performed because of laxity of the lateral collateral ligaments. Baseline characteristics are presented in Table 1.

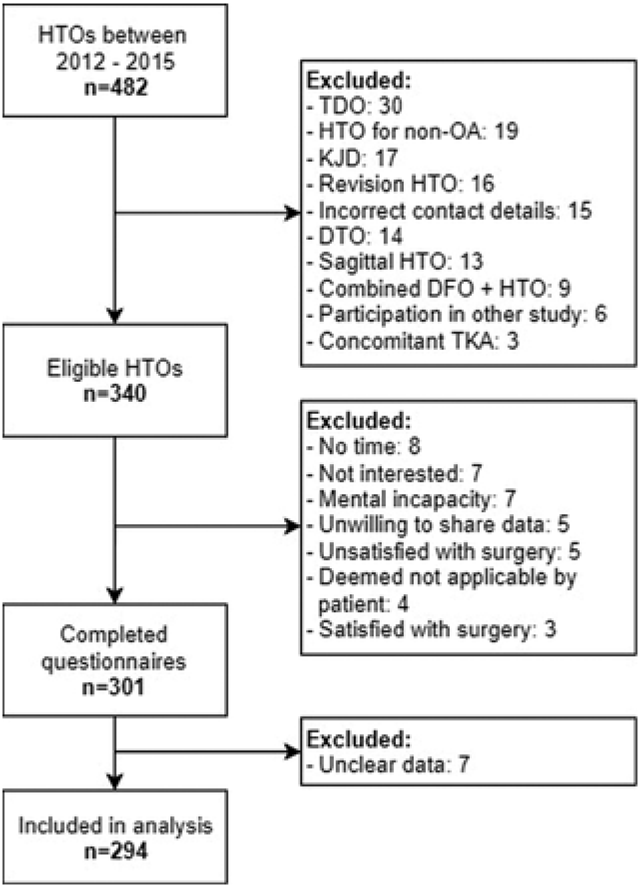

Fig. 3 Inclusion flow diagram.
DFO, distal femoral osteotomy; DTO, distal tibial osteotomy; HTO, high tibial osteotomy; KJD, knee joint distraction; OA, osteoarthritis; TDO, tibial de-rotation osteotomy; TKA, total knee arthroplasty.

Table 1 Baseline characteristics of the total group and varus and valgus osteoarthritis subgroups[a]

Outcome measure	Total group (n = 294)	Varus OA group (n = 235)	Valgus OA group (n = 59)
Mean age at surgery, y (SD)	50.3 (9.2)	51.1 (8.9)	47.1 (9.7)
Mean follow-up, y (SD)	3.7 (1.0)	3.8 (1.0)	3.5 (1.0)
Sex, female (%)	120 (41)	73 (31)	47 (80)
Mean BMI, kg/m^2 (SD)	27.5 (4.4)	27.5 (4.5)	27.5 (4.2)
Side, right (%)	151 (51)	115 (49)	36 (61)

ASA classification, n (%)			
I	171 (58)	137 (58)	34 (58)
II	122 (41)	97 (41)	25 (42)
III	1 (1)	1 (1)	–
Osteotomy type, n (%)			
Medial owHTO	235 (80)	235 (100)	–
Medial cwHTO	58 (20)	–	58 (98)
Lateral owHTO	1 (1)	–	1 (2)
Wedge size, mm (SD)			
Medial owHTO	10.0 (3.0)	10.0 (3.0)	–
Medial cwHTO	6.7 (2.1)	–	6.7 (2.1)
Lateral cwHTO		–	–[b]
Revision surgery, yes (%)	20 (7)	13 (6)	7 (12)
Revision osteotomy	2	2	–
Non-union	3	3	–
TKA	11	5	6
Arthroscopic debridement	2	2	–
Meniscectomy	1	1	–
MUA	1	–	1
Hardware removal, yes (%)	153 (52)	114 (49)	38 (63)
Timing of hardware removal, y (SD)	1.1 (0.6)	1.3 (0.6)	0.8 (0.4)

[a] ASA, American Society of Anesthesiologists; BMI, body mass index; cw, closing wedge; HTO, high tibial osteotomy; MUA, manipulation under anaesthesia; OA, osteoarthritis; ow, opening wedge; TKA, total knee arthroplasty; –, no data available.
[b] Wedge size not reported in the patient's file.

Tegner and Lysholm Scores

Patients reported that their median Tegner score decreased from 5.0 (interquartile range [IQR], 4.0-6.0) presymptomatically to 4.0 (IQR, 3.0-4.0) at follow-up ($p < 0.001$). The mean Lysholm score at follow-up was 68 (± 22). In total, 38% of patients reported a Lysholm score of <65 points (poor), 29% a score of 65-83 (fair), 25% a score of 84-94 (good), and 8% a score of >94 (excellent).

Return to Sport

Out of 256 patients participating in 1 or more sports preoperatively, 210 (82%) returned to sport postoperatively. In the varus OA group, 206 patients participated in 1 or more sports preoperatively, of whom 168 patients (82%) could RTS, compared with 42 out of 50 patients (84%) in the valgus OA group (not significant). For the 210 patients who returned to sport, time to RTS was ≤6 months in 158 patients (75%) and 193 patients (92%) returned within 1 year. Figure 4 presents the level of sports participation of the total group at the 4 time points (presymptomatically, 1 year preoperatively, 1 year postoperatively, at final follow-up). Table 2 presents the results for sports frequency in terms of times per week and hours per week and the type of performed sports activities (low, intermediate, and high impact). On average, patients performed 5.8 sports activities per patient presymptomatically, of which 34% were low-impact, 37% were intermediate-impact, and 29% were high-impact activities. This number decreased to 3.3 activities per patient 1 year preoperatively (49% low, 35% intermediate, and 16% high impact) and 3.1 activities per patient 1 year postoperatively (56% low, 34% intermediate, and 10% high impact). At follow-up, patients performed an average of 3.7 activities per patient (56% low, 34% intermediate, and 10% high impact). The participation in all mentioned sports activities at the 4 time points can be found in Appendix Table A1 (available in the online version of this article). Sports ability at final follow-up compared with the best lifetime sports ability was worse or much worse in 173 patients (68%), unchanged in 38 patients (15%), and improved or much improved in 44 patients (17%).

Table 2 Sports frequency and hours, level of impact and time to RTS at the 4 time points[a]

	Presymptomatically, n (%)	**1 year preoperatively, n (%)**	**1 year postoperatively, n (%)**	**At final follow-up, n (%)**
Sports frequency, times/week				
No participation	–	54 (21)	73 (29)	63 (24)
≤1	37 (14)	71 (28)	66 (26)	58 (23)
2	69 (27)	69 (27)	65 (25)	61 (24)
3	69 (27)	38 (15)	25 (10)	43 (17)
≥4	79 (32)	24 (9)	27 (10)	31 (12)
Sports participation, h/week				
No participation	–	48 (19)	70 (27)	61 (24)
0–2	54 (21)	98 (39)	100 (39)	70 (28)
3–4	80 (32)	67 (26)	49 (19)	74 (29)
5–6	51 (20)	20 (8)	17 (7)	24 (9)
>6	69 (27)	19 (8)	19 (8)	25 (10)
Level of impact				
Low	514 (34)	314 (49)	306 (56)	395 (56)
Intermediate	554 (37)	225 (35)	184 (34)	242 (34)
High	427 (29)	105 (16)	54 (10)	74 (10)
Total sports	1495 (–)	644 (–)	544 (–)	711 (–)

Time to RTS, week				
0–12	–	–	–	47 (24)
13–15	–	–	–	45 (23)
16–18	–	–	–	24 (12)
19–22	–	–	–	12 (6)
23–25	–	–	–	19 (10)
26 - 52	–	–	–	32 (16)
>52				16 (8)

[a] In cases with inconsistent answers, data were coded as missing. Thus, not all the numbers add up to 256 patients and percentages for level of participation and frequency may vary slightly. RTS, return to sport; –, no data available.

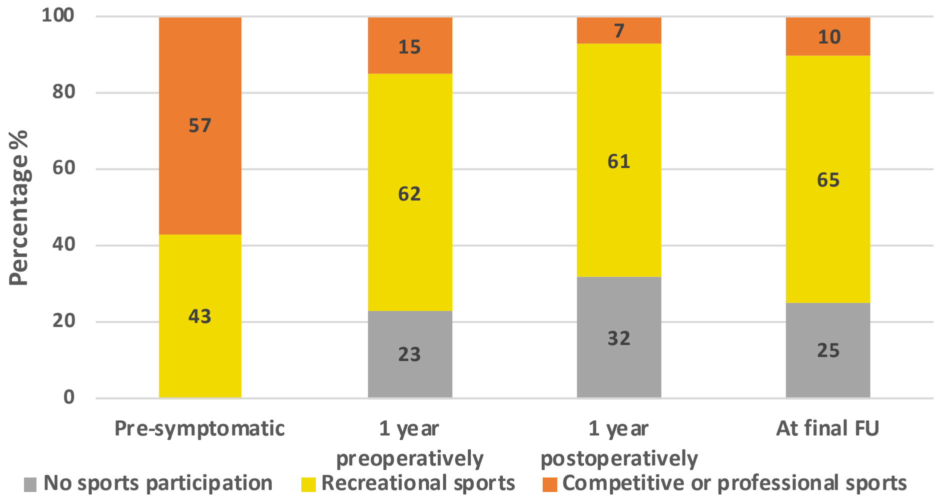

Fig. 4 Reported level of sports participation at 4 time points. Patients who participated in 1 or more sports pre- symptomatically (n = 256) were selected. Their sports participation at 1 year preoperatively, 1 year postoperatively, and final follow-up is presented as the proportion performing "no sports," "recreational sports," and "competitive or professional sports." FU, follow-up.

Prognostic Factors for RTS

On the basis of the DAG (Figure 2) and our univariate analysis (Table 3), the following variables were included in the logistic regression analysis: preoperative BMI, wedge size, and sports participation in the year before surgery (Table 4). The logistic regression model was statistically significant ($p < 0.05$), explained 8% (Nagelkerke R^2) of the variance in RTS, and correctly classified 81% of cases. The OR for RTS was significantly higher for patients who reported participation in 1 or more sports in the year before surgery compared with those who did not (OR, 2.81; 95% CI, 1.37-5.76). BMI and wedge size were not significantly associated with RTS.

Table 3 Univariate analysis of factors associated with RTS (yes vs no) after HTO[a]

Outcome measure	RTS (n = 210)	No RTS (n = 46)	*p*-value
Mean age at surgery, y (SD)	50.4 (9.2)	48.7 (8.2)	.25[b]
Mean follow-up, y(SD)	3.7 (1.0)	3.6 (1.1)	.27[b]
Sex, female (%)	81 (39)	20 (43)	.54[c]
Mean BMI, kg/m^2 (SD)	27.1 (3.8)	28.5 (4.1)	**.04**[b]
Side, right (%)	106 (51)	24 (52)	.84[c]
ASA classification, n (%)			.25[c]
I	131 (62)	23 (50)	
II	78 (37)	23 (50)	
III	1 (1)	–	
Indication, n (%)			.69[c]
Varus OA	168 (80)	38 (83)	
Valgus OA	42 (20)	8 (17)	
Wedge size, mm (SD)	9.2 (3.2)	9.7 (3.3)	.39[b]
Level of impact 1 year pre-operatively, n (%)			**.04**[c]
Low	43 (25)	14 (47)	
Intermediate	64 (38)	6 (20)	
High	62 (37)	10 (33)	
Sports participation 1 year pre-operatively, n (%)			**<.01**[c]
Yes	169 (81)	28 (61)	
No	41 (19)	18 (39)	

[a]Boldface type indicates statistical significance at $p < 0.10$. ASA, American Society of Anesthesiologists; BMI, body mass index; HTO, high tibial osteotomy; OA, osteoarthritis; RTS, return to sport; –, no data available.
[b]Independent samples t test.
[c]Chi-square test or Fisher exact test in cases with <5 expected counts.

Table 4 Logistic Regression Model Analysing the Effect of BMI, Wedge Size, and Preoperative Sports Participation on the Odds for RTS After HTO[a]

Predictors for RTS	Reference	OR	95% CI
BMI, kg/m^2	-	0.94	0.86–1.02
Wedge size, mm	-	0.97	0.87–1.08
Sport participation 1 year preoperatively (yes/no)	No	2.81	1.37–5.76

[a]–, no reference category for continuous variables in the model; BMI, body mass index; HTO, high tibial osteotomy; OR, odds ratio; RTS, return to sport.

DISCUSSION

The most important finding of the present study, in the largest reported HTO cohort analysed for RTS to date, was that 210 of 256 patients (82%) returned to sport after HTO. Furthermore, 158 (75%) of these patients returned within 6 months and 193 (92%) returned within 1 year. There was no difference in RTS between patients undergoing HTO for varus or valgus OA. Last, continued sports participation in the year before surgery was significantly associated with higher RTS.

In recent years, consideration has increased for patients' wish to participate in high-impact activities after knee surgery, including knee osteotomy[3]. Early studies reported RTS percentages after HTO of less than 50%[26]. Improvements in surgical techniques and the introduction of angular stable plate fixation resulted in higher RTS rates (60%-100%) in more recent studies[20,27]. Our RTS percentage of 82% is slightly lower than the percentages reported in 2 recent systematic reviews[11,12]. However, the RTS percentage is highly influenced by the definition of preoperative sports participation, that is, presymptomatic or preoperative participation[12]. Furthermore, several studies described RTS as postoperative sports participation rather than true RTS, namely postoperative sports participation of patients who also participated in sports preoperatively. For the present study, both presymptomatic and preoperative sports participation were asked, and only patients who participated in sports preoperatively were included in the RTS analysis. Consequently, our approach likely resulted in a more reliable RTS estimate compared with previous research.

Additionally, this is the first study investigating time to RTS after HTO. A majority of 75% of patients returned within 6 months. In comparison, 71% of patients returned within 6 months after distal femoral osteotomy (DFO)[21]. In total, KA median time to RTS was 13 weeks compared with 12 weeks in unicompartmental KA[24]. Thus, time to RTS was longer after knee osteotomy compared with KA. This may be explained by slower bone healing and the need for plate removal in many patients, resulting in extended rehabilitation protocols after knee osteotomy. Regarding level of impact, 44% of reported sports activities were intermediate- or high-impact sports after HTO in our cohort. After DFO, this percentage was 45%[21]. In contrast, participation in intermediate- and high-impact sports was only 11% after total KA and 23% after unicompartmental KA[24]. These findings appear to confirm our hypothesis that, by retaining native knee structures, knee osteotomy allows for more frequent participation in high-impact activities compared with KA.

To further improve patient selection in HTO, identification of predictors for a successful clinical outcome is essential. Our univariate analysis showed no difference in preoperative high-impact sports participation between the patients who did and did not RTS. This was an unexpected outcome, since participation in high-impact activities has been shown to decrease markedly after knee osteotomy, KA, and knee cartilage regeneration procedures[12,24,28]. Since obesity is considered a contraindication for HTO (Rand JA, Neyret P. Unpublished data. Presented at ISAKOS Meeting on the Management of Osteoarthritis of the Knee Before Total Knee Arthroplasty, Hollywood, FL, 2005), an association between BMI and RTS was not expected. While BMI was associated with RTS in our univariate analysis, our regression model did not show an association between BMI and RTS. This latter finding is in line with previous studies, which found no association between BMI and RTS[20,29].

Based on our DAG, wedge size was included in the regression model, but it was not associated with RTS. However, after HTO using angular stable plate fixation, early full weightbearing is possible[30,31]. Consequently, the use of angular stable fixation in our study may have eliminated the negative effect of increased wedge size on RTS. Last, continued sports participation in the year before surgery was the strongest prognostic factor for RTS. Interestingly, in patients with knee and hip arthroplasty, preoperative regular participation in physical activity also was the strongest predictor of physical activity 3 years postoperatively[32]. A possible explanation is patient motivation, which is undoubtedly high in cases of continued sports participation despite debilitating knee OA. Likewise, high patient motivation was associated with improved postoperative activity levels in 139 French HTO patients[27]. Thus, we may assume that patient motivation plays an important role. Therefore, the importance of motivation to RTS should be discussed with the patient and actively supported before HTO.

While the eligibility criteria for HTO and unicompartmental KA vary[33] (Rand JA, Neyret P. Unpublished data. Presented at ISAKOS Meeting on the Management of Osteoarthritis of the Knee Before Total Knee Arthroplasty, Hollywood, FL, 2005), recent meta-analyses have directly compared functional outcomes between these treatment options[9,34]. Both studies concluded that HTO results in better range of motion, while unicompartmental KA showed better pain relief and fewer complications. Knee function scores and the proportion of patients that acquired a good or excellent surgical result did not differ between HTO and unicompartmental KA. Unfortunately, none of the included studies directly compared sports participation. The authors concluded that HTO may be the preferred surgical option in patients with high activity requirements, where a superior range of motion is essential and the risk of polyethylene wear after unicompartmental KA would be highest[9,34].

Regarding clinical relevance, our data hopefully improve preoperative decision making, since many patients wish to know whether and when they can return to high-demanding sports activities. Furthermore, establishing realistic expectations concerning RTS before surgery may prevent postoperative dissatisfaction[15,35]. Additionally, our study is the first to include a regression analysis investigating factors associated with RTS after HTO. The presented DAG may serve as a theoretical framework to guide future variable selection when investigating prognostic factors for sports participation after HTO. In this way, counselling of younger patients with knee OA, eligible for HTO, can be further improved.

A limitation of the present study is its cross-sectional design, which increases the risk of recall bias. Also, we performed a monocentre study in a high-volume knee osteotomy clinic, which might limit the external validity of our findings. Future studies addressing these limitations are needed to confirm modern-day HTO as a worthwhile treatment option for young patients with ''old knees'' in terms of functional outcomes[13]. An important next step is the development of national registries. In the United Kingdom, the UK Knee Osteotomy Registry, including both surgical and patient-reported outcome measures, was launched in 2014[13]. Also, the Australian Knee Osteotomy Registry is currently being developed[36]. These registries, as well as future prospective studies, will hopefully fill the void in literature regarding patient-relevant outcomes after knee osteotomy.

CONCLUSION

In conclusion, more than 8 out of 10 patients RTS after HTO, of which the majority return within 6 months. A shift from participation in intermediate- and high-impact sports to low- and intermediate-impact sports can be expected. Sustained sports participation in the year before surgery is a prognostic factor for RTS after HTO. These findings support further justification of HTO as a surgical alternative to KA in young and active patients with knee OA.

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CHAPTER 6

Predictors of Return to Work After High Tibial Osteotomy: The Importance of Being a Breadwinner

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ABSTRACT

Background Limited evidence exists on patient-relevant outcomes after high tibial osteotomy (HTO), including return to work (RTW). Furthermore, prognostic factors for RTW have never been described.

Purpose To investigate the extent and timing of RTW in the largest HTO cohort investigated for RTW to date and to identify prognostic factors for RTW after HTO.

Study Design Cohort study; Level of evidence, 3.

Methods Consecutive patients who underwent HTO between 2012 and 2015 were included. Patients received a questionnaire at a mean follow-up of 3.6 years. Questions were asked pre- and postoperatively regarding work status, job title, working hours, preoperative sick leave, employment status, and whether patients were their family's breadwinner. The validated Work Rehabilitation Questionnaire (WORQ) was used to assess difficulty with knee-demanding activities. Prognostic factors for RTW were analysed using a logistic regression model. Covariates were selected based on univariate analysis and a directed acyclic graph.

Results We identified 402 consecutive patients who underwent HTO, of whom 349 were included. Preoperatively, 299 patients worked, of whom 284 (95%) achieved RTW and 255 (90%) returned within 6 months. Patients reported significant postoperative improvements in performing knee-demanding activities. Being the family's breadwinner was the strongest predictor of RTW (odds ratio [OR], 2.92; 95% confidence interval [CI], 1.27-6.69). In contrast, preoperative sick leave was associated with lower odds of RTW (OR, 0.20; 95% CI, 0.08-0.46).

Conclusion After HTO, 95% of patients were able to RTW, of whom 9 of 10 returned within 6 months. Breadwinners were more likely to RTW, and patients with preoperative sick leave were less likely to RTW within 6 months. These findings may be used to improve preoperative counselling and expectation management and thereby enhance work-related outcomes after HTO.

INTRODUCTION

Because of an aging society, the obesity epidemic, and the increasing retirement age in many countries, the number of patients of working age who suffer from debilitating knee osteoarthritis (OA) is steadily increasing[1-4]. Given the associated pain, functional limitations, and subsequent absenteeism from work[5], adequate treatment is clearly required, both from personal and societal perspectives[6–8]. While knee arthroplasty (KA) has long been considered the best surgical treatment option[5,9], reports of markedly increased revision rates in young, active patients have tempered enthusiasm for KA[10,11]. Given the worldwide increasing incidence of knee OA in working-age patients[12], who almost always wish to return to work (RTW) after surgery[3,13,14], clinicians search for treatment alternatives to KA in this demanding population.

As a result, high tibial osteotomy (HTO) has received renewed attention as a treatment alternative to KA, especially in younger, active patients with knee OA[15,16]. A study showed that up to 50% of patients with knee OA indicated for surgery have jobs that include knee-demanding activities, such as kneeling, lifting, and walking stairs[3]. In HTO, native knee structures are spared, which results in improved range of motion compared with unicompartmental KA and improved knee kinematics, which were comparable with healthy controls[17,18]. In theory, this improvement would lead to higher rates of RTW and less difficulty in performing knee-demanding activities. This was supported by a meta-analysis revealing that 85% of patients could RTW after HTO[19], while RTW after KA varied between 56% and 89%, with a pooled estimate of 70%[20]. Furthermore, patients who have undergone KA often experienced marked difficulty with knee-demanding activities postoperatively[20], although comparative data for patients undergoing HTO are lacking.

Thus, HTO has shown promising results regarding RTW, specifically when compared with KA. However, time to RTW and the ability to perform knee-demanding activities have been poorly studied[13,19]. Also, no study has investigated prognostic factors for RTW after HTO. Realistic preoperative expectations are known to play an essential role in obtaining postoperative satisfaction in patients with knee OA[13,21]. Furthermore, patients with knee OA of working age undergoing KA expressed a strong desire for more patient-tailored RTW advice[22]. Therefore, establishing factors that influence patient-relevant outcomes, including RTW, may facilitate more patient-tailored preoperative expectation management and could thus be of great importance to both patients and orthopaedic surgeons. Therefore, the primary aim of this study was to investigate the extent and timing of RTW after HTO in the largest cohort to date regarding work-related outcomes. The secondary aim was to identify prognostic factors for successful RTW. We hypothesized that HTO would allow for a high RTW rate and fast RTW, given the advantages of retaining native knee structures.

METHODS

Study Design and Patient Selection

We performed a monocentre cross-sectional study in consecutive patients who underwent HTO between 2012 and 2015. HTO procedures were identified based on the surgical code (038604) in the database of electronic patient records (HiX; ChipSoft). We previously reported that our clinic uses the HTO selection criteria as formulated by the International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine, stating that the ideal patient undergoing HTO is aged 40 to 60 years with a body mass index (BMI) <30 kg/m^2 [16]. Eligibility criteria for the present study included age between 18 and 70 years at follow-up, good understanding of the Dutch language, and sufficient ability to complete the questionnaire. Patients who had been treated with HTO bilaterally were asked to complete the questionnaire for the most recent operative procedure. An online questionnaire was developed using an electronic data management system (Castor EDC; www.castoredc.com). Eligible patients received an invitation by email between May and July 2017, followed by a maximum of 2 telephone reminders. Because the aim of the study was to investigate RTW in the largest possible cohort, a sample of convenience was used. However, based on a previous study on prognostic factors for RTW in patients undergoing KA, a minimum sample size of 120 patients was considered necessary to detect relevant differences in RTW[23]. The study was performed in accordance with the ethical standards of the Declaration of Helsinki of 1975, as revised in 2000. Institutional review board approval was obtained from the local medical ethical review board. All patients provided written informed consent.

Patient Characteristics

Patients' age, BMI, and education level were collected. Also, patients were asked if they had experienced postoperative complications and whether they had undergone surgery on the same leg again after HTO (e.g. revision surgery or KA). The American Society of Anesthesiologists classification, degree of correction, and additional information on possible revision surgery and hardware removal were collected from the electronic medical record.

Surgical Technique and Rehabilitation

Surgery was performed by 1 of 3 dedicated knee osteotomy surgeons. The frontal and transverse plane HTO techniques have been described in previous publications[16,24]. For varus malalignment, patients underwent biplanar medial opening wedge HTO. For valgus malalignment, patients underwent biplanar medial closing wedge HTO. Patients with rotational malalignment of the tibia were treated with biplanar transverse derotation HTO. In case of a sagittal plane deformity, patients were treated with single-plane flexion or extension HTO[25] (Figure 1). Before surgery, detailed planning was performed for each patient. Degrees of correction in the frontal and sagittal planes were converted to millimetres of wedge to be created or resected, as measured on the calibrated radiographs. In the operating room, callipers and rulers were used to define the wedge in the bone with K-wires under fluoroscopic guidance. Transverse-plane corrections were calculated from standardized computed tomography scans. Intraoperatively, a tracker specifically designed for rotational measurements was used, together with K-wires, defining the angle of rotation in the bone. Plate fixation for all opening wedge, closing wedge, and derotation HTO procedures was performed with angular stable plates (TomoFix; Synthes). For single plane flexion or extension HTO, fixation with 2 staples (Stryker) and 3 small fragment screws (Synthes) was performed. Postoperatively, physical therapy–guided immediate range of motion exercises and muscle strengthening were initiated. All patients were restricted to partial weightbearing for 6 weeks. No postoperative bracing was used. Thromboembolic prophylaxis (i.e. enoxaparin 40 mg) was prescribed once daily for 6 weeks. After 6 weeks, knee radiographs were obtained to verify bone healing and stability of fixation. Full weightbearing was allowed thereafter, provided that bone healing and stability of fixation were sufficient. At 3 months postoperatively, knee radiographs and, if deemed necessary, full-length standing radiographs were obtained to verify bone healing and the correction of deformities, respectively. Plate removal was performed only in patients with persistent functional limitations, which were likely caused by the plate.

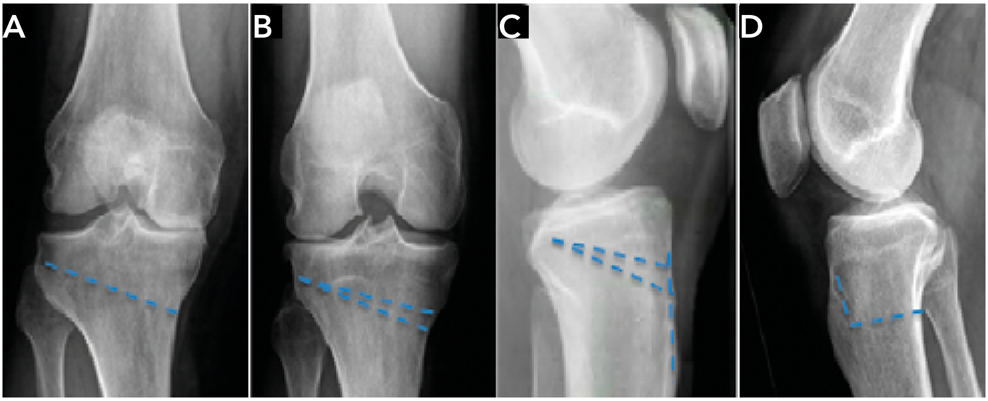

Fig. 1 Preoperative anteroposterior/lateral radiographs of high tibial osteotomy (HTO) with projected osteotomy cuts (striped lines). **A** Right knee before opening wedge HTO, **B** right knee before medial closing wedge HTO, **C** left knee before anterior closing wedge HTO, and **D** right knee before derotation osteotomy.

Work Outcome Measures

Because no validated RTW questionnaire exists, we developed a questionnaire based on previous studies in knee osteotomy and KA[23,26-28]. The primary outcome measure was the percentage of patients who returned to work postoperatively and the timing of RTW. Patients were asked whether they worked before the onset of restricting knee symptoms and in the 3 months prior to surgery. Job title was recorded and classified as low, intermediate, or high knee demanding work by

2 occupational experts, who independently scored all jobs based on work-related physical demands on the knee[4,29]. Also, patients reported preoperative sick leave for any reason in the month before surgery, and their intention to RTW was asked as well as their employment status and whether they were their family's breadwinner (i.e. providing >50% of the family's income). Next, information on working hours, changes in workload, and, if patients did not RTW postoperatively, reasons for not returning to work were obtained. Finally, the validated Work Rehabilitation Questionnaire (WORQ) was used to assess the effect of HTO on work-related activities[30]. The WORQ consists of questions on 13 knee-demanding activities such as kneeling, lifting/carrying, and climbing stairs. Patients graded the difficulty that they experience when performing each activity on a 5-point Likert scale, with 0 meaning "no difficulty at all" and 4 meaning "extreme difficulty/unable to perform". Patients were asked to retrospectively grade the difficulty at 3 time points: 3 months preoperatively, 1 year postoperatively, and at final follow-up.

Statistical Analysis

Demographic data, preoperative and postoperative work status, and timing of RTW were analysed using descriptive statistics. Primary analyses were performed for the total cohort. Next, because the predominant indication for surgery was OA, subgroup analyses on RTW were performed for the OA and non-OA groups. To investigate prognostic factors for RTW, a logistic regression model was used. Because of the expected low percentage of no RTW[19], RTW was divided into 2 categories for regression analysis: RTW within 6 months (RTW ≤6 months) and RTW after more than 6 months, including no RTW at all (no RTW ≤6 months)[31]. Univariate analysis was performed to assess baseline differences between patients who did RTW ≤6 months compared with patients who did not RTW ≤6 months. Variable selection was based on a causal path diagram that was created using the directed acyclic graph (DAG) approach[32]. Covariates were selected based on recent literature on HTO[19,33], known prognostic factors for functional outcomes in KA[34–37], and hypothesized relationships. With the DAG approach, an a priori model of the postulated relationships between the exposure (HTO), outcome variable of interest (RTW), and covariates was established[32]. This led to theoretical- and expert-based adjustments and the most parsimonious model being chosen, without the risk of overadjustment and associated reduction of statistical power. In the DAG (Figure 2), arrows represent direct causal effects of one factor on another. For example, being self-employed is hypothesized to increase patients' motivation, thereby positively influencing RTW. Based on the assumptions described in the diagram, the adjustment set required to estimate the effect of covariates on RTW after HTO included the following variables: BMI, degree of correction, breadwinner (yes/no), preoperative sick leave (yes/no), and preoperative workload. By adjusting for these factors, the effect of all the described covariates in Figure 2 on RTW was investigated. The DAG was created using DAGitty (Version 2.3)[38]. A p-value < 0.05 was considered significant. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. All statistical analyses were performed with SPSS for Windows (Version 24.0; IBM).

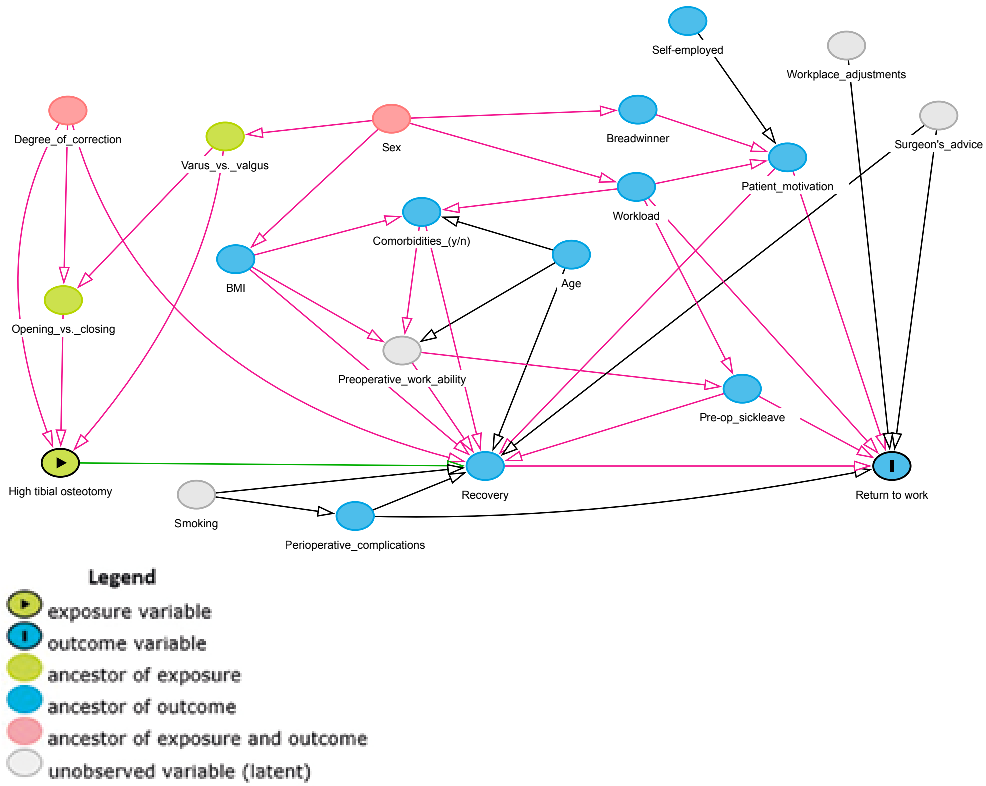

Fig. 2 Directed acyclic graph describing the causal assumptions used for the selection of covariates.

RESULTS

Participants

Of 482 identified consecutive HTO procedures in the electronic patient database, 402 were eligible for participation (Figure 3). A total of 402 patients responded at a mean follow-up of 3.6 ± 1.0 years, and 363 patients completed the questionnaire. For the final RTW analysis, 349 patients were included. Table 1 presents the baseline characteristics for the total cohort and for the OA and non-OA subgroups.

Return to Work

Of 349 patients, 315 worked presymptomatically, and 299 patients still worked 3 months preoperatively. Of these 299 patients, 76% were employees, 20% were self-employed, and 4% were both employed and self-employed. The preoperative knee-demanding workload was light in 51%, medium in 33%, and heavy in 16% of patients. Preoperative sick leave was reported by 44 patients (15%). Additionally, 290 patients (98%) declared that they intended to RTW. Postoperatively, 284 patients (95%) returned to work, of whom 255 patients (90%) returned within 6 months (Figure 4). Regarding reasons for no RTW, 8 patients reported complaints related to the operated knee, 6 patients reported physical complaints unrelated to the operated knee, and 1 patient had lost his job. Postoperative knee demanding workload was lower in 12% of patients, the same in 80%, and higher in 8%.

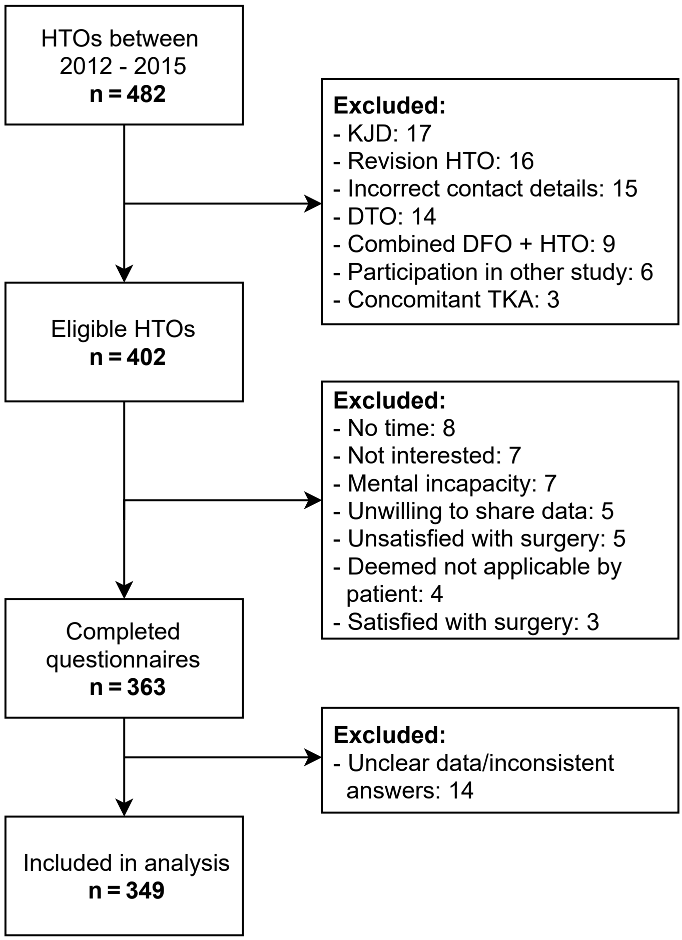

Fig. 3 Inclusion flow diagram. DFO, distal femoral osteotomy; DTO, distal tibial osteotomy; HTO, high tibial osteotomy; KJD, knee joint distraction; TKA, total knee arthroplasty.

Table 1 Baseline characteristics[a]

	Total group (n = 349)	OA group (n = 288)	Non-OA group (n = 61)
Age at surgery, y	47.1 ± 12.1	50.3 ± 9.2	32.0 ± 12.4
Follow-up, y	3.6 ± 1.0	3.7 ± 1.0	3.4 ± 1.0
Female sex, n (%)	157 (45)	118 (41)	39 (64)
BMI, kg/m^2	27.1 ± 4.5	27.5 ± 4.4	25.1 ± 4.4
Right side, n (%)	185 (53)	149 (52)	36 (59)
ASA classification, n (%)			
I	215 (61)	169 (58)	46 (75)
II	132 (38)	118 (41)	14 (23)
III	2 (1)	1 (1)	1 (2)
Osteotomy type, n (%)			
Medial opening wedge HTO	239 (69)	231 (80)	8 (13)
Medial closing wedge HTO	68 (19)	57 (20)	11 (18)
TDO[b]	29 (8)	-	29 (48)
Sagittal HTO	13 (4)	-	13 (21)
Wedge size, mm			
Medial opening wedge HTO	9.9 ± 3.0	10.0 ± 3.0	8.0 (6.0-9.0)[c]
Medial closing wedge HTO	6.8 ± 2.2	6.6 ± 2.0	7.0 (5.9-12.0)[c]
TDO[b]	15.0 (15.0-18.0)[c]	-	15.0 (15.0-18.0)[c]
Sagittal HTO	11.0 (7.5-13.5)[c]	-	11.0 (7.5-13.5)[c]
Revision surgery, n (%)	24 (7)	19 (7)	5 (8)
Osteotomy	2	2	-
Non-union	3	2	1
TKA	13	11	2
Arthroscopic debridement	4	2	2
Meniscectomy	1	1	-
MUA	1	1	-
Hardware removal, n (%)	194 (56)	150 (52)	44 (72)
Timing of hardware removal, y	1.1 ± 0.6	1.1 ± 0.6	0.9 ± 0.7

[a]Data are presented as mean ± SD unless otherwise indicated. ASA, American Society of Anesthesiologists; BMI, body mass index; HTO, high tibial osteotomy; MUA, manipulation under anaesthesia; OA, osteoarthritis; TDO, tibial derotation osteotomy; TKA, total knee arthroplasty.
[b]Degrees of rotational correction are presented.
[c]Data are presented as median (interquartile range).

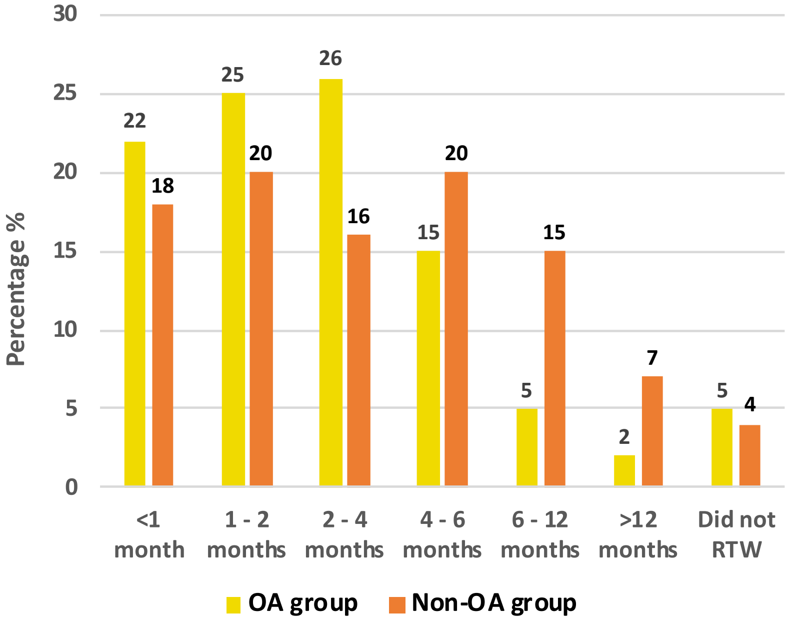

Fig. 4 Timing of return to work for the osteoarthritis (OA) and non-OA groups.

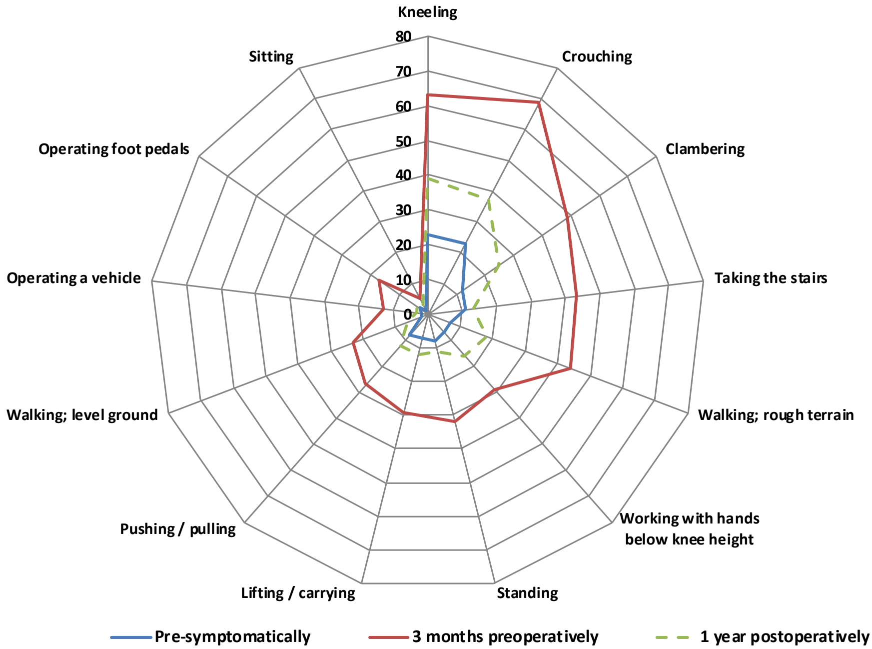

Fig. 5 Reported difficulty with work-related tasks at 3 time points. The percentage of patients who experienced severe or extreme difficulty or were unable to perform the activity for each of the 13 activities is depicted.

Patient-Reported Changes in Work-Related Capacity

WORQ scores at 3 time points revealed that preoperatively, patients experienced the most difficulty with crouching, kneeling, clambering, taking the stairs, and walking on rough terrain (Figure 5). Postoperatively, an improvement was observed for all activities. The largest improvement was reported for crouching and taking the stairs (32% and 30%, respectively), with fewer patients reporting extreme difficulty or being unable to perform these knee-demanding activities (Figure 5).

OA Versus Non-OA Group

In the OA group, 241 of 254 patients (95%) returned to work, which was comparable with 43 of 45 patients (96%) in the non-OA group ($p = 0.77$). In the OA group, 47% returned to work within 2 months compared with 38% in the non-OA group. The proportion of patients who returned to work within 6 months did not differ between the OA and non-OA groups ($p = 0.16$). Also, the postoperative changes in workload did not differ between groups ($p = 0.17$). For the OA group, the working hours were equal preoperatively, 1 year postoperatively, and at final follow-up. For the non-OA group, the number of working hours at follow-up increased compared with preoperatively ($p < 0.001$). Details on preoperative and postoperative working hours can be found in Appendix Table A1.

Prognostic Factors for RTW

Univariate analysis showed 8 variables that significantly differed between the RTW and no RTW groups (Table 2). The multivariable logistic regression model included BMI, wedge size (<10 or ≥10 mm), breadwinner (yes/no), preoperative sick leave (yes/no), and preoperative workload (low/intermediate/high). The model was statistically significant ($p < 0.05$), explained 24% (Nagelkerke R^2) of the variance in RTW, and correctly classified 88% of cases. Patients who reported being their family's breadwinner were more likely to RTW within 6 months (OR, 2.92; 95% CI, 1.27-6.69) (Table 3). In contrast, preoperative sick leave significantly lowered the odds of returning to work within 6 months (OR, 0.20; 95% CI, 0.08-0.46). Patients with an intermediate workload were less likely to RTW (OR, 0.40; 95% CI, 0.17-0.97), while no association was found between high workloads and RTW within 6 months. Last, BMI and wedge size were not significantly associated with RTW.

Table 2 Univariate analysis of factors associated with RTW[a]

	RTW (n = 255)	No RTW (n = 44)	*p*-value
Age at surgery, y	47.6 ± 10.8	42.6 ± 12.5	<.01[b]
Follow-up, y	3.7 ± 1.0	3.5 ± 1.1	.19[b]
Female sex, n (%)	98 (38)	28 (64)	<.01[c]
BMI, kg/m²	26.9 ± 4.0	28.1 ± 5.0	.09[b]
Right side, n (%)	136 (53)	23 (52)	.90[c]
ASA classification, n (%)			
I	160 (63)	23 (52)	.41[c]
II	93 (36)	21 (48)	
III	2 (1)	-	
Osteotomy type, n (%)			
Medial opening wedge HTO	186 (73)	27 (62)	**.03[c]**
Medial closing wedge HTO	48 (19)	8 (18)	
TDO	17 (7)	5 (11)	
Extending HTO	4 (1)	4 (9)	
Wedge sized, n (%)			
<10mm	119 (52)	26 (67)	**.07[c]**
≥10mm	108 (48)	13 (33)	
Employment status, n (%)			
Employee	190 (75)	38 (87)	.24[c]
Self-employed	54 (21)	5 (11)	
Both	11 (4)	1 (2)	
Breadwinner, n (%)			
Yes	180 (71)	21 (48)	**<.01[c]**
No	75 (29)	23 (52)	
Preoperative workload[e], n (%)			
Low	133 (55)	13 (32)	**.02[c]**
Intermediate	73 (30)	20 (49)	
High	38 (15)	8 (19)	
Preoperative sick leave[f], n (%)			
Yes	28 (11)	16 (38)	<.001[c]
No	226 (89)	26 (62)	
Preoperative intention to RTWg, n (%)			
Yes	250 (98)	40 (95)	.20[c]
No	4 (2)	2 (5)	

[a] Data are presented as mean ± SD unless otherwise indicated. Variables with a significance of $p < 0.10$ were considered significant and are presented in bold. ASA, American Society of Anesthesiologists; BMI, body mass index; HTO, high tibial osteotomy; RTW, return to work; TDO, tibial derotation osteotomy.
[b] Independent-samples t test.
[c] Chi-square test or Fisher exact test in cases with <5 expected counts.
[d] Wedge size could not be retrieved from the electronic patient record in 33 patients.
[e] Preoperative workload could not be determined in 14 patients.

[f] Preoperative sick leave was not reported in 3 patients.
[g] Preoperative intention to RTW was not reported in 3 patients.

Table 3 Logistic regression model analysing the effect of selected covariates on the odds of RTW[a]

Predictors for RTW	Odds Ratio	95% CI
BMI, kg/m^2	0.93	0.86–1.01
Wedge size, mm	1.41	0.60–3.31
Breadwinner	**2.92**	**1.27–6.69**
Preoperative sick leave	**0.20**	**0.08–0.46**
Preoperative workload		
Light	–	–
Intermediate	**0.40**	**0.17–0.97**
High	0.53	0.17–1.69

[a] Values with a significance of $p < 0.05$ were considered significant and are presented in bold. BMI, body mass index; CI, confidence interval; RTW, return to work.

DISCUSSION

The present study, describing the largest HTO cohort studied for RTW to date, showed that 95% of patients returned to work after HTO, of whom 90% returned within 6 months. We found no differences in RTW or time to RTW between patients with knee OA and patients with other indications for HTO. Compared with the preoperative situation, the postoperative workload was equal or higher in 88% of patients. A large number of patients reported a significant decrease in experiencing difficulty in performing knee demanding activities, such as kneeling and taking the stairs. Last, being the family's breadwinner was associated with a 2.9 times greater chance of RTW within 6 months. In contrast, preoperative sick leave resulted in a 5.0 times lower chance of RTW within 6 months.

Recently, Grünwald et al.[13] showed that patients undergoing HTO considered return to employment to be the most important expectation of their surgery. Also, almost all patients expected to RTW at their presymptomatic work ability level[13]. In that context, our RTW percentage of 95% seems very promising. It is noticeably higher than the average reported percentage of 85% in a meta-analysis on patients undergoing HTO[19], although the 2 largest included studies were in soldiers and farmers (i.e. patients with high workloads). Also, our RTW percentage is markedly higher than the pooled RTW estimate of 70% after KA, although the reported KA population was older (mean age, 66 years) and slightly heavier (mean BMI, 29.4 kg/m^2)[20]. Several explanations for our high RTW rate may exist, which include surgery- and patient-related factors.

Regarding surgery-related factors, it is known that high surgeon volume positively influences outcomes after surgical procedures, including KA[39]. Additionally, Liddle et al.[40] found that in unicompartmental KA, the proportion rather than the total number of performed KA procedures influenced outcomes. Surgeons who performed unicompartmental KA in 40% to 60% of their total KA practice obtained significantly better results compared with surgeons who performed unicompartmental KA in <20% of patients[40]. Thus, underusage of unicompartmental KA in eligible patients with knee OA resulted in worse results, and one could hypothesize that the same accounts for HTO. While no studies have investigated these effects in HTO, it is probable that the high surgeon volume (40-150 osteotomy procedures per year per surgeon) and high proportion of HTO procedures in our study positively influenced the outcomes. Furthermore, much work has been done in recent years to standardize and optimize the HTO surgical technique. This includes more accurate preoperative planning methods and perioperative improvements, such as biplanar osteotomy[41–43], use of angular stable implants[44], and early full weightbearing mobilization[45,46]. As a result, survival rates and functional outcomes have markedly increased[18,47].

Evidence on patient-related factors that influence RTW after HTO is extremely sparse[19]. Recent systematic reviews have described prognostic factors for RTW in patients of working age undergoing KA[35,36]. Our study is the first in patients undergoing HTO to include preoperative sick leave, and we found that it was associated with delayed and no RTW. Likewise, 3 studies found that preoperative sick leave was associated with worse RTW after KA[35]. Interestingly, being female was associated with no RTW in our cohort, which is in line with findings in patients undergoing KA[48]. Although no unequivocal explanation exists, one could speculate that women are less likely to be their family's breadwinner and therefore may decide more easily not to RTW[48]. The derotation osteotomy subgroup, with the highest percentage of female patients, was also associated with lower RTW at 6 months, supporting this hypothesis. Clearly, sex is an unmodifiable factor, and therefore, this finding should be mainly used to adequately inform patients. However, modifiable factors should be controlled as best as possible to lower the risk of delayed or no RTW after HTO. Preoperative sick leave was consistently found to be a predictor of delayed or no RTW after knee surgery, highlighting the need for better understanding reasons for being on sick leave. Possibly, adequate preoperative counselling and timely work-directed interventions, including referral to an occupational physician, could help to achieve this. Furthermore, earlier HTO surgery in these patients might be warranted to prevent the preoperative deterioration of functional status, resulting in delayed or no RTW[48].

This study is the first to use a multivariable model to analyse the prognostic factors for RTW after HTO. Also, this is the first study to ask patients undergoing HTO about work-related factors such as employment status, being the family's breadwinner, preoperative sick leave, and intention to RTW. We hypothesized that both employment status and being the family's breadwinner would influence patients' motivation to RTW and therefore their actual RTW. Indeed, we found that being the family's breadwinner was most strongly associated with RTW within 6 months. Interestingly, this factor has never been studied in patients undergoing HTO or KA, hampering comparison with the current literature. In our cohort, employment status was not associated with RTW. In contrast, in KA, self-employment was an accelerating factor for RTW[23], probably because of patients being highly motivated to start working again, being able to individually implement work adaptations, and of course, financial gains.

The association between workload and RTW after knee osteotomy remains debatable. Previous studies in patients undergoing HTO presented univariate analyses of the effect of workload on RTW, reporting conflicting findings[19]. There were 2 studies that found that higher workloads resulted in longer inability to work, while another study found no effect[19]. In patients undergoing KA, similar inconsistent findings have been reported[31,35], with the study on the largest working cohort reporting no association[31]. Our univariate analysis found an association between higher workload and lower RTW, while the multivariable model showed lower RTW for patients with intermediate workloads compared with low workloads but no significant association between RTW and high workloads possibly because of a lack of power. Based on the literature and clinical reasoning, workload likely plays a role in time to RTW after knee surgery[19,48] because physically demanding jobs likely require better knee function and/or work adaptations to overcome the disability because of insufficient knee function. It is possible that our analysis of workload lacked power because of the small number of patients with intermediate and high workloads who did not RTW. Another explanation could be the healthy worker effect. This effect implies that patients who still perform heavy knee-demanding work before KA are a select group of workers who are more fit than workers involved in medium knee-demanding jobs[48]. Unfit workers would have already left their heavy knee-demanding job at an earlier phase because of health complaints[48]. However, based on our data, we cannot convincingly confirm the assumption that having a physically demanding job is associated with worse RTW 6 months after HTO.

The most important limitation of the present study is its retrospective design, with data collection at a mean follow-up of 3.6 years, which makes our findings prone to recall bias. However, given the importance of RTW, most patients can probably adequately estimate their RTW date[49]. Next, despite including the largest cohort of working patients undergoing HTO to date, the low number of patients who did not RTW may limit the power of our regression model. Furthermore, we were unable to present separate logistic regression analyses for the OA and non-OA groups. Consequently, the use of our prognostic factors when counselling individual patients, that is, OA or non-OA groups, might be hampered. Future studies including even larger cohorts are required to analyse prognostic factors for these groups separately. In addition, our study did not include a KA control group. Also, all HTO procedures were performed by high-volume knee osteotomy surgeons at a single dedicated clinic. Consequently, the external validity of the present findings might be limited. However, adherence to the basic principles of patient selection, preoperative and intraoperative surgical planning, adequate plate fixation, and early rehabilitation likely result in improved and more homogeneous results in HTO surgery in different settings. Last, external validity may also be hampered because of differences in disability insurance policies between countries, as longer availability of workers' disability compensation could lead to slower RTW.

Patients with knee OA themselves are aware that proper RTW advice is lacking in the preoperative phase[22]. Consequently, patients are unsure about what to expect regarding their postoperative RTW and often await regular follow-up appointments to receive permission to RTW[22]. Studies have shown that thorough preoperative patient education results in improved postoperative outcomes after different orthopaedic procedures[50]. Thus, orthopaedic surgeons can play a crucial role in improving patient-related outcomes after HTO by preoperatively discussing expectations and recommendations, including adequate referral to occupational physicians. Such patient education, which should include advice regarding RTW, may be based on the present findings as well as previously reported expectations and outcomes of HTO[13,19]. Ultimately, the goal is for the surgeon to select the right patient at the right time to further improve satisfaction rates and patient-relevant outcomes after HTO.

CONCLUSION

In total, 95% of patients returned to work after HTO, and 9 of 10 patients returned within 6 months. Being the family's breadwinner was associated with RTW within 6 months, while preoperative sick leave was associated with RTW later than 6 months or even no RTW.

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PART III

OPTIMISING FUNCTIONAL OUTCOMES AND PATIENT SATISFACTION

CHAPTER 7

Outpatient Unicompartmental Knee Arthroplasty: Who Is Afraid of Outpatient Surgery?

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Knee Surgery, Sports Traumatology, Arthroscopy (2017)

ABSTRACT

Purpose In recent years, duration of hospitalisation after knee arthroplasty has decreased and fast-track and outpatient surgery protocols have been developed. Studies have shown that outpatient surgery is feasible, safe and cost-effective. However, the psychological well-being of patients undergoing outpatient surgery has never been described before. The purpose of this study was to investigate how patients experience outpatient surgery for unicompartmental knee arthroplasty (UKA), examining levels of anxiety and depression, satisfaction and pain. It was hypothesized that the same-day discharge following UKA would not result in higher levels of anxiety and depression, compared to standard fast-track surgery.

Methods This case-controlled study included 20 patients undergoing UKA in an outpatient surgery setting and 20 patients undergoing standard fast-track procedure. The Hospital Anxiety and Depression Scale (HADS, 0-42, lower is better) and numeric rating scales (NRS, 0-10) for pain and satisfaction were collected preoperatively, on the day of surgery, on the first, second and seventh postoperative day and after 6 and 12 weeks. The Oxford Knee Score (OKS), the KOOS, EuroQoL-5D and Net Promoter Score (NPS) were collected preoperatively and 3 months postoperatively.

Results 90% of patients in the outpatient surgery group were discharged on the day of surgery. At the first postoperative day, the median HADS score was significantly lower in the outpatient surgery group compared to the fast-track group (3 vs. 8, $p = 0.02$), the median NRS satisfaction score was significantly higher in the outpatient surgery group (8 vs. 5, $p = 0.03$), and no differences existed between both groups for the NRS pain scores. At 3-month follow-up, no significant differences in improvement scores existed between both groups for the HADS, the NRS scores, and for the OKS, KOOS, EuroQoL-5D, and NPS.

Conclusion The results of this study emphasize the feasibility of an outpatient surgery pathway in carefully selected UKA patients. The outpatient surgery pathway is safe, and clinical outcome, including levels of anxiety and depression, satisfaction, and pain, was similar in outpatient surgery patients compared to standard fast-track patients.

INTRODUCTION

For decades, unicompartmental knee arthroplasty (UKA) was considered a surgical procedure requiring prolonged hospitalisation periods, but in recent years, the shortening of hospitalisation after UKA has gained considerable interest. Already, the average length of stay has markedly decreased with the implementation and optimisation of postoperative fast-track pathways[1,2]. Fast-track UKA allows for safe, efficient care with fewer perioperative complications and early discharge, which in turn leads to higher patient satisfaction[2-5]. The average reported length of stay in fast-track programs for UKA patients has already decreased to 1 day, with good results[6].

Therefore, the introduction of outpatient surgery seemed like the logical next step in attempting to further improve clinical outcome and shortening length of stay in UKA. Several authors have described the use of an outpatient surgery pathway in UKA and so far, results have been very promising[4,7–10]. Discharge on the day of surgery was possible in almost all cases, varying from 85 to 100% of cases. Furthermore, incidence of adverse events, complications, and readmissions was low and rates were comparable to UKA patients operated on in a fast-track pathway[1,7,9,10].

While the abovementioned studies primarily focused on clinical outcome in terms of safety (adverse events, complications), practical challenges, and feasibility of outpatient surgery pathways for UKA, patients' levels of anxiety and depression when undergoing UKA in an outpatient setting have not been described before. Interestingly, previous research showed that, in 135 patients undergoing different types of elective procedures, outpatient surgery patients experienced significantly higher perioperative levels of anxiety and depression compared to fast-track patients[11]. The presence of psychological symptoms, such as anxiety and depression, may negatively influence surgical outcome following KA[5,12,13]. Thus, it is very important to ascertain that an outpatient surgery pathway for UKA is also safe in terms of the patients' psychological well-being. However, none of the previous studies on outpatient surgery for UKA have addressed the effect of an outpatient protocol on the patients' psychological well-being.

Therefore, the effect of an outpatient surgery pathway for UKA was investigated, comparing the levels of anxiety and depression, pain, and satisfaction that patients experienced perioperatively, compared to the standard fast-track treatment. Based on the excellent results from the previous outpatient surgery studies in UKA patients, it was hypothesized that the same-day discharge following UKA in carefully selected patients would not result in higher levels of anxiety or depression, more pain or lower satisfaction, compared to a fast-track pathway.

MATERIALS AND METHODS

Study design and patient population

In this case-control study, 20 patients undergoing UKA in an outpatient surgery setting and 20 patients undergoing UKA in a standard fast-track setting between June 2015 and June 2016 were compared. Baseline characteristics are shown in Table 1. The study was performed in compliance with the Helsinki Declaration of 1975, as revised in 2000. Eligible patients were <70 years of age, ASA 1-2, and motivated to participate in the outpatient surgery program. A personal coach (relative) had to be available during the first 24 h after discharge to assist the patient at home in the first postoperative phase. Figure 1 presents the flowchart for the screening and enrolment process. Patients with a BMI higher than 35 kg/m^2 or with a history of diabetes, recent myocardial infarction, congestive heart failure, stroke, thromboembolic events, respiratory disease or opiate use were excluded. Also, patients with a history of mental illness (depression and anxiety disorders) were excluded. Finally, patients living too far away from the hospital for the home visit by the hospital physiotherapists were excluded.

Table 1 Baseline characteristics

Variable	Outpatient surgery (n = 18)	Control (n = 18)	*p*-value[a]
Age at surgery, years	62.2 ± 5.5	63.8 ± 7.5	n.s.
Gender, male	10 (56%)	7 (37%)	n.s.
BMI, kg/m^2	27.8 ± 3.7	30.5 ± 7.0	n.s.
ASA			
1	7 (39%)	6 (32%)	
2	11 (61%)	10 (53%)	n.s.[b]
3	0	3 (15%)	
4	0	0	
OR time, min	62.6 ± 13.1	60.5 ± 20.8	n.s.
Anaesthesia			
General	10	12	n.s.
Spinal	10	8	
Surgical technique			
Signature	3	4	n.s.
Microplasty	17	16	
LOS, days	0	1.3 (1–4)	–

[a] Comparison with Chi-square Test, Fisher's Exact Test, or Independent Samples T-Test
[b] Fisher-Freeman-Halton test. LOS: length of stay

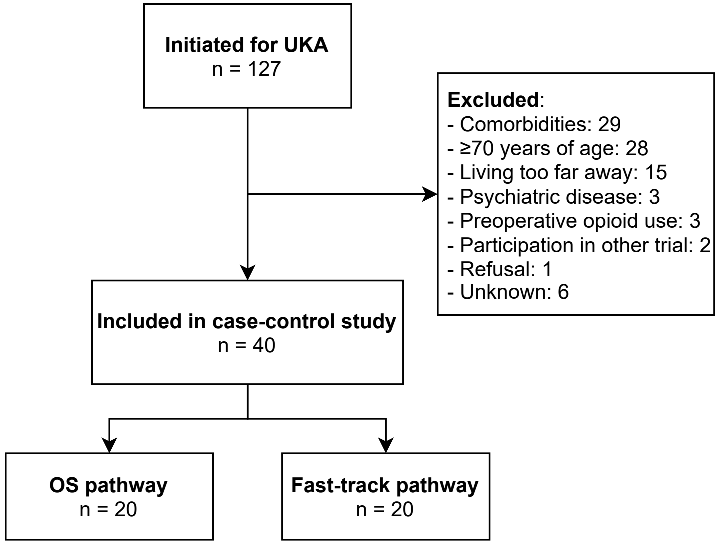

Fig. 1 Flowchart for the screening and enrolment process.

Standard fast-track protocol

Table 2 shows the differences between the fast-track protocol and the outpatient surgery protocol. Approximately 1 h before surgery, all patients received paracetamol (1 g), meloxicam (15 mg), pantoprazole (40 mg) and gabapentin (300 mg). All patients received the uncemented Oxford phase III prosthesis (Biomet, Bridgend, UK). Surgery was performed using patient-specific guides (Signature, Biomet, Warsaw INC) in four fast-track patients and in three outpatient surgery patients. The Microplasty instrumentation (Biomet, Bridgend, UK) was used in 16 fast-track patients and 17 outpatient surgery patients. Cefazolin was used as perioperative prophylactic antibiotics for 24 h. Patients were either operated under spinal or general anaesthesia (Table 1). All patients received a preoperative dose of tranexamic acid. Local infiltration analgesia (LIA) was administered intraoperatively. To prevent postoperative nausea, perioperative dexamethasone (8 g) was administered. At wound closure, another dose of tranexamic acid (1 g) was administered. No drains or urinary catheters were used. To reduce swelling and improve LIA effect, a compression bandage was used[14] (Table 1). Postoperatively, patients with a urinary retention over 500 mL were catheterised. For postoperative pain management, meloxicam (15 mg once daily) and paracetamol (1000 mg four times daily) were prescribed. In addition, in the fast-track protocol, oxycodone (10 mg) was administered 4-6 times daily on the first postoperative day. The hospital physiotherapist visited the patient two times on the day of surgery (two and 4 h postoperatively), and normal walking and walking stairs were practiced on the first postoperative day. Thromboprophylaxis was prescribed for 6 weeks and conform national guidelines. All patients were seen at the outpatient clinic after 14 days and after 6-8 weeks.

Outpatient surgery protocol

In contrast to the fast-track pathway, patients in the outpatient surgery pathway had a personal educational meeting with a nurse practitioner to avoid confusion in the standard group educational meetings (Table 1). Preferably, the patients' coach was also present at this meeting. Instructions on the outpatient surgery process, physiotherapy, and the rehabilitation protocol were provided, and patients' questions and expectations were addressed. No preoperative exercise training or rehabilitation was provided, but patients were advised to contact a physiotherapist to discuss postoperative arrangements.

Table 2 Differences between the outpatient surgery pathway and the fast-track pathway

	Fast-track pathway	**Outpatient surgery pathway**
Preoperative		
Patient education	Group education	Individual education
Perioperative		
Antibiotics	IV (preoperatively, 8 h and 16 h postoperatively)	IV (preoperatively and 8 h postoperatively)
Postoperative		
Compression bandage	16–24 h (removed on ward)	24 h (removed by physiotherapist)
Physiotherapy by hospital physiotherapist	After 2, 4 h and on postoperative day 1	After 2, 4, 6h At home on day 1
Opioid use	Oxycodone 5–10 mg (4–6 times daily)	–
Discharge criteria*	–	Independent transfers and independent walking

* Standard discharge criteria applied to all patients: no or limited wound drainage, acceptable pain level, no medical indication for prolonged hospital stay, patient feels confident going home.

All surgeries in the outpatient surgery group were performed by one experienced knee surgeon (RvG). All outpatient surgery patients were operated on in the morning to allow for completion of the entire postoperative rehabilitation protocol in the hospital. In contrast to the fast-track protocol, an opioid-sparing multimodal pain protocol was used. Only in case of breakthrough pain, oxycodone 5 mg (max. 4 times daily) was administered as rescue pain medication. Two hours postoperatively, patients were seen by a physiotherapist and knee flexion and extension was practiced. After 4 h, patients were mobilised with help of the physiotherapist. Mobilisation included transfers from bed to chair, standing, and walking with the use of an assistive device (walker, crutches). After 6 h, walking was practiced again, including walking stairs if this was required. The following discharge criteria were used: no or limited wound drainage, acceptable pain level, no medical indication for prolonged hospital stay, independent transfers in and out of bed, independent walking and, if necessary, walking stairs. Patients were allowed to go home under the supervision of their coach. The treating surgeon visited each patient before discharge. At the first postoperative day, a physiotherapist from the hospital visited the patient at home to remove the compression bandage, to explain and practice rehabilitation exercises, and to evaluate the day of surgery. After this visit, patients continued their rehabilitation with their own physiotherapist. At days 2 and 7, a nurse from the orthopaedic ward called the patient to check if there were any problems or complications.

Outcome measures

Outcome in terms of adverse events, opiate use, and complications was carefully monitored. Patient-reported outcome measures (PROMs) were collected preoperatively, at discharge, at home on the evening of the day of surgery, at three moments on the first postoperative day (morning, afternoon, and evening), and at postoperative days 2 and 7, at 6 weeks and at 3 months postoperatively. The Hospital Anxiety and Depression Scale (HADS, 0-42, lower is better) was used to assess patients' levels of anxiety and depression[15]. The HADS is a 14-item questionnaire with seven items (0-21 points) addressing patients' anxiety level and seven items addressing depression (0-21 points). It is the preferred measure of anxiety and depression for non-psychiatric hospital patients. Cut-off points for the presence of anxiety disorders or depression have been investigated[16]. A score of ≥ 8/21 points indicates the presence of an anxiety disorder and/or depression. Numeric rating scales (NRS, 0-10) were used to assess patient satisfaction, pain at rest, and pain after mobilisation. In addition, the Dutch validated versions of the Oxford Knee Score (OKS, 12-60, lower is better), Knee Injury and Osteoarthritis Outcome Score (KOOS, 5 subscales with scores 0-100, higher is better) and the EuroQol-5D VAS health score (EQ-5D; 0-100, higher is better)[17–19] are routinely collected preoperatively and 3 months postoperatively. Finally, the Net Promoter Score (NPS, 0-10), which evaluates how likely patients would recommend the operation to a relative or close friend, was collected[20].

Statistical analysis

All statistical analyses were performed with SPSS for Windows (Version 24.0. Armonk, NY: IBM Corp). Since the fast-track pathway and outpatient surgery pathway mainly differ on the first postoperative day, differences in HADS and NRS scores were compared with Mann-Whitney *U* tests at that time point. Mean HADS scores on the first postoperative day were 4.1 for the OS group and 9.3 for the fast-track group, with an SD of 5.2. For an expected difference of 5.2 points on the HADS at day one with an SD of 5.2, with a two-sided significance of 0.05 and a power of 0.8, a total of 20 subjects in each group would be required (nQuery Advisor® version 7.0). Differences from baseline to 3-month follow-up within each separate group were analysed with Wilcoxon signed-rank test. For all outcome parameters, differences between the outpatient surgery group and fast-track group, from baseline to 3-month follow-up, were analysed.

RESULTS

Of the 20 patients included in the outpatient surgery group, 18 patients (90%) could go home on the day of surgery. In one case, the required prosthesis was not available on the OR at the scheduled time of surgery, and thus, the operation was delayed. Therefore, the rehabilitation protocol in the hospital could not be completed and the patient had to stay for one night. In one case, anaesthesiologists disagreed on the ASA classification of the patient, who had a history of cardiac events. Therefore, it was decided on the OR that the patient had to stay for one night. Thus, 18 patients were included for analysis in the outpatient surgery group. Postoperatively, one patient in the outpatient surgery group visited the ER on the first postoperative day due to wound leakage. Two extra sutures were placed, and the patient could return home. In the fast-track group, 18 patients completed the questionnaires sufficiently and two patients were excluded due to insufficient data. The average length of stay in the control group was 1.3 days (range 1-4).

Patient-reported outcome measures

Figure 2 shows boxplots of the median HADS scores for both groups at all time points. Both groups showed a decrease, i.e. improvement, in HADS scores over time. The median HADS score appeared to be lower in the outpatient surgery group at all time points (Fig. 2). At day 1, the median HADS score was significantly lower ($p = 0.02$) in the outpatient surgery group (3.0, range 0-11) compared to the fast-track group (8.0, range 0-22). At the final follow-up, the median HADS score in the outpatient surgery group decreased from 4.0 to 1.0 (range 0-10, $p < 0.01$). In the fast-track group, the median HADS score decreased from 11.0 to 6.0 (range 0-15, $p < 0.01$). No significant difference was found between the groups in improvement of the HADS at final follow-up.

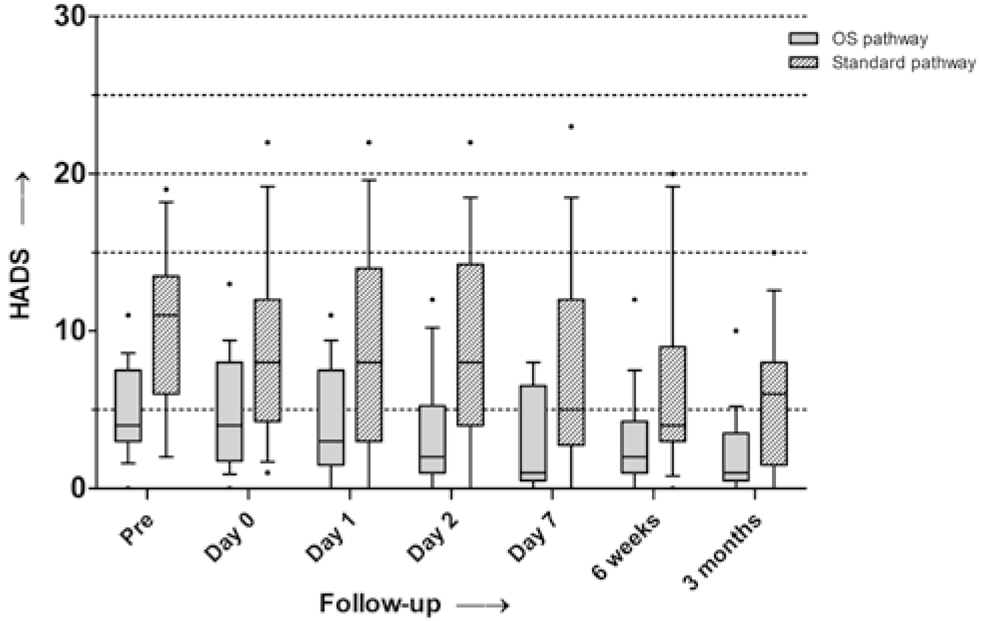

Fig. 2 Median HADS scores for both groups (*boxes* indicate first and third quartile; *whiskers* indicate 10–90 percentiles; dots indicate outliers).

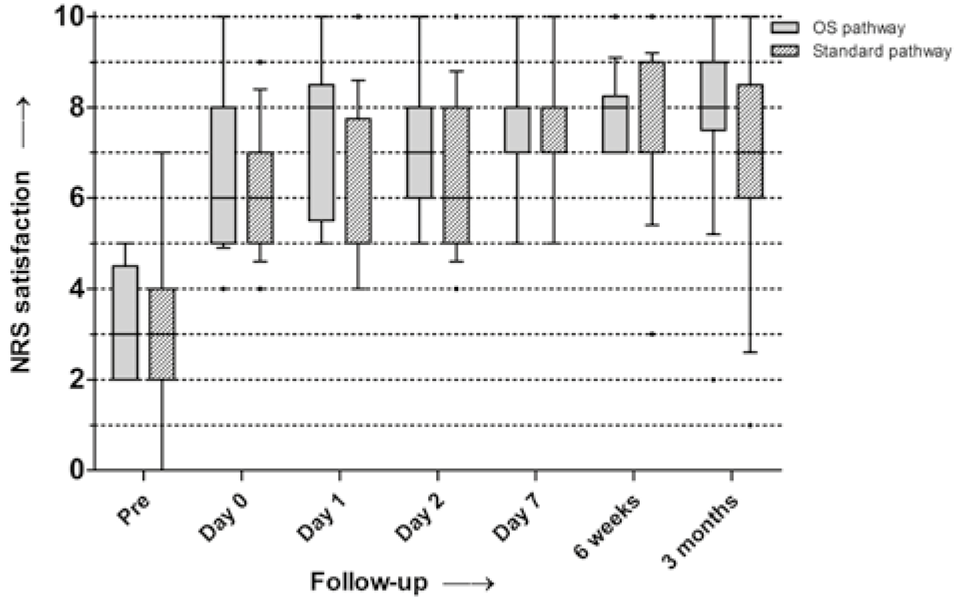

Fig. 3 Median NRS satisfaction scores for both groups (*boxes* indicate first and third quartile; *whiskers* indicate 10–90 percentiles; dots indicate outliers).

Figure 3 shows boxplots of the median NRS satisfaction scores. Higher satisfaction scores over time were observed for both groups independently (Fig. 2). At day 1, the median NRS satisfaction score was significantly higher ($p = 0.03$) in the outpatient surgery group (8, range 5-10) compared to the fast-track group (5, range 4-10). At final follow-up, the median NRS satisfaction score in the outpatient surgery group improved from 3 to 8 (range 2-10, $p < 0.001$) and in the fast-track group from 3 to 7 (range 1-10, $p < 0.01$). No significant difference was found between the groups in improvement of the NRS satisfaction score at final follow-up.

The NRS pain after activity scores decreased for both groups independently (Fig. 4). At day 1, the median NRS pain after activity score was not significantly different between both groups. At the final follow-up, the median NRS pain after activity score in the outpatient surgery group decreased from 8 to 3 (range 0-6, $p < 0.01$) and in the fast-track group from 7 to 3 (range 0-10, $p < 0.01$). No significant difference was found between the groups in improvement of the NRS pain after activity score at final follow-up. The NRS pain in rest scores showed the same pattern as the NRS pain after activity scores at all time points.

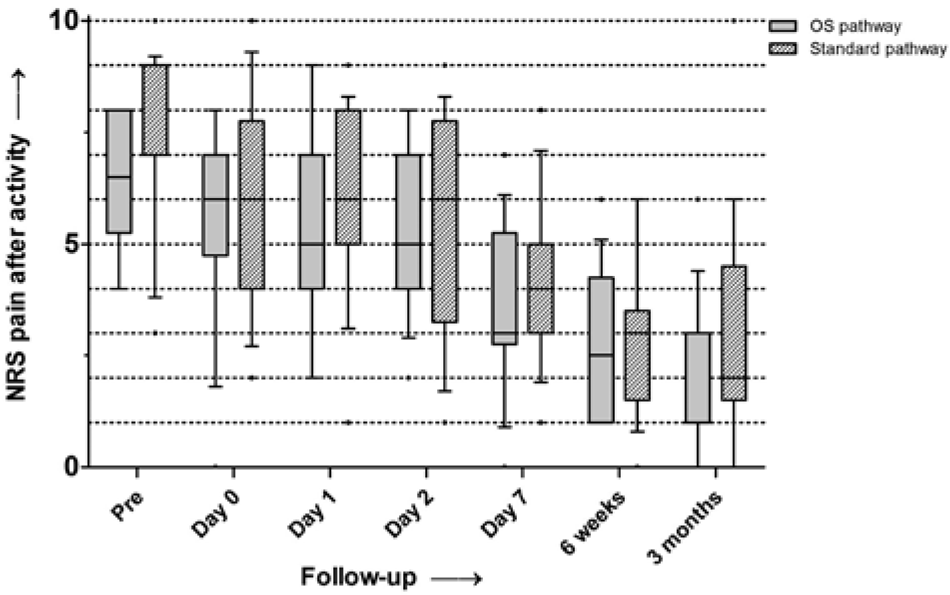

Fig. 4 Median NRS pain after activity scores for both groups (*boxes* indicate the first and third quartile, and *whiskers* indicate the range).

Table 3 presents the improvement scores for the KOOS, OKS, EQ-5D VAS scores, and the NPS. Improvement for the KOOS symptoms subscale was greater in the fast-track group, but the absolute score did not differ significantly (80 vs. 84, n.s.).

Table 3 Improvement scores for the KOOS, OKS and EQ-5D in both groups

PROM	Outpatient surgery group mean (SD)	Control group mean (SD)	*p*-value[a]
Δ KOOS Pain	28.0 (17.0)	35.6 (25.5)	n.s.
Δ KOOS Symptoms	19.3 (19.1)	33.2 (20.7)	**.04***
Δ KOOS ADL	23.2 (23.0)	37.8 (21.4)	n.s.
Δ KOOS Sport	28.9 (30.0)	35.8 (29.9)	n.s.
Δ KOOS QoL	33.8 (17.6)	39.9 (23.0)	n.s.
Δ OKS	12.0 (5.7)	16.1 (10.7)	n.s.
Δ EQ-5D VAS	15.0 (24.4)	16.2 (21.5)	n.s.[b]
NPS	47	47	-

* Significance is assumed at $p < 0.05$.
[a] Independent samples t-test
[b] Mann-Whitney U test

DISCUSSION

The most important finding of the present study was that UKA could be successfully performed in an outpatient setting with regard to the patients' psychological well-being. In carefully selected patients, outpatient surgery did not compromise outcome in terms of levels of anxiety and depression, satisfaction and pain scores. There were no medical complications that prohibited patients from going home in the outpatient surgery group, and 18 (90%) patients could go home on the day of surgery.

The present study is only the second study on outpatient surgery to include a control group, allowing for a comparison between fast-track surgery, which is currently seen as the golden standard, and outpatient surgery[5]. More importantly, this study is the first to describe the presence of symptoms of anxiety and depression, by means of the HADS, in UKA patients. The previous studies have shown that the presence of psychological symptoms in KA patients resulted in increased length of stay, readmissions, and morbidity, and worse patient-reported outcomes[12,13]. Duivenvoorden et al. found that HADS scores decreased over time in TKA patients, but patients with high preoperative HADS scores had worse PROMs at 3 and 12 months[21]. In the present study, HADS scores showed a similar decrease, i.e. less anxiety and depression, in both groups over time. Remarkably, significantly lower HADS scores were found in the outpatient surgery group compared to the fast-track group. The difference in HADS scores may be partly explained by the individual education meeting for outpatient surgery patients[22,23]. During this meeting an extensive explanation of the outpatient surgery procedure was given, and therefore, the patient knew exactly what to expect. In addition, after the operation, the hospital physiotherapist visited the patient more often. This additional personal attention may have led to outpatient surgery patients feeling more confident and less anxious. Finally, it is possible that patients in the outpatient surgery group were already less anxious preoperatively, since less anxious patients presumably would be more willing to undergo outpatient surgery. Nevertheless, the most important conclusion of the abovementioned findings is that an outpatient surgery pathway for UKA does not appear to compromise patients' psychological well-being.

In addition to the HADS sores, the present study is the first to describe satisfaction scores at several timepoints in the direct postoperative phase. Kolisek et al. found that satisfaction scores in UKA patients undergoing outpatient surgery or fast-track surgery did not differ at 24 months[24]. However, it seems unlikely that an additional effect of outpatient surgery on satisfaction would still be present after 24 months. The present study showed that satisfaction scores in the direct postoperative phase, up until 3 months follow-up, were equal or even better in outpatient surgery patients, compared to fast-track patients. Furthermore, no significant differences in pain scores existed, indicating that pain scores were not influenced by the early discharge to the home-environment for outpatient surgery patients. This is in line with reported pain scores in the only other case-control study by Kort et al. showing that outpatient surgery and fast-track surgery result in similar pain scores[10]. In contrast, high pain intensity was the main factor for an overnight stay in the study by Kort et al., while none of our patients experienced pain that prevented them from going home on the day of surgery. Finally, the improvement for the KOOS symptoms' subscale was significantly higher in the fast-track pathway compared to the outpatient surgery pathway. However, the KOOS and OKS scores were already higher preoperatively in the outpatient surgery group and no significant differences existed between both groups in overall KOOS and OKS scores at final follow-up. In conclusion, outpatient surgery patients were very satisfied and performed at least as good as fast-track surgery patients.

Concerning the general applicability of the abovementioned studies, it is important to note that the authors had already implemented fast-track surgery as the standard pathway for hip and knee arthroplasty in their institutions. Accordingly, the hospitals' staff had experience with local infiltration analgesia, multimodal opioid-sparing anaesthetic regimens, mobilising patients on the day of surgery, and checking the standard discharge criteria twice a day to prevent unnecessary hospitalisation. In addition, different authors stress the importance of a dedicated team of surgeons, anaesthesiologists, physiotherapists, and nursing staff when implementing outpatient pathways. Implementation of an outpatient pathway, as experienced by us, Berger et al. and Kort et al.[1,10], required an extensive change in mindset for both the patients and the multidisciplinary team. It is, therefore, recommended to gradually reduce LOS from ≥ 2 days to next-day discharge first. Subsequently, only when staff and patients are comfortable with the next-day discharge, the same-day discharge can be carefully attempted [4].

Finally, patient selection in KA is an important topic in recent literature, since proper selection is considered essential in assuring patient safety and preventing negative outcome and dissatisfaction[25,26]. Two recent studies have pointed out that well-conducted patient selection in outpatient surgery is very important to assure a safe procedure. Based on a literature review[25] and a retrospective review of patient characteristics associated with same-day discharge[26], the authors stated that exclusion criteria for outpatient joint arthroplasty should include[25,26]: high ASA classification (>II), bleeding disorders, poorly controlled and/or severe cardiac (e.g. congestive heart failure and arrhythmia) or pulmonary comorbidities (e.g. embolism and respiratory failure), uncontrolled DM (type I or II), chronic opioid consumption, functional neurologic impairments, dependent functional status, chronic/end-stage renal disease, and/or reduced preoperative cognitive capacity. However, both authors observed a void in literature concerning proper selection criteria for outpatient knee arthroplasty. The additional risk of outpatient surgery compared to a fast-track pathway, which is considered standard care, may not justify much stricter inclusion criteria. Recently, Jorgensen et al. showed that the incidence of early (<7 days) thromboembolic events, the main life-threatening early complication postoperatively, was seen in 11/13.775 unselected patients (0.23%) undergoing knee or hip replacement[27]. Patients were discharged after a mean LOS of 2 days. Out of 43 thromboembolic events, 11 events occurred in the first two postoperative days and only two events occurred after discharge. This study illustrates that, if a patient is considered eligible for standard fast-track KA surgery, the additional risk of an outpatient surgery pathway appears to be negligible.

A limitation of the present study is the fact that patients were not randomised. In accordance with several other studies describing KA in an outpatient setting, a case-control study was performed[10,24]. Strict inclusion and exclusion criteria were used to ensure a safe introduction of our novel outpatient surgery pathway[25]. It cannot be ruled out that patients in the outpatient surgery pathway were healthier as a group at the time of surgery. Therefore, randomized controlled trials should be conducted to eliminate possible confounders, such as the allocation of patients with less severe symptoms to the outpatient surgery pathway.

CONCLUSION

In conclusion, the findings of this study suggest that outpatient surgery for UKA is a safe and attractive treatment option in selected, motivated patients. This is a clinically relevant finding that will aid the orthopaedic surgeon in the decision to implement outpatient surgery for UKA. The patients' psychological well-being appears to influence outcome and should be taken into account when selecting patients for outpatient surgery. Future studies, including case series with larger numbers of patients and, most importantly, randomized controlled trials, are necessary to endorse findings of the present case-control study.

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CHAPTER 8

Does activity-based rehabilitation with Goal Attainment Scaling increase physical activity among younger knee arthroplasty patients? Results from the randomized-controlled ACTION trial

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ABSTRACT

Background Especially in younger knee osteoarthritis patients, the ability to perform physical activity (PA) after knee arthroplasty (KA) is of paramount importance, given many patients' wish to return to work and perform demanding leisure time activities. Goal Attainment Scaling (GAS) rehabilitation after KA may improve PA because it uses individualized activity goals. Therefore, our aim was to objectively quantify PA changes after KA and to compare GAS-based rehabilitation to standard rehabilitation.

Methods Data were obtained from the randomized controlled ACTION-trial, which compares standard rehabilitation with GAS-based rehabilitation after total and unicompartmental KA in patients <65 years of age. At 2 timepoints, preoperatively and 6 months postoperatively, 120 KA patients wore a validated 3-dimensional accelerometer for 1 consecutive week. Data were classified as sedentary (lying, sitting), standing, and active (walking, cycling, running). Repeated measures analysis of variance was used to compare PA changes over time.

Results Complete data were obtained for 97 patients (58% female), with a mean age of 58 years (± 4.8). For the total group, we observed a significant increase in PA of 9 minutes (± 37) per day ($p = 0.01$) and significant decrease in sedentary time of 20 minutes (± 79) per day ($p = 0.02$). There was no difference in standing time ($p = 0.11$). There was no difference between the control group and the intervention group regarding changes in PA, nor between the total KA group and unicompartmental KA group.

Conclusion We found a small but significant increase in overall PA after KA, but no difference between GAS-based rehabilitation and standard rehabilitation. Likely, enhanced multidisciplinary perioperative strategies are needed to further improve PA after KA.

INTRODUCTION

In knee osteoarthritis patients, severe pain and associated functional limitations are the most important reasons to perform knee arthroplasty (KA)[1]. Nowadays, the largest growth in KA utilization rates is seen in patients <65 years of age[2]. Given this increasing use of KA in younger and more active patients, physical activity (PA) demands and expectations will likely increase sharply[3,4]. Although the beneficial effects of PA on musculoskeletal and cardiorespiratory health are indisputable[5], it remains doubtful whether patients actually increase their PA following KA[6,7]. Previous studies showed significant improvements in patient-reported function and self-reported PA after KA[8,9]. Unfortunately, it is known that people in general [10], and KA patients in particular tend to overestimate their daily PA[9,11]. Consequently, the validity and reliability of PA comparisons in studies that rely on self-report is limited. More recently, studies based on objective accelerometer data showed no or minor PA improvements at 6 and 12 months after KA[9,12,13]. A meta-analysis showed no increase in PA at 6 months and a small-to-moderate increase at 12 months [6]. Finally, Frimpong et al.[14] showed an increase in patient-reported PA as well as an accelerometer-measured decrease in sedentary behaviour (-5.9%) and concomitant increase in light PA (+5.8%) 6 months after KA.

Thus, while KA aims to provide a solution for knee pain and associated activity limitations, the postoperative increase in PA seems small at best. To achieve behavioural changes in addition to functional improvements, enhanced multi-disciplinary perioperative strategies may prove useful. One such strategy might be Goal Attainment Scaling (GAS), which showed promising results in varying rehabilitation settings[15,16], including attainment of >90% of personal activity goals within 6 months in KA patients[17]. With GAS, patients define personal and realistic activity goals preoperatively together with a clinician. Postoperatively, patients work on these goals both in an outpatient physical therapy setting and in their home environment[17,18]. For instance, for a patient with a job that requires walking, rehabilitation would focus on the patient's walking ability, with leg strengthening exercises and endurance training.

We hypothesized that such an activity goal-oriented rehabilitation might result in a larger postoperative increase in PA compared to standard rehabilitation. Therefore, our aim was to objectively quantify PA changes after KA and to evaluate whether KA patients increase their PA levels more when following an individualized rehabilitation with GAS, compared to standard rehabilitation. Also, we investigated differences in PA between total KA (TKA) and unicompartmental KA (UKA).

MATERIAL AND METHODS

Study Design & Patient Selection

For the present study, data were used from the randomized controlled ACTION-trial (trial registry number: NTR5251). This trial investigated the effect of GAS rehabilitation on patient satisfaction regarding activities of daily living (ADL), work, and leisure time activities, compared to standard rehabilitation after KA[18]. Patients were randomized in a 1:1 allocation and, by necessity, patients and physicians were unblinded. For the present study, all patients were asked to wear an accelerometer for 1 consecutive week at 2 timepoints, namely in the month prior to surgery and 6 months after surgery. Patients were included from October 2015 to November 2017 at 1 large regional hospital performing ±600 KAs per year. Eligible patients were <65 years of age, suffering from debilitating knee osteoarthritis and awaiting KA, participating in a paid or voluntary job or working as an informal caregiver, and able to define and perform personal rehabilitation goals. Surgery was performed by dedicated knee surgeons (>5 years of experience). For TKA, patients received the cemented cruciate-retaining or posterior-stabilized Vanguard prosthesis (Biomet, Warsaw, IN). For UKA, patients received the uncemented Oxford phase III prosthesis (Biomet, Bridgend, UK) with Microplasty instrumentation (Biomet). Patients were either operated under spinal or general anaesthesia. All patients received a 1 g of tranexamic acid on induction and at the time of closure. Local infiltration analgesia was administered intraoperatively. The study was approved by the local medical ethical committee (NL53697.018.15) and all patients provided written informed consent.

Goal Attainment Scaling

Preoperatively, the intervention group formulated 3 personal activity goals together with a GAS-trained physical therapist, according to the GAS format[15,17]: 1 ADL activity, 1 work activity, and 1 leisure time activity (Fig. 1). Patients and physical therapists developed a 6-point scale: "–3" represents a deterioration in performance from baseline, "–2" is the initial pre-treatment (baseline) level, "–1" represents progression towards the formulated goal without goal attainment, "0" is the desired and thus expected level after treatment, "+1" represents a better outcome than expected, and "+2" is the best possible outcome that could have been expected for this goal[19]. To reduce patient bias and therapist bias, all created goals were discussed and approved by our multidisciplinary team, including orthopaedic surgeons, a human movement scientist, and an occupational health expert. The goals were described according to the International Classification of Functioning, Disability and Health (ICF) activity and participation level, in accordance with the S.M.A.R.T. (i.e. Specific, Measurable, Attainable, Realistic and Time-specific) criteria[20]. Based on these goals, an individualized rehabilitation schedule was created by the physical therapist. The control group underwent regular outpatient physical therapy after KA[21].

Goal: I want to speed walk for 10 consecutive minutes

Goal Attainment Level		
-3	**Decline**	Patient can speed walk <3 minutes
-2	**Baseline**	Patient can speed walk 3 – 5 minutes
-1	**Less than goal**	Patient can speed walk 6 – 8 minutes
0	**Goal**	Patient can speed walk 9 – 11 minutes
+1	**More than goal**	Patient can speed walk 12 – 14 minutes
+2	**Far more than goal**	Patient can speed walk >14 minutes

Fig. 1. Example of a GAS-based patient activity goal. Goal: I want to speed walk for 10 consecutive minutes. GAS, Goal Attainment Scaling

Activ8 Accelerometer

To reliably quantify PA, we used the validated triaxial Activ8 accelerometer (Remedy Distribution Ltd., Valkenswaard, The Netherlands). In the Activ8, raw acceleration signals (12.5 Hz) are converted to body postures and movements at a resolution of 1.56 Hz and buffered at 2.56-second intervals. In the output file, a summation of time spent in specific body postures and movements over 5-minute epochs is given. The Activ8 reliably measures and classifies PA into 5 categories: lying/sitting, standing, walking, cycling, running/high-intensity activity[22]. To obtain valid measurements, a minimum of 3-5 consecutive days of measuring is recommended[23]. For this study, patients wore the Activ8 for 5-7 consecutive days (24 h/d) in the month prior to KA and 6 months after KA. If, for any reason, patients were unable to complete the measurement, we used a minimum of 3 measurement days for inclusion in the analysis. The accelerometer was attached with Tegaderm skin tape to the front of the non-operated thigh, halfway between the hip and knee[22]. Patients were asked to keep a diary including dates, time in and out of bed, and non-wear, for instance patients were asked to remove the monitor when bathing or swimming. Patients received the Activ8 instructions and additional skin tape for 1 week during the inclusion meeting. They returned the Activ8 after 1 week, using a return envelope. Six months after surgery, patients were notified by e-mail or telephone and received the Activ8 and a return envelope by mail. For the analysis, the comma-separated values output files were imported in MATLAB (version R2017b) for further processing. Based on diary data, sleep and non-wear periods were removed from the data, leaving total daily waking wear time. Next, the total number of minutes and the proportion of time spent on each activity were calculated for the total daily waking wear time.

Statistical Analysis

Demographic data of all participants were analysed using descriptive statistics and categorized as intervention group vs control group. Activ8 data were further categorized as “active” (walking, cycling, running), “sedentary” (sitting, lying), and “standing”. Changes in absolute percentages of time spent in each activity were analysed. To test changes in PA, for “active”, “sedentary”, and “standing” time, 2-way repeated measures analysis of variance was performed with preoperative vs postoperative as within-subjects factor and intervention vs control and UKA vs TKA as between-subjects factors. Also, we used 2-way repeated measures analysis of variance to test the hypothesis that having a specific GAS goal (e.g. walking 5 km or 2 hours of cycling) would lead to a postoperative PA increase for that specific activity only. For these analyses, the groups were defined as “specific goal involving this activity” vs. controls. For instance, standing data of patients of the intervention group with specific goals regarding standing were compared with the data from the control group. A p-value of < 0.05 was considered significant. All statistical analyses were performed with SPSS for Windows (Version 24.0. Armonk, NY: IBM Corp.).

RESULTS

Patient characteristics

A total of 97 patients completed the study: 46 in the intervention group and 51 in the control group (Fig. 2). During the study, 7 patients in the intervention group (12%) and 2 patients in the control group (3%) withdrew their consent. Other reasons for exclusion included technical failure of the Activ8 (n = 5; 8%), allergic skin reaction (n = 2; 3%), Activ8 lost in the postal mail (n = 3; 5%), less than 3 consecutive measurement days (n = 3; 5%), and no available diary data (n = 1; 2%). Complete preoperative and postoperative accelerometer data were obtained for 97 (81%) patients (Table 1).

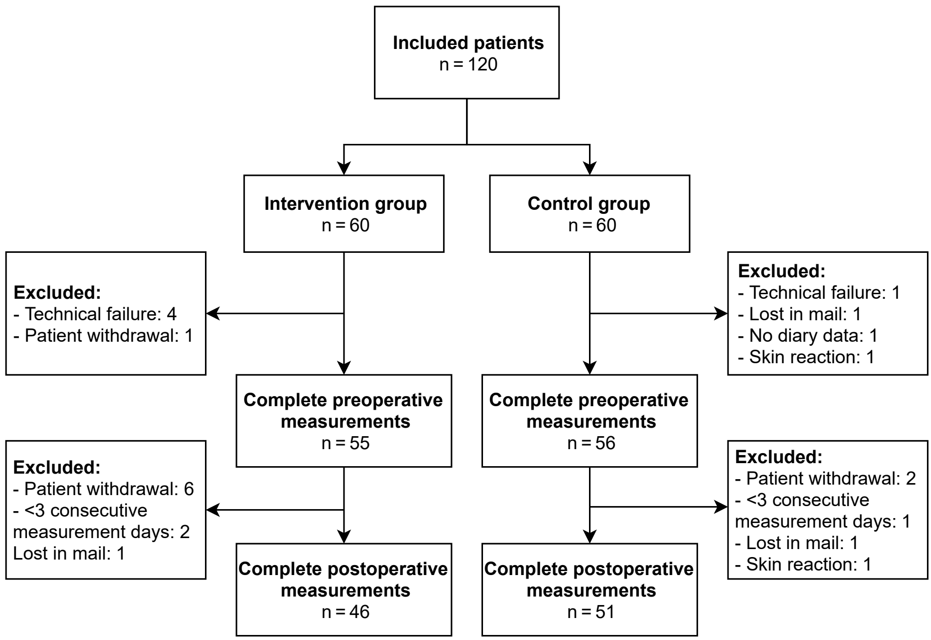

Fig. 2 Inclusion flowchart

Table 1 Baseline characteristics of the total group, intervention group, and control group

Outcome measure	Total group (n = 97)	Intervention group (n = 46)	Control group (n = 51)	*p*-value
Mean age at surgery (y) (SD)	58.4 (4.8)	58.6 (5.0)	58.2 (4.6)	.69[a]
Gender: female, n (%)	56 (58)	28 (61)	28 (55)	.55[b]
Mean BMI (kg/m^2) (SD)	31.4 (5.5)	30.7 (5.3)	32.0 (5.6)	.26[a]
Side: right, n (%)	46 (47)	23 (50)	23 (45)	.63[b]
ASA classification, n (%)				.96[b]
I	18 (18)	9 (20)	9 (18)	
II	55 (57)	26 (56)	29 (57)	
III	24 (25)	11 (24)	13 (25)	
KA type, n (%)				
Total	52 (54)	25 (54)	27 (53)	.89[b]
Unicompartmental	45 (46)	21 (46)	24 (47)	
Valid wear time (d) (range)				
Preop	6 (4-7)	6 (4-7)	6 (4-7)	.16[a]
Postop	7 (3-7)	7 (4-7)	7 (3-7)	.12[a]
Mean awake time (min/d) (SD)				
Preop	934 (65)	924 (52)	943 (75)	.16[a]
Postop	937 (73)	929 (51)	945 (89)	.27[a]

ASA, American Society of Anesthesiologists; BMI, body mass index, KA: knee arthroplasty; SD, standard deviation. [a] Independent samples t-test [b] Chi-squared test

Changes in PA Patterns (Active, Sedentary, and Standing Time)

Preoperatively, patients were active for 153 minutes (± 56), standing for 139 minutes (± 56), and sedentary for 641 minutes (± 112) per day. Postoperatively, patients were active for 163 minutes (± 57), standing for 150 minutes (± 76) and sedentary for 624 minutes (± 123) per day. Overall, the analyses showed a significant postoperative absolute increase in active time of 1.0% (9 minutes; p = 0.01), an overall absolute decrease in sedentary time of 2.1% (20 minutes; p = 0.02). No significant change in total standing time was observed (Table 2). No differences were found for preoperative to postoperative changes in active time, standing time, and sedentary time between the intervention and control group and between the UKA and TKA group (Table 2). On average, postoperatively patients were active for 17%, standing for 16%, and sedentary for 67% of the time they were awake (on average 937 minutes, or 15.6 hours, per day). We found no interaction effects between time and prosthesis type nor between time and assigned group (Intervention vs Control; Table 2). In the UKA group, patients were awake for a total of 946 (± 71) minutes per day preoperatively and 937 (± 62) minutes postoperatively, compared to 924 (± 58) and 938 (± 83) minutes in the TKA group (not significant).

Table 2 Two-way RM ANOVA results for distribution of percentages of time spent in Active, Sedentary and Standing activities

	Active		**Standing**		**Sedentary**	
	Pre-op	Δ	Pre-op	Δ	Pre-op	Δ
Total group, % (SE)	16.4 (0.6)	1.0 (0.4)	14.9 (0.6)	1.1 (0.6)	68.8 (1.1)	-2.1 (0.9)
***p*-value** *pre-post effect*		**.01** [a]		.11 [a]		**.02** [a]
Intervention, % (SE)	15.9 (0.9)	1.4 (0.6)	14.8 (0.9)	0.4 (0.7)	69.3 (1.6)	-1.8 (1.1)
Control, % (SE)	16.9 (0.8)	0.6 (0.6)	14.9 (0.8)	1.7 (1.0)	68.2 (1.4)	-2.3 (1.3)
***p*-value** *intervention effect*		.59		.57		.51
UKA, % (SE)	16.1 (0.9)	1.3 (0.6)	14.7 (0.8)	1.2 (0.9)	69.2 (1.5)	-2.5 (1.3)
TKA, % (SE)	16.7 (0.8)	0.7 (0.6)	15.0 (0.9)	1.0 (0.9)	68.2 (1.5)	-1.8 (1.2)
***p*-value** *subgroup effect*		.72		.84		.74

ANOVA, analysis of variance; RM, repeated measures; SE, standard error; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.

[a] *P*-value for the pre- to postoperative difference in percentage of time spent in each activity.

Effect of Goal Attainment Scaling on Goal-Specific PA

Regarding goal-specific activities, 39 patients formulated a walking goal, 15 patients formulated a cycling goal, and 3 patients formulated a running goal. Comparing the PA between those patients that formulated a specific goal regarding these activities (either for ADL, leisure, or work) and the control group revealed no effect. Also, no subgroup effect (UKA vs TKA) for walking and running was found (Table 3). For cycling, an interaction effect between prosthesis type and time (preoperative to postoperative) was found (Table 3). Post hoc analyses for UKA and TKA revealed no group effects (i.e. controls vs specific goals; $p = 0.49$ and $p = 0.60$, respectively) and only for the TKAs an increase in cycling over time was found ($p < 0.01$ vs $p = 0.78$ in the UKA group).

Table 3 Two-way RM ANOVA results for distribution of percentages of time spent in specific Walking, Cycling and Running activities

	Walking		Cycling		Running	
	Pre-op	Δ	Pre-op	Δ	Pre-op	Δ
Total group, % (SE)	15.0 (0.6)	0.5 (0.4)	1.0 (0.2)	0.4 (0.2)	0.04 (0.06)	0.01 (0.06)
***p*-value** *pre-post effect*	.22		n/a [a]		.82	
Specific goal on activity, % (SE)	14.4 (0.8) n = 39	0.8 (0.6)	0.8 (0.3) n = 15	0.5 (0.6)	0.03 (0.01) n = 3	0.01 (0.02)
Controls, % (SE)	15.7 (0.7) n = 51	0.2 (0.6)	1.1 (0.2) n = 51	0.4 (0.2)	0.06 (0.03) n = 51	0.03 (0.03)
***p*-value** *specific goal effect*	.29		n/a [a]		.63	
UKA, % (SE)	14.6 (0.8)	1.0 (0.6)	1.3 (0.3)	0.1 (0.3)	0.08 (0.05)	-0.02 (0.04)
TKA, % (SE)	15.5 (0.7)	0 (0.6)	0.8 (0.2)	0.7 (0.3)	0.04 (0.02)	0.07 (0.03)
***p*-value** *sub-group effect*	.57		n/a [a]		.89	

ANOVA, analysis of variance; N/A, not applicable; RM, repeated measures; SE, standard error; TKA, total knee arthroplasty; UKA, unicompartmental knee arthroplasty.
[a] Indicates an interaction effect was observed between time and prosthesis type.

DISCUSSION

Our results, in the largest accelerometer-based study in KA patients <65 years, showed a postoperative increase in total PA of 9 minutes and a decrease in sedentary time of 20 minutes. Despite the use of individualized rehabilitation in the intervention group, focused on achieving patient-relevant activity goals, we found no PA differences between the intervention group and the control group. Thus, formulating a specific activity goal preoperatively and a presumably tailored postoperative rehabilitation to achieve this goal did not result in significant improvements in goal-specific PA compared to standard rehabilitation in our patient cohort.

The increasing use of KA in patients between 55 and 65 years of age likely results in a growing patient population with high postoperative functional demands. Indeed, younger KA patients have high expectations of their KA, including return to work and participation in strenuous leisure time activities and sports[3,4]. Furthermore, PA is known to prevent chronic diseases, improve fitness and prolong functional independence, resulting in higher quality of life[7]. We used GAS with the aim of better meeting our patients' expectations regarding activities. Although we previously found that patients attained >90% of all their personal activity goals within 6 months[17], the present study showed that this rehabilitation intervention did not result in improvement of objectively measured postoperative PA levels. Also, comparing patients with specific activity goals (i.e. walking, cycling, running) and the control group did not show a significant difference in attained PA levels for those specific activities. However, these comparisons were not very reliable due to the small group sizes and thus limited power. Still, the current study was the first to use GAS in an orthopaedic rehabilitation setting, which did show promising results regarding physiotherapist-based reporting of activity goal attainment[17].

A possible reason for GAS not demonstrating an improvement in PA might be the fact that the overall increase in PA after KA in our cohort was small. In the current study, the complete KA group was 9 minutes more active and 20 minutes less passive after 6 months. With respect to an increase in activity after 6 months, varying results were demonstrated in previous studies[13]. One study found a postoperative increase of 4903 steps/d in a small group of patients[24]. Frimpong et al. demonstrated an increase of 50 minutes spent on light PA[14]. Three other studies found no significant difference in walking time, gait cycles, or accelerometer counts at 6 months[9,12,25]. The small PA increase of 9 minutes after 6 months found in our study is therefore more or less in line with the current literature. A further increase in PA after the first 6 months might be expected, since 1 study reporting accelerometer-based PA data 1 year postoperatively, found an increase of 1195 steps/d and an increase in time spent in moderate to vigorous PA after KA (no minutes reported)[26]. With respect to the decrease in passive time of 20 minutes found in the current study, Frimpong et al. found a decrease in total time spent in sedentary behaviour from 70% preoperatively to 64% postoperatively (56 minutes), compared to respectively 69% and 67% in our cohort. Although these improvements are promising, time spent in sedentary behaviour at follow-up was still more than 64% of awake time[14].

Thus, after KA a small increase in light PA, that is, standing time and possibly walking, may be expected at best. Given the significant improvements in PROMs and KA's objective of improving the patient's impaired functional status, this is a disappointing finding because one would expect a better improvement in objective PA measurements. Several reasons for the limited increase in PA have been suggested that may also apply to our younger population. First, because knee osteoarthritis is a condition that progresses over the course of several years, it seems likely that patients adjust their entire lifestyle to disease-related limitations[9]. Also, clinicians may advise knee osteoarthritis patients to limit PA in order to manage their knee pain. Therefore, offering a possible solution for osteoarthritic knee pain and subsequent physical impairment, namely KA, will not automatically lead to an improvement in PA. Another theory is that knee osteoarthritis patients tend to remain quite active up until the moment of surgery and as a result only obtain small changes in PA postoperatively[9]. Both explanations may apply to our population. Our cohort consisted of younger, active knee osteoarthritis patients who were still of working age prior to surgery and wished to return to work and leisure time activities. Consequently, their preoperative PA levels may still have been relatively high and therefore a significant postoperative PA increase may have been unlikely[9]. Finally, high body mass index (BMI) is negatively associated with PA behaviour in patients undergoing total joint arthroplasty[26,27]. In KA, Twiggs et al.[28] found that obese patients reached a mean of 4819 steps 6 weeks postoperatively, compared to 7151 steps for overweight patients and 8022 steps for healthy weight patients. Thus, the mean BMI of 31.4 in our cohort likely was a limiting factor for PA, and the mean BMI of 34.0 in the previously mentioned study by Frimpong et al. also negatively influenced the observed PA changes[14].

Regarding possible solutions to further increase PA after KA, in order for more patients to meet health-enhancing PA guidelines, several authors have suggested a need for improved and individually tailored rehabilitation strategies[27,29]. The patient-tailored GAS rehabilitation of our intervention group focused specifically on achieving activities that our individual patients wished to perform better. Thus, we were hoping for larger PA improvements in our intervention group compared to the usual care rehabilitation group. Unfortunately, in this cohort we did not find any significant differences between both groups. Possible reasons are a lack of specific PA feedback by the treating physical therapists, and not using the accelerometers to help patients meet their daily PA requirements. Currently, a randomized controlled trial is running that investigates the effect of a weekly PA intervention in KA patients, including an accelerometer, individualized step goals, and face-to-face feedback provided by a physical therapist[30]. A prior pilot study already showed that the use of direct PA feedback in the postoperative rehabilitation results in larger increases in PA after KA, which is important for better reaching health-enhancing PA levels[31,32]. Furthermore, we did not provide dietary therapy to our overweight patients. Short-term dietician-supervised weight loss interventions to lower BMI prior to KA may further improve postoperative outcomes, including PA[33]. Finally, it is believed that patient factors, such as comorbidities, lifestyle changes due to long-lasting osteoarthritis symptoms, and inherent motivation, negatively influence postoperative PA in KA patients[9,14].

Therefore, additional behavioural interventions are likely required to alter sedentary behaviour and achieve PA improvements[6,9,12,13] to meet health-enhancing PA guidelines[7].

A possible limitation of the present study is our follow-up of 6 months. Although we expected the largest improvement in PA to occur in the first 6 months of rehabilitation, previous studies showed that further improvements in PA after KA might be expected up to 1 year postoperatively[13,34]. Thus, a longer follow-up might have resulted in more pronounced PA changes in our patients. Furthermore, we only obtained complete data for 97 out of 120 patients. However, since our loss to follow-up was mainly due to technical issues, we believe our drop-outs to be at random and thus of limited influence on our results. Finally, comparing our data with other studies was challenging due to the different types of accelerometers and PA outcome measures that were used.

CONCLUSION

In conclusion, we observed a limited increase in PA after KA and found no effect of GAS-based rehabilitation on PA at 6 months postoperatively. Likely, enhanced multidisciplinary perioperative strategies are needed to further improve PA after KA. Therefore, future research investigating such strategies is warranted to improve overall PA, and thus general health, in patients undergoing KA.

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CHAPTER 9

Goal Attainment Scaling Rehabilitation Improves Satisfaction with Work Activities for Younger Working Patients After Knee Arthroplasty: Results from the Randomized Controlled ACTION Trial

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ABSTRACT

Background Knee arthroplasty (KA) is increasingly performed in relatively young, active patients. This heterogeneous patient population often has high expectations, including work resumption and performance of knee-demanding leisure-time activities. Goal attainment scaling (GAS) may personalize rehabilitation by using patient-specific, activity-oriented rehabilitation goals. Since unmet expectations are a leading cause of dissatisfaction after KA, personalized rehabilitation may improve patient satisfaction. We hypothesized that, compared with standard rehabilitation, GAS-based rehabilitation would result in younger, active patients having higher satisfaction regarding activities after KA.

Methods We performed a single-centre randomized controlled trial. Eligible patients were <65 years of age, working outside the home, and scheduled to undergo unicompartmental or total KA. The required sample size was 120 patients. Using GAS, patients developed personal activity goals with a physiotherapist preoperatively. These goals were used to monitor patients' goal attainment and provide goal-specific feedback during postoperative outpatient rehabilitation. Standard rehabilitation consisted of regular outpatient physiotherapy visits. The primary outcome measures were visual analogue scale (VAS) scores (scale of 0 to 100) for satisfaction regarding activities of daily living and work and leisure-time activities 1 year postoperatively, which were analysed using generalized estimating equation models.

Results Patient satisfaction with work activities was significantly higher in the GAS group (β = 10.7 points, 98% confidence interval [CI] = 2.0 to 19.4 points) than in the control group. Patient satisfaction with activities of daily living and leisure-time activities did not differ between groups. We found no differences in VAS satisfaction scores between unicompartmental KA and total KA.

Conclusions Personalized, goal-specific rehabilitation using GAS resulted in higher patient satisfaction with work activities, compared with standard rehabilitation, 1 year after KA.

INTRODUCTION

The use of knee arthroplasty (KA) in patients <65 years of age is rapidly increasing[1,2]. These younger patients often have high expectations from their surgery, including a rapid return to work and the ability to perform knee-demanding leisure-time activities postoperatively[3,4]. Consequently, orthopaedic surgeons are facing a major challenge, since we know that unmet expectations are the leading cause of dissatisfaction after KA[5,6]. Also, current data show that up to one-third of patients never return to work after KA[7]. Thus, relatively younger, active patients who undergo KA due to knee osteoarthritis are prone to dissatisfaction with the results.

The need for postoperative rehabilitation, including physical therapy, after KA is generally accepted, although there is much debate regarding the appropriate form[8-11]. Since younger patients have a wide variety of activity goals and expectations for KA[3,4], a "one-size-fits-all" rehabilitation approach likely does not suffice. Furthermore, the use of specific, difficult goals consistently leads to higher performance[12]. One possible instrument to tailor the rehabilitation to patients' personal goals is goal attainment scaling (GAS)[13,14]. Originally, GAS was developed as a method to score the extent to which patients' individual goals are attained during an intervention[14,15]. Theoretically, GAS could prove to be a more useful outcome measure compared with standard patient-reported outcome measures (PROMs), which have shown ceiling effects and a weak correlation with patient satisfaction in present-day heterogeneous KA populations[16]. In addition, GAS scores can be used as a direct feedback instrument for patients during rehabilitation, by objectively monitoring their progress. Involving patients in the formulation of their own rehabilitation goals increases the chances of actually attaining these goals[17-19]. Accordingly, this approach resulted in high patient satisfaction in several rehabilitation settings – for example, for children with motor delays and geriatric patients with multiple chronic conditions, including musculoskeletal diseases[15,20]. Despite these promising results, to our knowledge GAS has never been used to guide rehabilitation after KA.

Therefore, we investigated the effect of GAS-based rehabilitation following KA in relatively younger, active patients. We hypothesized that, compared with usual-care rehabilitation after KA, GAS-based, personalized, goal-directed rehabilitation leads to higher satisfaction scores for postoperative performance of activities.

MATERIALS AND METHODS

Study Design and Participants

Study design and implementation followed the Consolidated Standards of Reporting Trials (CONSORT) statement guidelines for reporting randomized trials[21]. The study protocol for this single-centre randomized controlled trial with 1:1 allocation was registered in the Dutch National Trial Register (NTR5251) and published[22]. The study was conducted in accordance with the principles of the Declaration of Helsinki. The local medical ethics review committee approved the study. All patients provided written informed consent. Eligible patients were younger than 65 years of age, had end-stage knee osteoarthritis, were awaiting KA, and worked (paid or voluntary) outside the home preoperatively. Exclusion criteria included cognitive impairments, insufficient understanding of the Dutch language, and comorbidities that prevented patients from performing regular rehabilitation activities or regular activities of daily living and work and leisure-time activities. The study was performed at a regional teaching hospital performing approximately 600 KAs annually.

Intervention

We compared GAS-based rehabilitation with standard rehabilitation. Each of the patients in the intervention group was referred to 1 of 23 GAS-trained physiotherapists prior to surgery[17,19]. Preoperatively, the patient and the physiotherapist discussed and formulated 3 postoperative activity goals (1 each for activities of daily living, work activity [Fig. 1], and leisure-time activity). Corrected metabolic equivalents of task values were calculated for each goal[4]. A multidisciplinary team consisting of 2 orthopaedic surgeons, a human movement scientist, an occupational medicine expert, a physiotherapist, and the primary investigator assessed the goals for applicability and feasibility. Based on these activity goals and the assessment, a postoperative rehabilitation scheme was designed by the physiotherapist. Our GAS-based rehabilitation is described in further detail in the published protocol[22] and in the Appendix. There were no additional costs for GAS because reimbursement for physical therapy after KA was standard. Postoperatively, patients visited physiotherapists at least once a week for at least 3 months. Standard rehabilitation consisted of usual-care outpatient physiotherapy, the content of which we described previously[23]. In short, patients were allowed immediate full weight-bearing and were advised to use crutches for 4 to 6 weeks. For postoperative weeks 1 through 4, primary goals were obtaining full extension as well as flexion up to 100° to 110° and starting low-resistance quadriceps training (for example, with a home trainer). From week 5 onward, more static and dynamic weight-bearing exercises, core stability training, and quadriceps and hamstrings exercises were added. A full range of motion was aimed for after 6 to 10 weeks.

Setting	A 59-year old female patient with left knee osteoarthritis. Patient works as a cleaner and she has to clean windows every day. She uses a step stool (±40 centimeter) and has to step up and down the step stool to clean 20 – 30 consecutive windows daily.	
Measurement	The physiotherapist observes and counts the number of times that the patient can step up the step stool with her left leg and step down with her right leg.	
Patient Instruction	Step up the step stool with your left leg without support. Step down the step stool with your right leg. Repeat this as often as you can.	
Goal Attainment Level		
-3	**Decline**	Patient can step up and down <4 times
-2	**Baseline**	Patient can step up and down 4 – 6 times
-1	**Less than goal**	Patient can step up and down 7 – 18 times
0	**Goal**	Patient can step up and down 19 – 30 times
+1	**More than goal**	Patient can step up and down 31 – 42 times
+2	**Far more than goal**	Patient can step up and down >42 times

Fig. 1 Example of a GAS goal and GAS scale for a work activity.

Outcomes

Data were collected with an electronic follow-up system (OnlinePROMs; Interactive Studios, the Netherlands). The primary outcome measures were 3 visual analogue scales (VASs), ranging from 0 to 100, for satisfaction regarding the performance of activities of daily living, work activities, and leisure-time activities at 1 year postoperatively. Secondary outcome measures were the Knee injury and Osteoarthritis Outcome Score (KOOS)[24]; the Oxford Knee Score (OKS)[25]; the Work, Osteoarthritis or joint-Replacement Questionnaire (WORQ)[26]; the EuroQol-5 Dimensions (EQ-5D)[27]; and the Net Promoter Score (NPS)[28]. Physical activity was objectively measured preoperatively and 6 months postoperatively using a 3-dimensional (3D) accelerometer. The physical activity data were published previously[29].

Sample Size and Randomization

We based our sample size calculation on a minimal clinically important difference of 10 points on a 100-point VAS[30] for patient satisfaction with postoperative performance of activities. The authors of a previous study reported work-related satisfaction of 62 points after KA[7]. Calculating with a power of 90%, 2-tailed testing with a *p*-value of 0.05, and a standard deviation of 15 resulted in a minimum of 98 participants (nQuery Advisor, version 7.0; Statsols). To adjust for a 15% rate of dropouts, 120 participants (60 in each group) were deemed necessary[22]. Patients were randomized in a 1:1 ratio during an additional visit to the hospital. Block randomization, with separate blocks for total KA (TKA) and unicompartmental

KA (UKA), was used. Sequentially numbered opaque envelopes that, prior to opening, were kept in a vault that was accessible only to the primary investigator were used. The primary investigator generated the random allocation sequence, enrolled participants, and assigned participants to interventions. By necessity, participants, researchers, and physiotherapists were unblinded to group allocation.

Statistical Analysis

Descriptive statistics were used to report baseline characteristics. Primary outcome measures were analysed according to the intention-to-treat principle. A generalized estimating equations (GEE) model was used to analyse differences in the change of the VAS satisfaction scores relative to the preoperative scores between the GAS and control groups and between TKA and UKA groups. The GEE model included time as the within-subject variable, GAS/No GAS (control) and TKA/UKA as factors, and the preoperative VAS satisfaction scores as covariates, with an unstructured correlation matrix. Because we tested 3 primary outcome parameters, a Bonferroni correction was applied. Consequently, mean estimated VAS scores with the 98% confidence interval (CI) for the GAS and control groups were calculated. Secondary outcomes were analysed according to the available-data principle. Independent samples t tests were performed to compare the change in scores from baseline to 3, 6, or 12 months postoperatively between the GAS and control groups. For the NPS, the percentage of detractors (scores of 1 to 6 out of 10) was subtracted from the percentage of promoters (a score of 9 or 10 out of 10)[28], and the proportions of detractors and promotors were compared between groups using a chi-square test. We used SPSS software (version 24.0; IBM) for all statistical analyses.

RESULTS

Participants and Baseline Characteristics

From October 2015 to November 2017, when the required number of patients was reached, 398 patients younger than 65 years of age were screened for eligibility; 147 of them did not meet the inclusion criteria, 99 declined to or could not participate for various reasons, and 32 declined to participate without any reason (Fig. 2). Thus, 120 patients were randomized to the GAS (n = 60) and control (n = 60) groups (Table 1). Complete follow-up data were available for 53 patients in the GAS group and 58 in the control group (Fig. 2).

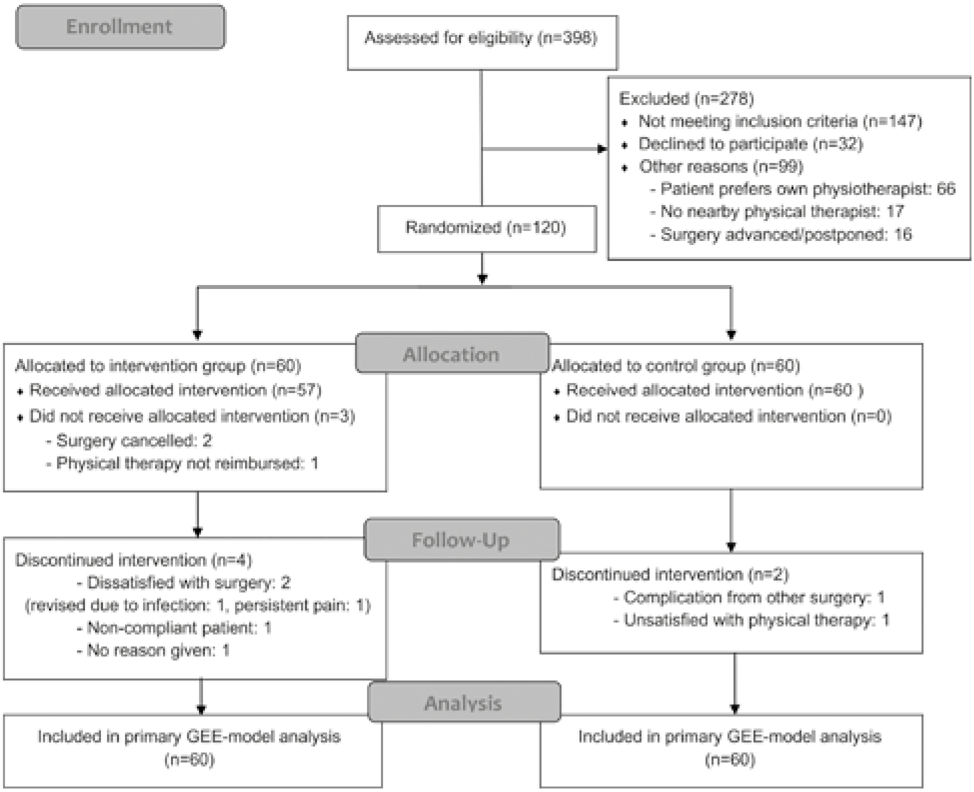

Fig. 2 CONSORT inclusion flowchart.

Table 1 Baseline characteristics of the GAS and control groups[a]

	GAS rehabilitation (n = 60)	Standard rehabilitation (n = 60)
Mean age (SD) (yr)	58.3 (5.3)	58.1 (4.6)
Female sex (no. [%])	38 (63)	34 (57)
Mean BMI (SD) (kg/m^2)	31.1 (5.6)	31.9 (5.5)
ASA classification (no. [%])		
I	12 (20)	10 (17)
II	31 (52)	35 (58)
III	17 (28)	15 (25)
Physical workload (no. [%])		
Light	26 (43)	28 (47)
Intermediate	18 (30)	25 (42)
Heavy	16 (27)	7 (11)
Median corrected METs (IQR)		
Activities of daily living goals	5.3 (4.4–6.9)	–
Work goals	5.1 (4.5–6.2)	–
Leisure time goals	8.0 (6.7–10.4)	–
KA type[b] (no. [%])		
Total	31 (52)	31 (52)
Unicompartmental	29 (48)	29 (48)

[a] ASA = American Society of Anesthesiologists, BMI = body mass index, IQR = interquartile range, MET = metabolic equivalent of task, and SD = standard deviation.
[b] Surgery was cancelled by 2 patients in the intervention group (both scheduled for unicompartmental KA).

Primary Outcome Measures

All patients indicated an increase in the mean VAS scores for satisfaction for all activities over time (Fig. 3). Based on the outcome of the GEE model, the difference in the work satisfaction score over time from preoperatively to 1 year postoperatively was 10.7 points (98% CI = 2.0 to 19.4 points) higher for the GAS group than the standard rehabilitation group (Fig. 3, Table 2). We found no differences in the satisfaction scores for the performance of activities of daily living or leisure-time activities between the GAS-based rehabilitation and standard rehabilitation groups (Table 2). In the same statistical model, no differences were found between the UKA and TKA groups for activities-of-daily-living or work or leisure-time activity satisfaction scores.

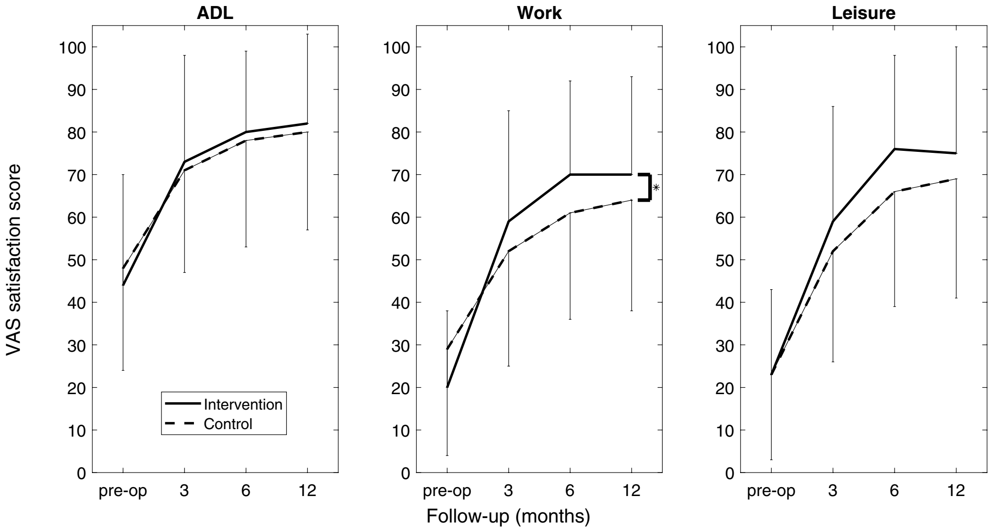

Fig. 3 Mean VAS satisfaction scores over time. Error bars represent 1 standard deviation, presented as positive error bars for the intervention (GAS) group and as negative error bars for the control group. *$p < 0.01$. ADL = activities of daily living.

Table 2 GEE model analysing the effect of therapy (GAS versus No GAS) and prosthesis type (UKA versus TKA) on VAS satisfaction scores over time

Type of activity	Effect	Reference	β	98% CI
Daily living	Therapy	No GAS	2.1	-5.6–9.8
Daily living	Prosthesis type	TKA	7.8	0.2–15.4
Work	Therapy	No GAS	**10.7***	**2.0–19.4***
Work	Prosthesis type	TKA	5.3	-3.1–13.6
Leisure	Therapy	No GAS	7.3	-2.1–16.7
Leisure	Prosthesis type	TKA	7.1	-2.2–16.4

*A significant difference between the GAS and control groups.

Secondary Outcome Measures

We found no significant differences between the GAS and standard rehabilitation groups for the improvements in KOOS scores from preoperatively to 3 or 12 months (Table 3). Also, we found no differences between the 2 groups with respect to change scores at 3 and 12 months for the OKS, WORQ, EQ-5D, or NPS (Table 4).

Table 3 Mean KOOS scores and change scores at 3 and 12 months

	GAS rehabilitation* (n = 53)		Standard rehabilitation* (n = 58)		
	Total score	Δ	Total score	Δ	*p*-value †
Pain					
Preoperatively	41 (17)	–	39 (18)	–	–
3 months	73 (16)	32 (21)	70 (19)	30 (23)	0.74
12 months	87 (16)	46 (22)	80 (20)	40 (26)	0.27
Symptoms					
Preoperatively	49 (17)	–	46 (19)	–	–
3 months	67 (16)	18 (20)	66 (16)	19 (27)	0.79
12 months	78 (17)	28 (21)	79 (17)	31 (26)	0.57
Activities of daily living					
Preoperatively	49 (19)	–	47 (18)	–	–
3 months	78 (15)	29 (23)	72 (18)	24 (22)	0.33
12 months	85 (18)	36 (24)	81 (21)	32 (26)	0.50
Sports/recreation					
Preoperatively	15 (21)	–	13 (18)	–	–
3 months	31 (26)	16 (29)	28 (27)	16 (29)	0.99
12 months	46 (30)	31 (27)	46 (32)	32 (28)	0.85
Quality of life					
Preoperatively	23 (16)	–	22 (14)	–	–
3 months	56 (20)	31 (24)	49 (22)	26 (25)	0.32
12 months	67 (23)	45 (28)	65 (27)	41 (29)	0.57

*The values are given as the mean with the standard deviation in parentheses. Δ = change in score from preoperative to 3 months or from preoperative to 12 months.
†Independent samples *t* test for the difference in the change score between the GAS and control groups at 3 or 12 months.

Table 4 Mean scores and 3 and 12-month change scores for the OKS, WORQ, EQ-5D, and NPS

		GAS rehabilitation* (n = 53)		Standard rehabilitation* (n = 58)		
		Total score	Δ	Total score	Δ	*p*-value †
OKS	Preoperatively	25 (7)	-	23 (7)	-	-
	3 months	36 (7)	11 (10)	35 (8)	11 (10)	0.87
	12 months	40 (7)	16 (9)	39 (9)	15 (10)	0.56
WORQ	Preoperatively	44 (13)	-	41 (16)	-	-
	3 months	61 (18)	16 (21)	57 (19)	16 (21)	0.90
	12 months	73 (18)	28 (18)	69 (22)	28 (21)	0.88
EQ-5D	Preoperatively	0.60 (0.24)	-	0.56 (0.25)	-	-
	3 months	0.81 (0.19)	0.21 (0.30)	0.76 (0.22)	0.23 (0.33)	0.84
	12 months	0.85 (0.19)	0.27 (0.24)	0.86 (0.18)	0.29 (0.27)	0.76
EQ-5D VAS						
	Preoperatively	64 (19)	-	60 (19)	-	-
	3 months	74 (16)	10 (21)	74 (11)	12 (20)	0.67
	12 months	77 (17)	12 (16)	75 (19)	14 (21)	0.60
NPS	6 months	38	-	36	-	0.27
	12 months	40	-	29	-	0.35

*The values are given as the mean with the standard deviation in parentheses. Δ = change in score from preoperative to 3 months or from preoperative to 12 months.
†Independent samples t test for the difference in the change score (except for the NPS) between the GAS and control groups at 3 or 12 months.

DISCUSSION

The hypothesis of this randomized controlled trial was that, compared with usual-care rehabilitation, goal attainment scaling (GAS)-based, personalized, goal-directed rehabilitation would lead to higher satisfaction with postoperative performance of activities after KA. We found that GAS-based rehabilitation resulted in significantly higher patient satisfaction with the performance of work activities but no difference in satisfaction regarding activities of daily living or leisure-time activities. We also found no differences between UKA and TKA in terms of satisfaction with activities of daily living or work or leisure-time activities.

Since fulfilment of preoperative expectations is crucial for patient satisfaction after KA[5,6,31], GAS's personalized approach theoretically leads to improved satisfaction. Toto et al. previously found that the use of GAS for geriatric patients with multiple chronic conditions facilitated patient-centred care and, more importantly, that the process of personalized goal-setting itself could facilitate goal attainment[20]. Although we found a patient-relevant and significant effect on work-related satisfaction, we did not observe this effect for satisfaction with activities of daily living or leisure-time activities. There may be several explanations for this discrepancy. First, our inclusion criteria focused specifically on patients who worked outside the home. It is possible that our patients were primarily focused on attaining their work-related goals since a return to work is both desirable and often a financial necessity[32]. Also, one could speculate that the activities-of-daily-living and leisure-time goals were not ambitious enough, given the previously reported low metabolic equivalent of task values in our cohort[4]. Finally, it is known that patients' perception that their knee symptoms are work-related is associated with worse results in terms of return to work after KA[33]. In our study, only in the intervention group, by formulating personal GAS goals, did patients specifically address their most important work-specific activity limitations caused by knee symptoms with their therapist. This consultation and the following focus on improving their most important work activity likely led to higher satisfaction with these work activities. An ongoing study is currently investigating whether GAS is also associated with faster and/or higher return-to-work rates in our cohort.

Given GAS's specific focus on goal attainment, and the known difficulties with capturing patient satisfaction using regular knee-related PROMs such as the KOOS[16,34], we did not expect significant differences between both groups with regard to the regular PROMs. Indeed, none of the change scores for the secondary outcomes differed between the 2 groups. In fact, we consider this a further endorsement for the use of GAS in KA rehabilitation for working patients since it is a PROM that can be individualized without ceiling effects. By allowing patients to set personalized goals, GAS may address constructs that are not captured by regular PROMs or quality-of-life measures.

Since this is the first study of which we are aware to focus on a post-KA rehabilitation that was personalized using GAS as an intervention, our ability to compare it with existing literature is limited. However, the effect of GAS-based rehabilitation has been recently studied in several other musculoskeletal conditions. We previously reported that, in a subgroup analysis, 91%, 93%, and 89% of patients who underwent GAS-based rehabilitation attained their desired goal for activities of daily living, work activities, and leisure-time activities, respectively, at 6 months of follow-up[4]. These rates were higher than the reported goal-attainment rates after GAS rehabilitation for patients with arthritis-related pain, with 13 of 17 of those patients attaining their desired goal after 4 months[35]. Encouragingly, 16 of those 17 patients were either satisfied or very satisfied with the success of their goal attainment[35]. In addition, GAS-based rehabilitation recently was shown to result in significant motor function improvements compared with standard rehabilitation in a randomized controlled trial of patients with Parkinson disease[36] as well as high patient satisfaction with treatment of chronic lower back pain[37]. Still, the most persuasive evidence until now comes from research in paediatric rehabilitation, in which GAS has been broadly used and could detect meaningful change, as experienced by patients and caregivers, in most studies[38]

A limitation of the present study was that the physiotherapists received only 1 training session. Ideally, a longer training program to introduce GAS into clinical practice should be used[17]. Our research team, including experienced GAS users, did monitor the GAS goals and rehabilitation schemes. However, we would advise future users to plan additional repeated face-to-face training sessions for new users[17]. Also, a large group of physiotherapists (n = 23) treated a relatively small group of patients (n = 60), which limited the additional benefit of increasing experience with GAS for physiotherapists. We believe that, by using GAS regularly, physiotherapists could improve their use of the tool. We also believe that the improvements in VAS satisfaction scores regarding activities might be further increased by optimizing the introduction of GAS into clinical practice. Lastly, the OKS Activity & Participation Questionnaire supplement[39], Patient Activation Measure[40], and Short QUestionnaire to ASsess Health-enhancing physical activity (SQUASH)[41] were described in the protocol but were not included in the analysis because of erroneous data collection (wrong answering options were included in the online questionnaire). We believe that the lack of blinding did not influence our outcomes based on a recent meta-epidemiological study that showed that blinding of patients, health-care providers, or outcome assessors had no impact on effect estimates in randomized controlled trials[42].

The growing population of younger patients desiring KA highlights the need for a more patient-tailored approach to rehabilitation[43]. GAS's personalized, goal-oriented approach appears to be suitable for the increasingly heterogeneous KA population, as both an intervention in the rehabilitation and an outcome measure that can be individualized appropriately. Our studies showed that GAS-based rehabilitation is feasible for patients who have undergone KA and resulted in a high percentage of goal attainment[4]. These results may encourage future studies on the use of GAS in challenging orthopaedic patient populations, such as patients with jobs placing heavy demands on the knee. Tools to facilitate the use of GAS in daily rehabilitation practice are being developed, with the recent launch of an application (GOALed) encouraging selfcare by allowing patients to monitor their own progress as the most recent promising example[44]. Our first results of using GAS as a tool for a more patient-tailored rehabilitation may encourage further research and implementation in order to improve patient-relevant outcomes after KA.

In conclusion, the satisfaction of working patients with the performance of work activities after KA was higher after rehabilitation based on GAS than after standard rehabilitation.

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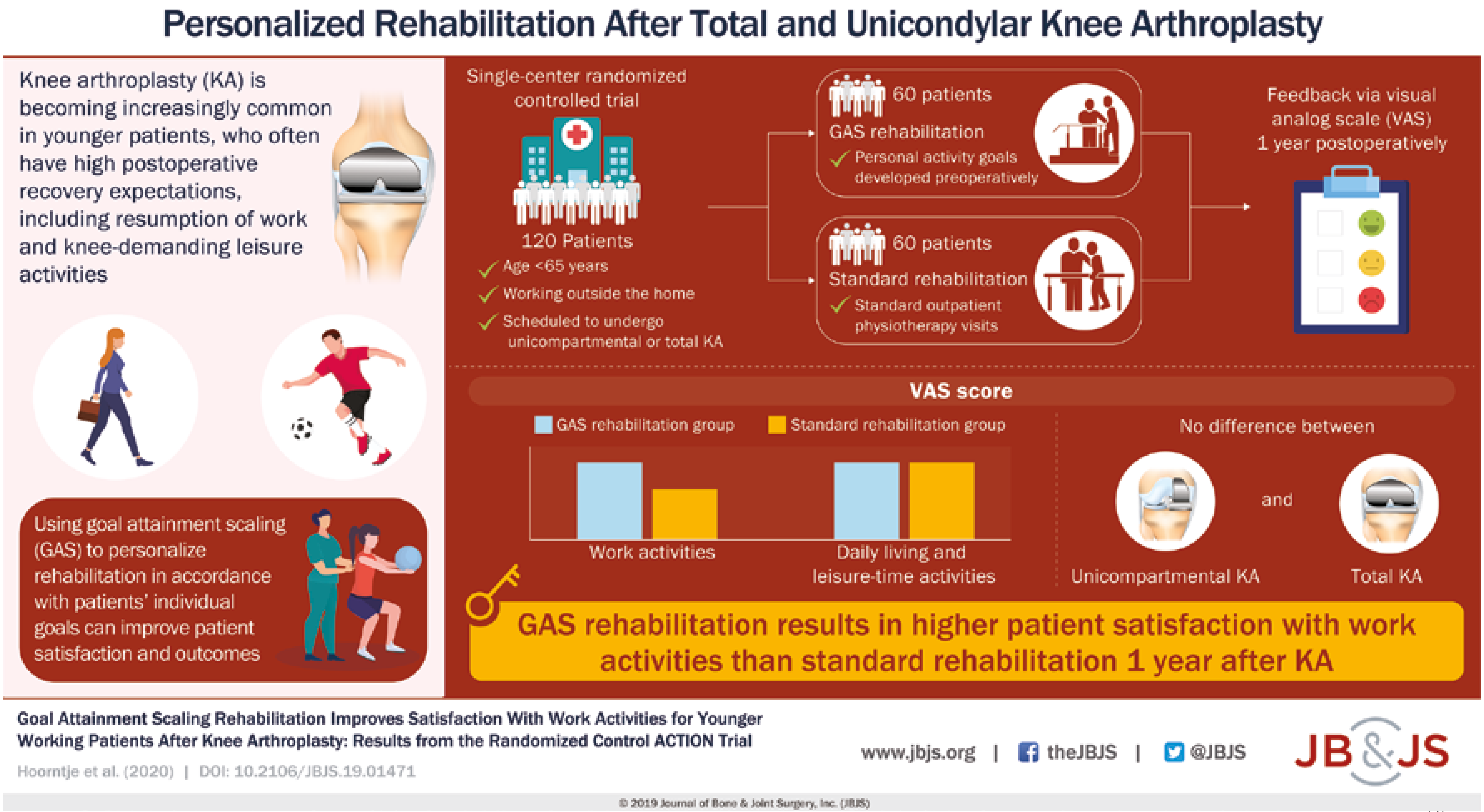
Appendix: infographic ACTION trial



GENERAL DISCUSSION AND FUTURE PERSPECTIVES

The rising number of relatively young patients with invalidating knee osteoarthritis (OA) poses a challenge to orthopaedic surgeons. This patient population is characterized by high functional demands and diverse expectations. To optimize patient relevant outcomes, selecting the right treatment for the right patient at the right time is crucial. The main objective of this thesis is to facilitate the process of shared-decision making to choose the best surgical treatment strategy in relatively young and active knee OA patients, based on their individual expectations and activity goals. To this end, a variety of research methods was used, including a systematic review, prospective and retrospective cohort studies, directed acyclic graphs (DAGs), a case-control study, and a randomized controlled trial. First, this thesis explored current functional outcomes for sport and work after joint preserving alternatives to knee arthroplasty (KA). Next, prognostic factors that are associated with functional outcomes after KA and knee osteotomy were studied. Last, strategies to improve patient relevant outcomes, including satisfaction, were investigated.

The studies in both the first and second part of this thesis reveal that joint preserving alternatives to KA show good results regarding resumption of sport and work activities. These findings support the concept of joint preservation when selecting the appropriate surgical treatment in younger knee OA patients, by the time non-operative treatment options do not suffice anymore. The third part focusses on optimizing rehabilitation after KA in younger, active patients. Goal Attainment Scaling (GAS) as an intervention showed promise as a rehabilitation method that takes individual activity goals and expectations into account. The interpretation of this thesis' findings in the following paragraphs will therefore focus on the promise of joint preserving alternatives to KA, on patient selection criteria for knee osteotomy and KJD, and on improving goal attainment and physical activity in the rehabilitation of relatively young knee OA patients.

A call for knee joint preservation

With the growing number of KA in relatively young patients, and the rising life expectancy, more and more KA patients are at risk of revision KA[1]. Yet, clinical and functional outcomes after revision KA are generally worse than after primary KA[2]. Thus, the need for adequate joint preserving therapies to delay a primary KA is increasing. To adequately counsel our patients, data on patient-relevant outcomes such as participation in sport, work and leisure-time activities are essential. **Chapter 1** reports better functional outcome in terms of return to sport (RTS) and return to work (RTW), both 85%, after high tibial osteotomy (HTO), when compared to RTS and RTW after KA (ranges between 36-100% and 71-83% respectively)[3,4]. The same accounts for patients undergoing distal femoral osteotomy (DFO), with rates of 77% for RTS and 91% for RTW (**Chapter 2**). Perhaps more importantly, participation in knee demanding activities was higher after HTO and DFO than KA, which supports the idea that maintaining the native knee joint allows for higher joint loading capacity. After HTO and DFO, one year postoperative participation in high-impact sports such as running and tennis was 16% and 14% respectively

(**Chapters 2 and 5**). After KA, these sports activities are discouraged by both Dutch and American orthopaedic surgeons[5,6]. Thus, for younger, physically active knee OA patients, a knee osteotomy is an attractive treatment option with regards to postoperative participation in high-impact activities.

Low survival rates, with the endpoint of conversion to KA, were previously considered a down-side of knee osteotomies. Modern-day studies, however, have reported excellent 5-year survival rates, with a pooled estimate of 95% for opening-wedge HTO and 94% for closing-wedge HTO, and pooled 10-year survival rates of 92% for opening-wedge HTO and 85% for closing-wedge HTO[7]. The probability of survival after ten years declines more sharply, with reported 15-year survival rates of 55–93%[8-10], and 20-year survival rates of less than 40%[8]. For DFO, reported 5-year survival rates range from 74–92%, and 10-year survival rates range from 64–90%[11-14]. Likewise, survival rates declined after ten years, with 15-year survival rates of 45–79%[13,14] and a reported 20-year survival rate of 22%[14]. Finally, a recent Canadian study prospectively followed 556 patients who received 643 medial opening-wedge HTOs, and found that 79% of knees did not undergo TKA within ten years[15]. Despite worse survival rates after the first decade, these numbers also show that a significant group of patients undergoing knee osteotomy may never proceed to undergo KA at all. Clearly, relatively young patients, eligible for HTO or DFO, should be counselled regarding the chance of requiring KA surgery later in life, and the possible downsides of KA after previous HTO.

Specifically, the higher revision risk of KA after previous knee osteotomy is a serious concern[16-19]. Performing KA after previous HTO is considered technically demanding, due to more difficult joint exposure, possible extra-articular and intra-articular malalignment, bone stock loss, joint line alteration, and possibly soft tissue and ligament imbalance[18,20]. Yet, studies have also suggested that KA after opening-wedge HTO has a lower risk of revision[17], and poses less technical concerns[21]. Indeed, recent database studies as well as large cohort studies have shown excellent survival rates for KA after previous opening- and closing-wedge HTO[20,22,23]. Our preferred technique, as described in **Chapter 5** and **Chapter 6** of this thesis, is a medial opening-wedge HTO with angular stable fixation[24], which provides a better starting position for future KA by maintaining adequate bone stock and correcting the deformity close to its origin[25]. Thus, the possibly increased revision risk when performing KA after previous HTO should emphatically be discussed with the patient. Yet, more and more evidence shows that this risk is likely not increased after modern-day HTO, and it should not be a reason to refrain from HTO in the first place[17,20,26].

Patient selection in joint preserving knee surgery

Patient selection is crucial to obtain satisfactory results with knee osteotomy and KJD. The International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) defined ideal, possible and unsuited candidates for

HTO and DFO[24,27,28]. The ideal candidate for valgising HTO is aged 40–60 years, has a body mass index (BMI) <30, malalignment of <15°, metaphyseal varus of >5°, full range-of-motion, normal lateral and patellofemoral compartments, normal ligament balance, Ahlbäck grade I to IV OA, some level of pain tolerance, is a non-smoker and performs high-demand activities but no running or jumping[24,27]. Possible candidates are aged 60–70 years or <40 years, have a flexion contracture of <15°, anterior/posterior cruciate ligament insufficiency, moderate patellofemoral OA, have a history of infection, and wish to continue all sports. Unsuitable candidates have bi-compartmental (medial and lateral) OA, a fixed flexion contracture of >25°, BMI >30, or previous meniscectomy in the compartment to be loaded by the osteotomy[24,27]. According to the recent proceedings of the 2017 International Osteotomy Congress and a recent systematic review, these indications still apply for present-day HTO[29,30]. Regarding DFO, the same criteria generally apply, with the addition of <10° of extension loss and >90° of flexion for the ideal DFO candidate[28]. Also, patients with soft, atrophic appearing bone on X-ray and/or severe femoral bone loss are unsuitable candidates for DFO[27,28].

Regarding KJD, as stated in **Chapter 3**, larger studies have yet to confirm the appropriateness of the eligibility criteria as used in the only RCT comparing KJD with HTO, namely: OA of the medial compartment of the knee with a tibiofemoral angle of less than 10° of varus, age <65 years, intact knee ligaments, normal range of motion (minimum of 120° flexion) and a BMI <35 kg/m^2 [31]. For their study comparing KJD with TKA, the authors included patients that were eligible for TKA according to routine standard of care, aged <65 years, with functionally intact knee ligaments, >120° of knee flexion and BMI <35 kg/m^2 [32]. In addition, the authors have suggested that KJD could also have a place in the treatment algorithm in cases of low to moderate grade knee OA without tibial malalignment in the coronal plane or in cases of previous meniscectomy, i.e. in patients unsuitable for HTO[31,33], although data to support this hypothesis are still lacking.

Concerning prognostic factors for inferior outcomes after joint preserving surgery, more research is clearly warranted. Recent studies found that older age, female sex and obesity were independent predictors of early conversion to TKA after HTO[10,34]. Smoking is considered a relative contra-indication[24,27], although some authors even propagate refraining from knee osteotomy until patients quit smoking. It seems reasonable to assume that smoking will also negatively affect outcomes of KJD, although presumably more regarding the occurrence of pin tract infections rather than bone healing issues. Whether or not these risk factors should be included as definite rather than potential exclusion criteria for knee osteotomy and KJD could be investigated by future database studies or large surgeon surveys. In any case, the directed-acyclic graph approach proved to be useful in investigating prognostic factors (**Chapters 5 and 6**), and it provides a framework for other researchers to build upon and to perform analyses in a transparent way. As to KJD's place in the treatment for knee OA, a limited body of evidence suggests that KJD is clinically non-inferior to HTO (20 KJDs vs. 41 HTOs) and TKA

(19 KJDs vs. 34 TKAs) at two years according to the WOMAC scores[35]. The only available 5-year follow-up data (20 KJDs) showed that the WOMAC scores were still significantly improved compared to preoperative scores, although a decline in WOMAC scores over time was observed[36]. In contrast, HTO is a well-established procedure with excellent 5-year survival rates and persistent good clinical outcomes at 10–15 years follow-up (**Chapters 1, 5, 6**)[7,8]. The small cohorts reported in these KJD designer studies demonstrate a clear need for larger, non-designer studies to confirm survival rates and clinical outcomes. Multi-centre KJD cohort studies are currently underway and will help elucidate remaining uncertainties. Also, the role of KJD in patients with anteromedial bone-on-bone OA, i.e. UKA candidates, is unclear, since no comparative studies exist. A RCT comparing KJD to UKA would therefore be another relevant study. Overall, much work is still required to establish the place of KJD in the treatment algorithm for younger knee OA patients.

Goal-oriented rehabilitation after knee arthroplasty

Fulfilment of expectations is generally accepted as a crucial factor in obtaining patient satisfaction after KA and knee osteotomy[37–41]. Actually, one may argue that the association between expectations and satisfaction is present throughout society. As stated by professor Yuval Noah Harari, happiness depends on expectations rather than objective conditions, and we become satisfied only when reality matches or exceeds our expectations[42]. With our ever-improving conditions, the expectations we have in life rise accordingly. Analogous to this observation, significant improvements in KA surgery have resulted in higher patient expectations, especially in younger, active patients.

Based on this premise, and on the findings of this thesis, surgeons and younger knee OA patients should discuss the expected functional outcome of various treatment options, should establish realistic goals together with their treating physical therapist, and should use a rehabilitation method that enables them to attain their personal activity goals. The studies in this thesis show that GAS is applicable as a rehabilitation intervention to address the three aforementioned areas in KA surgery. After six months, our patients attained 91% of their daily life activity goals, 93% of their work activity goals, and 89% of their leisure time activity goals[43]. Goal attainment resulted in significantly higher satisfaction with work-related activities in the GAS group in our selected working population (**Chapter 9**). Satisfaction with leisure time activities showed a trend towards higher satisfaction in the GAS group ($p < 0.05$), which we did not report as such because we used a Bonferroni correction for multiple testing (three main outcome measures). Lastly, satisfaction with ADL activities did not differ but showed a ceiling effect, with both groups reporting very high satisfaction scores over time (**Chapter 9**). Therefore, we assume that, especially for knee-demanding tasks during work and leisure time activities, goal-specific rehabilitation is valuable in attaining ambitious activity goals.

Since the original publication by Kiresuk and Sherman in 1968[44], the use of GAS in medical research has increased over the years (Figure 1). Most studies have focused on rehabilitation for children with neurological deficits and stroke patients[45-47]. Yet, GAS can be used to cover all the fields of the International Classification of Functioning, Disability and Health, since GAS goals can be formulated at the level of activity, participation and quality of life[48]. Thus, rehabilitation after orthopaedic surgery, of which the goal often is to improve the patient's physical functioning and participation in desired activities, lends itself well for the GAS approach. In addition, 78–85% of physical therapists consider GAS a good way to measure treatment results, and 64–85% beliefs that the use of GAS leads to an improvement in the quality of rehabilitation treatment[46,49]. We have yet to analyse these data for the physical therapists involved in the ACTION trial, to verify whether these assumptions also apply in KA rehabilitation using GAS.

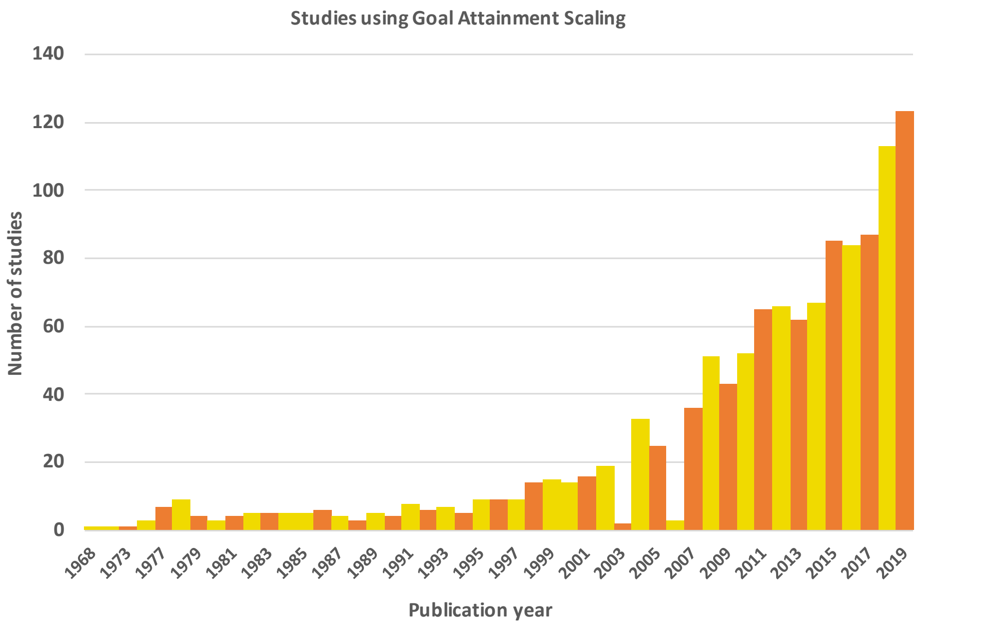


Fig. 1 Number of studies using Goal Attainment Scaling (source: https://pubmed.ncbi.nlm.nih.gov/)

Perhaps somewhat disappointing, we only found a nine-minute daily increase in objectively measured pre- to postoperative PA for the entire RCT cohort (**Chapter 8**). Despite the use of individualized rehabilitation in the intervention group, we found no PA differences between the intervention group and the control group. Our findings were in line with previous activity tracker studies in KA patients, which found no or limited postoperative increases in PA[50,51]. Apparently, improving knee pain and function, and using patient-specific activity goals, is not enough to achieve meaningful improvements in PA after KA. Since knee OA is a condition that often progresses over the course of many years, patients likely adjust their lifestyle to disease-related limitations[52]. Also, orthopaedic surgeons might be somewhat reluctant in their advice regarding return to sport activities. Bayliss et al. showed that patients aged 50 to 54 undergoing TKA have a one in three risk of requiring revision surgery, although the authors did not investigate reasons for this risk[1]. However, contemporary studies in 2,038 TKAs and 1,000 UKAs showed that the risk of revision surgery was actually reduced in patients with high levels of postoperative PA, compared to less physically active patients[53,54]. Furthermore, meeting the PA recommendations is of utmost importance given the known beneficial effects on chronic conditions such as cardiovascular disease, obesity, diabetes and cancer[55]. Therefore, the time is now for orthopaedic surgeons and patients to make PA a priority in the outcome after surgery[56].

As stated, behavioural changes are likely required to accomplish PA improvements. Our patients did not receive direct feedback from their activity tracker. However, a randomized study with wrist worn activity monitors in 68 TKA patients and 95 total hip arthroplasty patients used direct feedback and did show promising results[57]. Patients who received daily feedback on step count and step goal, had significantly higher daily step counts (ranging from +43% in week 1 to +17% at six months), and were 1.7 times more likely to achieve their mean daily steps goal. A smaller feasibility study in 45 TKA patients also found significant increases in daily step count in the physical activity feedback group, compared to the control group[58]. These findings prompted the authors to design a RCT including 125 TKA patients who will undergo standard physical therapy or physical therapy with the addition of wearable activity trackers, individualized step goals and face-to-face feedback from a physical therapist[59]. Therefore, a follow-up RCT to our ACTION trial, including activity trackers with direct feedback from a mobile application, is currently underway (ACTIVE trial, Dutch Trial Registry #NL8525).

Lastly, in analogy with the stepped-care strategy for non-operative treatment of knee and hip OA[60,61], a stratified model of physical therapy interventions for knee OA patients might be necessary to obtain behavioural changes[62]. Such a model of stratified exercise therapy for knee OA patients, based on patient characteristics including quadriceps muscle strength, depression, and obesity, showed clinically relevant improvements on physical functioning and knee pain[63]. A larger RCT (the OCTOPuS study) is currently performed to compare these improvements to standard physical therapy[62]. Also, the Dutch PaTIO study is presently being conducted, with the aim to investigate the effect of treat-to-target, or individualized, physical therapy on functional outcomes after TKA and total hip arthroplasty. Likewise, such a stratified model for physical therapy interventions after KA, based on patient-specific activity goals, may prove useful in further improving PA after KA[64]. For example, patients that need to climb several flights of stairs for their ADL or work activities, should focus their rehabilitation on quadriceps strength and knee flexion. While this form of stratification was a secondary objective of the ACTION trial, we did not actively monitor the usage of our preoperatively established, personalized rehabilitation protocols. Ongoing work must reveal our physical therapists' experience with the use of GAS in the ACTION trial. Hopefully, we can establish to what extent the physical therapists indeed personalized, or stratified, their patients' rehabilitation protocol based on their GAS activity goals.

The findings of this thesis will hopefully contribute to a better shared-decision making process to choose the optimal treatment for younger, active knee osteoarthritis patients, based on their individual goals and expectations. Furthermore, we hope to raise renewed attention amongst orthopaedic surgeons for knee joint preserving surgery. Modern-day knee osteotomy is an excellent treatment option with established, though still evolving, eligibility criteria. Broader implementation through larger studies will further clarify the definite place of knee joint distraction in the treatment algorithm for younger knee osteoarthritis patients. Finally, if patients go on to require a knee arthroplasty, goal-oriented and personalized rehabilitation should be offered, and new strategies should be tested to further enhance postoperative physical activity. In this way, we are getting closer and closer to the ultimate goal of providing the optimal treatment for every young and active knee osteoarthritis patient.

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APPENDICES

SUMMARY

NEDERLANDSE SAMENVATTING

CONTRIBUTING AUTHORS

LIST OF PUBLICATIONS

PHD PORTFOLIO

DANKWOORD

SUMMARY

The main objective of this thesis is to facilitate the shared-decision making for the best surgical treatment strategy in relatively young and active knee osteoarthritis (OA) patients, based on their individual expectations and activity goals. We investigated three topics: I) current functional outcomes, including participation in sports and work, of joint preserving alternatives to knee arthroplasty (KA), II) prognostic factors for patient relevant outcomes, such as return to sport and work, after knee osteotomy and KA, and III) strategies to optimize outcomes like goal attainment and patient satisfaction in this relatively young and active group of KA patients.

Part I - Current functional outcomes for sport and work of joint preserving surgery

Patients undergoing knee osteotomy are often physically active and of working age, and thus wish to be informed on their prospects of returning to sport and work postoperatively. Therefore, **Chapter 1** provides a systematic overview, including a meta-analysis, of the extent and timing of return to sport and work after osteotomies around the knee. Also, we studied factors that might influence the resumption of sport and work activities. We found that 85% of patients could return to sport (RTS), and observed a tendency of postoperative participation in lower impact sports, compared to preoperative. Mean return to work (RTW) was 85%, and time to RTW varied from 10 to 22 weeks. Contrasting findings for the effects of age, sex, BMI, and comorbidities on RTS and RTW were reported. The preoperative sports level did appear to be associated with RTS, with higher preoperative levels resulting in higher RTS rates. Thus, patients eligible for knee osteotomy may be told that they have a good chance of returning to sport and work postoperatively.

Data on resumption of sport and work activities after distal femoral osteotomy (DFO) are sparse. In **Chapter 2** we present data from a retrospective cohort study including 100 DFO patients, who reported their pre- and postoperative participation in sports and work. The RTS rate was 77%, and seven out of ten patients returned within six months. The RTW rate was 91%, and eight out of ten patients returned within six months. A shift was observed from participation in high- and intermediate impact sports pre-symptomatically to participation in intermediate- and low impact sports postoperatively. Thus, DFO may be suggested to younger, active knee OA patients who have relatively high activity demands.

Knee joint distraction (KJD) is a relatively new and promising joint preserving alternative to KA. Since KJD is primarily advocated in relatively young knee OA patients, data on functional outcomes including RTS and RTW are essential. **Chapter 3** reports on functional outcomes in patients who were previously randomized to undergo KJD or HTO. Patients completed a questionnaire at a follow-up of 5 years. After KJD and HTO, the RTS rate was 79% and 80% respectively, and time to

RTS was comparable, namely about 75% within six months. For RTW, these rates were 94% and 97% respectively, and time to RTW was also comparable, namely about 90% within six months. HTO patients reported slightly better work ability at the five-year final follow-up, according to the WORQ questionnaire. Thus, KJD and HTO appear to result in comparable resumption of sport and work. Yet, given the small sample size, larger studies are required to confirm our initial findings.

Part II - Predicting patient relevant outcomes for sport and work

Physical activity (PA) has proven beneficial effects on work participation and sick leave in healthy persons. For **Chapter 4**, we investigated this relationship in patients undergoing KA, using the prospective Longitudinal Leiden Orthopaedics Outcomes of Osteo-Arthritis database. Preoperatively, 144 out of 266 patients (54%) adhered to the Dutch Recommendation for Health-Enhancing PA (NNGB). Adherence to the NNGB was not associated with postoperative RTW rates. In contrast, self-reported work-relatedness of knee symptoms and patients' expected timing of RTW were associated with RTW rates. Thus, not PA but patient beliefs and expectations are apparently more strongly associated with RTW after KA.

Many patients who are eligible for HTO still participate in sports and work. To improve preoperative counselling for these patients, we investigated factors that may influence rates of RTS and RTW after HTO, based on a directed acyclic graph approach. In **Chapter 5**, we report results of a retrospective cohort study. We found that 210 out of 256 patients (82%) could RTS after HTO, and that 75% did so within six months. The strongest prognostic factor for RTS was continued sports participation in the year before surgery, while wedge size and BMI were not associated with RTS. Regarding the RTW rate, we show in **Chapter 6** that 284 out of 299 patients (95%) could RTW, and that nine out of ten patients returned within six months. Being the family's breadwinner was the strongest predictor of RTW, while preoperative sick leave resulted in lower odds of RTW.

Part III – Optimising functional outcomes and patient satisfaction

To further improve outcomes after KA, rapid recovery protocols have been successfully developed. These protocols enable patients to go home on the first postoperative day, and result in improved early functional results and higher patient satisfaction. As a possible next advancement, outpatient surgery protocols for KA are being studied. **Chapter 7** reports on a case-control study of 20 outpatient unicompartmental KAs, compared to 20 unicompartmental KAs who were operated using the standard rapid recovery protocol. Nine out of ten patients in the outpatient group could actually be discharged on the same day. In carefully selected patients, outpatient surgery resulted in comparable outcome in terms of symptoms of anxiety and depression, satisfaction, and pain scores, compared to standard treatment.

Given the importance of fulfilling preoperative expectations, especially concerning activity goals in younger, working patients undergoing KA, we conducted the randomized controlled ACTION trial. In this trial, we compared standard rehabilitation to Goal Attainment Scaling (GAS) based rehabilitation. With GAS rehabilitation, patients established personal activity goals preoperatively, and subsequently their rehabilitation protocol was adjusted to these goals. The prospective activity monitor study presented in **Chapter 8** describes the first results from the ACTION trial. We found a small but significant overall PA increase of nine minutes (SD ± 37) per day after KA, compared to one month preoperatively. Also, a decrease in sedentary time of 20 minutes (SD ± 79) was observed, while standing time did not significantly change. No differences were found between GAS and standard rehabilitation in terms of PA. Likely, enhanced multidisciplinary strategies are needed to further improve PA after KA.

In **Chapter 9**, we compare patient satisfaction with the performance of activities in ADL, work and leisure time after GAS rehabilitation and standard rehabilitation after KA. At one year follow-up, patient satisfaction with performing work activities was more than 10 points higher (confidence interval 2.0 to 19.4 points; scale 0-100) in the GAS group. Thus, personalized and goal-specific rehabilitation using GAS resulted in higher satisfaction for work-related activities. Satisfaction with ADL activities and leisure time activities did not differ, nor did we find differences in VAS satisfaction scores between total KA and unicompartmental KA.

The results reported in this thesis support the use of knee joint sparing alternatives to KA in the treatment of relatively young, active patients. Individual activity goals and prognostic factors for patient relevant outcomes, such as preoperative sports participation and being the family's breadwinner, should be taken into account when deciding which treatment option is best for each specific patient. Finally, if patients go on to require a knee arthroplasty, goal-oriented and personalized rehabilitation should be offered.

NEDERLANDSE SAMENVATTING

Het doel van dit proefschrift is om de gedeelde besluitvorming te verbeteren bij de keuze van het soort knieoperatie voor relatief jonge, actieve patiënten met knieartrose. Wij onderzochten hiervoor drie thema's: I) de huidige functionele uitkomsten, in het bijzonder participatie in sport en werk, van gewrichtsparende alternatieven voor een knieprothese, II) de voorspellende factoren voor patiënt-relevante uitkomsten, zoals terugkeer naar sport en werk, na een knie-osteotomie (KO) of knieprothese bij deze actieve patiënten, en III) de strategieën om uitkomsten zoals patiënttevredenheid en het behalen van persoonlijke activiteitdoelen te optimaliseren bij relatief jonge, actieve knieprothesepatiënten.

Deel I – Functionele uitkomsten voor sport en werk na een gewrichtsparende operatie

Patiënten die een KO krijgen, hebben vaak werk en zijn fysiek actief. Zij willen daarom geïnformeerd worden over de verwachte kans om hun sport en/of werk te hervatten. Voor **hoofdstuk 1** voerden we een systematisch literatuuronderzoek en meta-analyse uit van onderzoeken naar terugkeer naar sport en werk na een KO. Ook onderzochten we welke factoren deze terugkeer beïnvloeden. We vonden een terugkeer naar sport (TNS) van 85%, waarbij patiënten vaker deelnamen aan sporten met een lagere kniebelasting dan preoperatief. De terugkeer naar werk (TNW) was ook 85%, en de tijd tot TNW varieerde van 10 tot 22 weken. Studies rapporteerden tegenstrijdige invloeden van leeftijd, geslacht, BMI en co-morbiditeit op TNS en TNW. Het preoperatieve sportniveau was duidelijk positief geassocieerd met TNS; een hoger preoperatief sportniveau resulteerde in hogere TNS percentages. Aan patiënten die in aanmerking komen voor een KO kan dus worden verteld dat zij een goede kans hebben op het hervatten van sport en werk.

Er is nog weinig bekend over de mogelijkheid om terug te keren naar sport en werk na een distale femurosteotomie (DFO). Daarom verzamelden wij in **hoofdstuk 2** van 100 DFO patiënten gegevens over hun pre- en postoperatieve participatie in sport en werk. Het TNS percentage was 77%, en zeven van de tien patiënten hervatten binnen zes maanden het sporten. Het TNW percentage was 91%, en acht van de tien patiënten gingen binnen zes maanden weer aan het werk. Wij vonden wel een verschuiving van deelname aan hoge- en gemiddelde-impact sporten presymptomatisch, naar gemiddelde- en lage-impact sporten postoperatief. De resultaten suggereren dat DFO geschikt is voor patiënten met knieartrose op basis van een afwijkende stand van het femur, die ook relatief hoge postoperatieve fysieke eisen hebben.

Kniedistractie (KD) is een relatief nieuwe gewrichtsparende operatie die een alternatief kan zijn voor een knieprothese. Omdat KD vooral wordt aangeraden voor jongere patiënten, zijn data over TNS en TNW belangrijk. **Hoofdstuk 3** beschrijft functionele uitkomsten, waaronder TNS en TNW, van patiënten die eerder gerandomiseerd waren om KD of een tibiakop osteotomie (TKO) te ondergaan. Na KD was het TNS percentage 79%, en 80% na een TKO. De timing van TNS was vergelijkbaar in beide groepen, namelijk ongeveer 75% binnen zes maanden. Het TNW percentage na KD was 94% en 97% in de TKO groep. Ook het interval tot TNW was vergelijkbaar, namelijk 90% binnen zes maanden. Na 5 jaar rapporteerden TKO patiënten, vergeleken met drie maanden preoperatief, grotere verbeteringen in het uitvoeren van werk-gerelateerde activiteiten, zoals knielen en traplopen, dan KD patiënten. KD en TKO lijken dus vergelijkbare uitkomsten wat betreft hervatting van sport en werk te geven, hoewel deze bevindingen in grotere studies bevestigd moeten worden.

Deel II – Voorspellen van patiënt-relevante uitkomsten voor sport en werk

Fysieke activiteit (FA) vermindert op populatieniveau het ziekteverzuim en heeft zo een bewezen positief effect op werkparticipatie bij gezonde mensen. In **hoofdstuk 4** onderzochten wij of deze relatie ook bestaat bij patiënten die een knieprothese krijgen. Hiervoor gebruikten wij de prospectieve Longitudinale Leiden Orthopedische Uitkomsten van Osteo-Arthrose database. Preoperatief voldeden 144 van de 266 patiënten (54%) aan de Nederlandse Norm Gezond Bewegen (NNGB), een maat voor FA. Het voldoen aan de NNGB hing opmerkelijk genoeg niet samen met postoperatieve TNW. Daarentegen waren de zelf-gerapporteerde relatie van het werk als oorzaak voor de knieklachten, en de door patiënten verwachte timing van TNW, wél geassocieerd met TNW. Dus niet de FA maar de opvattingen en verwachtingen van de patiënt zijn kennelijk van invloed op TNW na een knieprothese.

Veel patiënten die in aanmerking komen voor een TKO werken en sporten. Om het preoperatieve advies voor deze patiënten te verbeteren, onderzochten wij welke voorspellers die TNS en TNW positief of negatief kunnen beïnvloeden. Wij gebruikten hiervoor een nieuwe analysetechniek, met de Engelse naam directed acyclic graph, waarin bewezen en veronderstelde verbanden tussen TNS en TNW in één figuur worden weergegeven. In **hoofdstuk 5** beschrijven we de resultaten van een retrospectieve cohort studie. Wij vonden dat 210 van de 256 patiënten (82%) konden terugkeren naar sport na een TKO, waarvan 75% binnen zes maanden. De sterkste voorspeller voor TNS was sportparticipatie in het jaar voorafgaand aan de operatie. De grootte van de bot wig en BMI waren niet van invloed op TNS. Voor TNW beschrijven we in **hoofdstuk 6** dat 284 van de 299 patiënten (95%) terugkeerden naar werk en dat negen van de tien patiënten dat binnen zes maanden deden. Kostwinner zijn was de sterkste voorspeller voor TNW, terwijl preoperatief ziekteverzuim TNW ongunstig beïnvloedde.

Deel III – Optimaliseren van functionele uitkomsten en patiënttevredenheid

Om de uitkomsten van een knieprothese verder te verbeteren, zijn de afgelopen jaren zogeheten '*fast track*' protocollen geïmplementeerd. Met deze behandelingsaanpak worden patiënten binnen enkele dagen weer op de been geholpen en vaak kunnen zij na één dag het ziekenhuis verlaten. Als mogelijke verbeterslag wordt nu het uitvoeren van knieprotheses in dagbehandeling onderzocht. **Hoofdstuk 7** beschrijft een case-control studie waarin twintig unicompartimentele knieprotheses (UKP) in een dagbehandeling protocol werden vergeleken met twintig UKP's in een standaard '*fast track*' protocol. Negen van de tien patiënten in de dagbehandeling groep konden daadwerkelijk op de dag van operatie naar huis. In zorgvuldig geselecteerde patiënten resulteerde UKP in dagbehandeling in vergelijkbare uitkomsten wat betreft symptomen van angst en depressie, patiënttevredenheid en pijnscores, vergeleken met de standaard behandeling.

Het is van groot belang voor de patiënttevredenheid om aan preoperatieve verwachtingen te voldoen. Voor jongere, werkende knieprothese patiënten geldt dit in het bijzonder wat betreft hun activiteitendoelen, en daarom voerden wij de gerandomiseerde ACTION trial uit. Deze trial vergeleek standaard revalidatie met Goal Attainment Scaling (GAS) revalidatie na een knieprothese. Voor GAS revalidatie stelden patiënten preoperatief individuele activiteitendoelen op met hun fysiotherapeut, waarna het revalidatieprotocol werd aangepast op basis van die persoonlijke doelen. De activiteitenmonitor studie die wordt beschreven in **hoofdstuk 8** rapporteert de eerste data van de ACTION trial. Met behulp van een activiteitenmonitor, die telkens zeven aaneengesloten dagen werd gedragen, werd FA één maand voor en zes maanden na de operatie gemeten. In de eerste studie vonden we een kleine maar significante FA toename van negen minuten (standaarddeviatie ±37) per dag na een knieprotheseoperatie, vergeleken met één maand preoperatief. Patiënten brachten gemiddeld twintig minuten (standaarddeviatie ± 79) minder zittend door, terwijl de staand doorgebrachte tijd niet veranderde. We vonden geen verschil in FA tussen GAS en standaard revalidatie. Er zijn waarschijnlijk meerdere gecombineerde maatregelen, ook gericht op gedragsverandering, nodig om FA na een knieprothese verder te verbeteren.

In **hoofdstuk 9** vergelijken we patiënttevredenheid met het uitvoeren van ADL-, werk- en vrijetijd activiteiten na GAS revalidatie en standaard revalidatie. Na een jaar was de tevredenheid met het uitvoeren van werkactiviteiten meer dan tien punten (betrouwbaarheidsinterval 2.0–19.4 punten; schaal 0-100) hoger in de GAS groep dan in de standaard groep, die de huidige standaard zorg kreeg. Gepersonaliseerde en op eigen doelen gebaseerde revalidatie resulteerde dus in hogere patiënttevredenheid met het kunnen uitvoeren van werkactiviteiten. Tevredenheid met de uitvoer van ADL- en vrijetijd activiteiten verschilde niet. Ook vonden we geen verschil in tevredenheidsscores van patiënten met een totale knieprothese of een unicompartimentele knieprothese.

De resultaten beschreven in dit proefschrift ondersteunen de hypothese dat gewrichtsparende alternatieven voor een knieprothese geschikt zijn voor de behandeling van relatief jonge, actieve patiënten met knieartrose. Individuele activiteitendoelen, alsmede voorspellende factoren voor patiënt-relevante uitkomsten, zoals sportparticipatie in het jaar voor de operatie en het zijn van de kostwinner, moeten worden meegenomen in de besluitvorming voor de meest geschikte operatie. Als patiënten tenslotte in aanmerking komen voor een knieprothese, adviseren wij het gebruik van doelgerichte en geïndividualiseerde revalidatie.

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All authors read and approved the final version of each manuscript that they contributed to. In addition, each of the authors contributed to the chapters in this thesis as follows:

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LIST OF PUBLICATIONS

Hoorntje A•, Colen S•, Maeckelbergh L, van Diemen M, Dalemans A, van den Bekerom MPJ, Mulier M. (•Contributed equally). *Intra-Articular Hyaluronic Acid Injections Less Than 6 Months Before Total Hip Arthroplasty: Is It Safe? A Retrospective Cohort Study in 565 Patients*. J Arthroplasty. 2021 Mar;36(3):1003-1008.

Hoorntje A, Kuijer PPFM, Koenraadt KLM, Waterval-Witjes S, Kerkhoffs GMMJ, Mastbergen SC, Marijnissen ACA, Jansen MP, van Geenen RCI. *Return to Sport and Work after Randomization for Knee Distraction versus High Tibial Osteotomy: Is There a Difference?* J Knee Surg. 2020 Nov 23. Erratum in: J Knee Surg. 2021 Apr 14; PMID: 33231278.

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Hoorntje A, Witjes S, Kuijer PPFM et al. *Does activity-based rehabilitation with Goal Attainment Scaling increase physical activity among younger knee arthroplasty patients? Results from the randomized-controlled ACTION trial.* J Arthroplasty. 2020 Mar;35(3):706-711.

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Hoorntje A, Koenraadt KLM, Boevé MG, van Geenen RCI. *Outpatient unicompartmental knee arthroplasty: who is afraid of outpatient surgery?* Knee Surg Sports Traumatol Arthrosc. 2017 Mar;25(3):759-766.

Hoorntje A•, Witjes S•, Kuijer PPFM, Koenraadt KLM, Blankevoort L, Kerkhoffs GMMJ, van Geenen RCI (•Contributed equally). *Does Goal Attainment Scaling improve satisfaction regarding performance of activities of younger knee arthroplasty patients? Study protocol of the randomized controlled ACTION trial*. BMC Musculoskelet Disord. 2016 Mar 2;17:113.

CO-AUTHOR PUBLICATIONS

Witjes S, **Hoorntje A**, Koenraadt KLM, Kerkhoffs GMMJ, van Geenen RCI. *Higher Function Scores and Satisfaction in Patients with Anteromedial Osteoarthritis Compared with Other Wear Patterns of the Knee: 2 Years after Both Total and Unicondylar Knee Arthroplasties.* J Knee Surg. 2020 Jul;33(7):629-635.

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Witjes S, **Hoorntje A,** PPFM Kuijer, Koenraadt KL, Blankevoort L, Kerkhoffs GM, van Geenen RC. *Goal setting and achievement in individualized rehabilitation of younger total and unicondylar knee arthroplasty patients: a cohort study.* Arch Phys Med Rehabil. 2019 Aug;100(8):1434-1441.

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Vuurberg G, **Hoorntje A,** Wink LM, van der Doelen BFW, van den Bekerom MP, Dekker R, van Dijk CN, Krips R, Loogman MCM, Ridderikhof ML, Smithuis FF, Stufkens SAS, Verhagen EALM, de Bie RA, Kerkhoffs GMMJ. *Diagnosis, treatment and prevention of ankle sprains: update of an evidence-based clinical guideline.* Br J Sports Med. 2018 Aug;52(15):956.

Siques P, López de Pablo AL, Brito J, Arribas SM, Flores K, Arriaza K, Naveas N, González MC, **Hoorntje A**, León-Velarde F, López MR. *Nitric oxide and superoxide anion balance in rats exposed to chronic and long term intermittent hypoxia.* Biomed Res Int. 2014:610474.

PHD PORTFOLIO

Name: A. Hoorntje
PhD period: June 2015 – December 2017
Supervisor: prof. dr. G.M.M.J. Kerkhoffs

1. PhD TRAINING

General courses	Year	ECTS
Searching for a Systematic Review	2015-2016	0.1
Practical Biostatistics	2016-2017	1.1
CE 1: Randomized Clinical Trials	2016-2017	0.6
CE 2: Observational Epidemiology: Effects and Effectiveness	2016-2017	0.6
CE 3: Evaluation of Medical Tests	2016-2017	0.9
CE 4: Systematic Reviews	2017-2018	0.7
Communication with patients	2016-2017	0.3
Entrepreneurship in Health and Life Sciences	2016-2017	1.5
Scientific Writing in English	2016-2017	1.5
Oral Presentation in English	2016-2017	0.8
Basic Course Legislation and Organization for Clinical Researchers	2017-2018	1.0

Seminars, workshops and master classes	Year	ECTS
Weekly Journal Club (AMC)	2015-2017	1.5
GCP-WMO (Amphia hospital)	2015	1.0
Effective Scientific Writing (Text & Training)	2016	1.5
MOVE Institute kick-off meeting	2017	0.3
Basic Knee Osteotomy course (Kliniek ViaSana)	2017	0.5
3rd Lovisenberg Osteotomy Course, Oslo, Norway	2018	0.5

Oral presentations	Year	ECTS
Outpatient unicompartmental knee arthroplasty: who dares? Nordic Orthopaedic Federation Congress, Linköping, Sweden	2015	0.5
Is de preoperatieve Kellgren-Lawrence score geassocieerd met PROMs na een totale knieprothese? Voorjaarsvergadering Nederlandse Orthopaedische Vereniging, Utrecht	2016	0.5
Oxford uniknieprothese in dagbehandeling: Wie durft? Voorjaarsvergadering Nederlandse Orthopaedische Vereniging, Utrecht	2016	0.5
Betere functiescores en hogere tevredenheid na knieprotheseplaatsing bij anteromediale slijtage, vergeleken met andere slijtagepatronen Jaarcongres Nederlandse Orthopaedische Vereniging, 's-Hertogenbosch	2017	0.5
Fysieke activiteit: een voorspeller voor werkhervatting na TKP? Jaarcongres Nederlandse Orthopaedische Vereniging, 's-Hertogenbosch	2018	0.5
Return to sports after distal femoral and high tibial osteotomy 3rd Trauma Platform Young Generations Seminar, Amsterdam	2018	0.5
Return to sport after knee osteotomy – Is it possible? 5th International Joint Preservation Congress, Warsaw, Poland	2018	0.5
Return to sport and work after knee osteotomy International Joint Preservation Congress, Warsaw, Poland	2018	0.5
Most patients return to sport and work after total hip arthroplasty – a systematic review and meta-analysis European Hip Society Congress, The Hague	2018	0.5
Verstandig Kiezen: Het gebruik van niet-operatieve behandelingen bij eindstadium heup- en knieartrose Jaarcongres Nederlandse Orthopaedische Vereniging, 's-Hertogenbosch	2020	0.5
Goal Attainment Scaling verbetert patiënttevredenheid voor werk gerelateerde activiteiten onder jonge, actieve knieprothesepatiënten Jaarcongres Nederlandse Orthopaedische Vereniging, 's-Hertogenbosch	2020	0.5
Higher patient satisfaction with work activities using Goal Attainment Scaling rehabilitation after knee arthroplasty EFORT, 1st Online Congress	2020	0.5

Poster presentations	Year	ECTS
Predicting patient-reported outcome based on radiographic severity in TKA NOF, Linköping, Sweden	2016	0.5
High rates of return to sports activities and work after osteotomies around the knee – a systematic review and meta-analysis EKS, London, United Kingdom	2017	0.5
Return to sport and work after distal femoral osteotomy: is it possible? EFORT, Barcelona, Spain & ESSKA, Glasgow, Scotland	2018	1.0
Not physical activity, but patient beliefs and expectations are associated with return to work after total knee arthroplasty EFORT, Barcelona, Spain & ESSKA, Glasgow, Scotland	2018	1.0
Most patients return to work and sports after total hip arthroplasty – a systematic review and meta-analysis EFORT, Barcelona, Spain & ESSKA, Glasgow, Scotland	2018	1.0
Prognostic factors for return to sport after high tibial osteotomy – A directed acyclic graph approach EKS, Valencia, Spain	2019	0.5
Does exercise-based rehabilitation with Goal Attainment Scaling increase physical activity among working knee arthroplasty patients? EKS, Valencia, Spain	2019	0.5

(Inter)national conferences	Year	ECTS
NOF Congress, Linköping, Sweden	2016	0.5
Voorjaarsvergadering NOV, Utrecht	2016	0.25
Jaarcongres NOV, 's-Hertogenbosch	2017-2020	1.5
EHS, Den Haag	2018	0.25
EFORT, Barcelona, Spain	2018	0.75
ESSKA, Glasgow, Scotland	2018	0.75
International Joint Preservation Congress, Warsaw, Poland	2018	0.5
EKS, Valencia, Spain	2019	0.5
EFORT (online conference)	2020	0.5

Reviewing	Year	ECTS
BMJ Open	2020	0.5
Journal of Clinical Medicine	2020	0.5
Clinical Medicine Insights: Arthritis and Musculoskeletal Disorders	2020	0.5
Disability and Rehabilitation	2020	0.5
Clinical Interventions in Aging	2020	0.5

2. TEACHING

Lecturing	Year	ECTS
Totale heupprothese in één dag: totally hip, ROA dag, Amphia, Breda	2016	0.5
Workshop musculoskeletal health: Outcome measures for musculoskeletal health, MOVE Institute kick-off meeting, Amsterdam	2017	0.5
Generatie Y: millennials bestormen de orthopedie, ROA dag, Amphia, Breda	2018	0.5
Terugkeer naar sport & werk na een knieprothese, FORCE symposium, Breda	2020	0.5

Tutoring, Mentoring, Supervising	Year	ECTS
Bachelor thesis: Kim Janssen, Julian Polman, Ahmed Bayoumy, Meike van Haeringen, Sten van der Wilk	2016-2021	5
Master thesis Ted van Iersel	2020	0.5

3. PARAMETERS OF ESTEEM

Grants	Year
Nordic Orthopaedic Federation travel grant	2016
KNAW Van Walree grant	2017
ZonMw Choosing Wisely grant	2017
Spinoza grant	2018

Awards and Prizes	Year
Nomination Best Poster Award, EFORT	2018
FORCE Award	2018
Best Poster Award, EKS	2019
Nomination Best Paper Award, EFORT	2020

DANKWOORD

Voor de familieleden, vrienden, collega's en andere geïnteresseerden die mijn boekje hier als eerste openslaan: dank voor jullie belangstelling! Ik hoop dat jullie zo nog een stukje terugbladeren, hoofdstuk 9 is bijvoorbeeld een aanrader.

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Kay, Luuk en Diederik, als je onze foto's van het eerste jaar terugkijkt had je niet voorspeld dat we nu alle vier promoveren, (bijna) in opleiding zijn en ook nog zo lekker gewoon zijn gebleven. Als ik er per ongeluk een keer behoefte aan had kon ik bij jullie terecht met promotiestruggles. Ik vind het heel leuk dat we elkaar de laatste jaren weer vaker zien en natuurlijk dat jullie speldenprikken ervoor zorgden dat ik de Bananaflits, ondanks beroerde Excel-prognoses, tóch maar heb gekocht.

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Lies en Tijn, altijd al geweldig betrokken maar sinds pap zijn jullie nog belangrijker voor ons geworden. Geweldig hoe jullie altijd klaarstaan, met daad maar vooral ook met raad, dat is voor mij absoluut onmisbaar geweest. Ik hoop dat jullie de komende jaren nog lekker drie keer de wereld rond gaan fietsen, blijven schaven aan de handicap en andere mooie avonturen gaan beleven, met z'n tweeën maar zeker ook met ons.

Capi, als jongetje kwam ik bij je in Amsterdam om mijn eigen CD hoes te ontwerpen, waarvoor we mijn stekelhaar in alle kleuren van de regenboog toverden. Achteraf ben ik blij dat we het, op dringend advies van mam, bij Photoshop hebben gehouden. Je bent geweldig creatief en ik ben heel erg blij dat jij voor mij de vormgeving van dit boek hebt willen doen, dankjewel!

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RICHARD KRAJICEK is the only male Dutch tennis player who won a Grand Slam singles title. In 1996, he won the trophy at the holy grass of Wimbledon, the most prestigious tennis tournament in the world. Throughout his career, he suffered from numerous injuries, including to his knee. After his professional career, Krajicek received knee osteotomies on both knees, and still plays tennis now and then. He kindly allowed the use of images of his characteristic serve and volley game to illustrate the types of knee surgery discussed in this thesis.

Amsterdam Movement Sciences

Amsterdam Movement Sciences conducts scientific research to optimize physical performance in health and disease based on a fundamental understanding of human movement in order to contribute to the fulfillment of a meaningful life.