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# No differences in knee joint loading between individuals who had a medial or lateral meniscectomy: An ancillary study

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ABSTRACT

*Background:* Arthroscopic partial meniscectomy is a frequently undertaken procedure for traumatic meniscal injuries. The location of knee joint degeneration and long-term prognosis differs between knees who have had a medial or lateral meniscectomy. However, there is no evidence comparing knee loading following a medial or lateral meniscectomy during sporting tasks. This study compared knee loading during walking and running between individuals who either had a medial or lateral meniscectomy.
*Methods:* Knee kinematic and kinetic data were collected during walking and running in individuals three to twelve months post-surgery. Participants were grouped according to the location of surgery (medial, n = 12, and lateral, n = 16). An independent t-test compared knee biomechanics between the groups and Hedge's *g* effects sizes were also conducted.
*Results:* External knee adduction and knee flexion moments were similar between groups for walking and running with negligible to small effect sizes (effect size, 0.08–0.30). Kinematic (effect size, 0.03–0.22) and spatiotemporal (effect size, 0.02–0.59) outcomes were also similar between the groups.
*Conclusions:* The lack of differences in surrogate knee loading variables between medial and lateral meniscectomy groups was unexpected. These findings suggest that combining groups in the short-term period following surgery is applicable. However, the data presented in this study cannot explain the differences in long-term prognosis between medial and lateral meniscectomies.


## 1. Introduction

Partial meniscectomies are commonly performed surgical procedures, particularly if the injury is more central where the blood supply to the meniscus is limited, or if there is a mechanical block [2]. Return to sport (RTS) following a meniscectomy is typically 7 to 9 weeks [3], however, differences in the time taken to return are apparent between individuals who had a medial meniscectomy and those following a lateral meniscectomy [4,5]. Currently, there is no consensus on whether medial or lateral meniscectomy results in longer RTS time [3–12]. Irrespective of RTS time, individuals following a lateral meniscectomy reported greater pain, swelling and adverse events following RTS compared with those following a medial

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meniscectomy [4]. Differences in RTS and short-term clinical outcomes are not fully understood and data examining knee loading could provide an insight into observed differences following a medial and lateral meniscectomy.

Knee osteoarthritis (OA) is common in those who previously sustained a meniscal injury and subsequent meniscectomy [6–21]. When assessed 10 to 15 years post-surgery, clinical outcomes such as pain and perceived function were similar between individuals who had a medial meniscectomy and a lateral meniscectomy [9,13]. However, individuals who had a lateral meniscectomy presented with worse radiographical changes and had higher occurrences of re-surgery compared to medial meniscectomy [6,9,15]. Medial meniscectomies have been associated with the development of medial compartment knee OA and reduced cartilage volume on the medial aspect of the patellar [6]. Whereas, lateral meniscectomies are associated with the development of OA in the lateral aspect of the knee and reduced cartilage volume on the lateral aspect of the patella [6,8,9]. Differences in degeneration location and proportion of knee OA suggest differences in loading patterns between medial and lateral meniscectomies, yet evidence exploring loading of the knee between groups is limited.

Individuals with knee OA or those at risk of knee OA often present with greater knee joint loading [16–25]. Surrogate biomechanical measures such as the external knee adduction moment (KAM) and external knee flexion moments (KFM) have been associated with medial compartment knee OA and patellofemoral joint OA, respectively [16,25–27]. Biomechanical studies have explored knee loading during walking and running in individuals following a meniscectomy but have not compared medial and lateral meniscectomy [21–31]. These studies have either examined medial [21,22,24] or lateral meniscectomy [25] separately or grouped them in their analysis [26].

Given the different times to return to sport, re-surgery rates, adverse events occurrences, and long-term degenerative changes, it could be assumed knee loading could differ between medial and lateral meniscectomies. To our knowledge, there has been no study examining differences in knee loading between medial and lateral meniscectomies during walking and running gait. This ancillary study aims to compare knee loading during walking and running in those who have had a medial meniscectomy with those who have had a lateral meniscectomy. We hypothesise that those who have a medial meniscectomy will demonstrate greater KAM and KFM during walking and running compared to individuals who had a lateral meniscectomy.

## 2. Methods

This ancillary study is part of a larger cross-sectional cohort study (https://www.clinicaltrials.gov/ ID: NCT03379415) which aimed to compare biomechanical outcomes in individuals following a meniscectomy with healthy individuals. Individuals who had undergone a meniscectomy were recruited through NHS and private orthopaedic clinics. Participants were recruited between 3 to 12 months post-surgery and were eligible for the study if they were aged between 18 and 40 years and competed or played sport at least twice a week and sustained their meniscal injury during a sporting task (e.g. change of direction, landing or running). Participants were excluded if they had a history of lower extremity surgeries (e.g. ACL reconstruction) other than their meniscectomy, demonstrated evidence of knee osteoarthritis development either clinically or radiographically, previous traumatic (other than the sustained meniscal injury) injury, inflammatory or infectious pathology in the lower extremities or evidence of ligament laxity. Participants were grouped into a medial meniscectomy group (individuals who have had medial meniscectomy) and a lateral meniscectomy group (individuals who have had lateral meniscectomy) without stratifying by the amount resected. The Regional Ethical Committee (IRAS: 239135) approved the study and informed consent was obtained from each participant before testing.

Participant characteristics were obtained and included age, height, mass, and time in months since their surgery. Participants were asked to complete the Knee injury and Osteoarthritis Outcome Score (KOOS) to quantify knee function [27]. KOOS includes of five subscales which have previously distinguished between those with a history of meniscectomy and those without [26].

Synchronised kinematic (200 Hz; 27 Qualisys Oqus, Gothenburg, Sweden) and kinetic (1000 Hz; four AMTI force plates, Advanced Mechanical Technology, Inc, Newton, MA) data were collected during walking and running trials. Data were collected for five successful (clean force plate contacts without targeting) walking trials and five successful running trials at a self-selected pace to reflect their typical speeds. Participants wore standardised trainers (Asics Gel Windhawk) throughout the data collection to remove confounding effects of footwear.

Retro-reflective markers were placed on anatomical landmarks on the thorax and bilaterally on the lower limbs as recommended by the CAST marker technique (Figure 1). Placement of markers included the jugular notch, spinous processes of the 2nd and 10th thoracic vertebrae, anterior superior iliac spine, posterior superior iliac spine, lateral and medial femoral epicondyles, lateral and medial malleoli, 1st and 5th metatarsal heads, the base of the 2nd metatarsal and the most posterior aspect of the calcaneus [28,29]. To track thigh and lower leg movements rigid clusters with four non-orthogonal markers attached were attached to each leg. A static calibration trial was collected before the dynamic walking and running trials.

Visual3D (Visual3D v6 software; C-Motion, Inc., Germantown, MD, USA) software was used to create the six-degree of freedom model. A regression model based on the anterior and posterior superior iliac spine markers was used to calculate hip joint centres [30]. Ankle and knee joint centres were calculated as the midpoints between the malleoli and femoral epicondyles respectively. Marker motion data and analogue force data were filtered using a 4th order low pass Butterworth filter with a matched 15 Hz cut off frequency [31]. Knee joint kinematics were calculated using XYZ Euler rotation sequence equivalent to the joint coordinate system [28,32]. External knee joint kinetic data were calculated using three-dimensional

**Figure 1.** The marker setup used for data collection.

inverse dynamics, resolved to the proximal segment and normalised to body mass multiplied by height and expressed as a percentage.

Spatiotemporal outcomes, knee kinematic and kinetic curves were calculated in Visual3D and expressed as a percentage of stance for both walking and running. Kinematic and kinetic curves were then exported to Matlab (Matlab R2020a, Mathsworks, Natrick, MA, USA) and a custom-written code was used to determine outcome variables for both walking and running. For walking, knee flexion angle at initial contact and maximum angle during early stance (0–50% of stance phase) were identified and maximum knee adduction angle and internal rotation angle obtained. Peak knee flexion moments were obtained, peak knee adduction moment, and peak rotation moments identified during early (0 – 50%) and late stance (51 – 100%). Peak values for knee flexion, adduction, and internal rotation angles and peak knee flexion, adduction moments, and rotation moments were obtained during running. For both walking and running knee angular adduction impulse (KAAI) was calculated as the integral of the KAM during the stance phase [33]. For each outcome, the mean across the five trials were taken and used in the statistical analysis. Prior to commencing data collection, we assessed the repeatability of our procedures using a test–retest analysis of 17 healthy. Standard error of measurements was calculated for knee joint angles and moments and were within accepted values for walking (knee joint angles 1.3 – 1.8°; knee joint moments 0.05 – 0.11 Nm/kg) and running (knee joint angles 1.9 – 3.9°; knee joint moments 0.06 – 0.25 Nm/kg) [34,35].

To assess differences in outcomes between the medial and lateral meniscectomy group independent t-tests were conducted (SPSS, v25). An alpha level of 0.05 was used to determine significance. Hedge's *g* effect sizes with bias correction were calculated with 0.2, 0.5 and 0.8 determining small, medium and large effect sizes respectively [36].

## 3. Results

### 3.1. Participant characteristics

Eligibility was assessed for 298 individuals, with 186 excluded due to age and 53 excluded as they had a concurrent ACL injury. Of those invited (n = 59), 29 individuals declined resulting in a total of 30 individuals recruited for the study. Two participants who underwent both a medial and lateral meniscectomy were excluded from the current analysis. Of the remaining 28 participants, participants were grouped into those who had a medial meniscectomy (n = 12) and those who had a lateral meniscectomy (n = 16). There were no significant ($p$ >.05) differences in participant characteristics between groups (Table 1). Both medial and lateral meniscectomy groups had similar values for KOOS overall and subscales ($p$ >.05). Both groups were assessed at similar time points ($p$ =.47) following surgery ranging between 3 to 12 months for the medial meniscectomy group and 3 to 11 months for the lateral meniscectomy group.

**Table 1**
Participant characteristics (means (SD)).

| | Medial (n = 12) | Lateral (n = 16) | *p* values | *g* |
|---|---|---|---|---|
| Sex, male/female (n) | 7/5 | 12/4 | | |
| Age (years) | 31.1 ± 6.7 | 28.6 ± 6.4 | 0.319 | 0.38 |
| Height (cm) | 174.2 ± 10.0 | 176.3 ± 8.1 | 0.548 | 0.23 |
| Mass (kg) | 77.8 ± 14.3 | 85.1 ± 13.0 | 0.175 | 0.52 |
| Time since surgery (months) | 6.3 ± 3.4 | 5.5 ± 2.7 | 0.472 | 0.27 |
| KOOS | 71.3 ± 15.5 | 65.5 ± 18.1 | 0.389 | 0.33 |
| Pain | 78.0 ± 13.6 | 73.2 ± 17.1 | 0.445 | 0.30 |
| Symptoms | 67.5 ± 22.9 | 62.3 ± 19.4 | 0.527 | 0.24 |
| Activities of daily living | 88.9 ± 13.2 | 83.7 ± 13.7 | 0.339 | 0.37 |
| Sports and recreation | 70.5 ± 22.3 | 58.4 ± 23.0 | 0.189 | 0.51 |
| Quality of life | 51.7 ± 19.0 | 49.6 ± 26.2 | 0.822 | 0.09 |

### *3.2. Walking*

Table 2 presents outcome variables for both medial and lateral meniscectomy groups during walking. No significant ($p$ >.05) differences in spatiotemporal outcomes were observed between groups with small to medium effect sizes. Walking speed was similar between groups ranging between 1.3 to 1.8 m/s and 1.2 to 1.7 m/s for the medial and lateral meniscectomy groups respectively. No differences in knee kinematic outcomes between groups were reported ($p$ >.05). Both medial and lateral meniscectomy groups presented with similar ($p$ >.05) knee joint kinetic outcomes during walking with negligible to small effect sizes. Similarities between groups in kinematic and kinetic curves during stance phase when walking can be observed in Figure 2.

### *3.3. Running*

No significant ($p$ >.05) differences in spatiotemporal outcomes were observed between both meniscectomy groups with negligible to small effect sizes (Table 3). Running speeds were similar between groups (Table 3). No differences ($p$ >.05) in knee kinematics were reported between groups. Both medial and lateral meniscectomy groups presented with similar ($p$ >.05) knee joint kinetic outcomes during running with negligible to small effect sizes. Similarities between groups in kinematic and kinetic curves during the stance phase when running can be observed in Figure 3.

## 4. Discussion

We hypothesised that knee loading would differ between medial and lateral meniscectomies. Despite previous studies reporting differences between outcomes following medial and lateral meniscectomies including; time to RTS, re-surgery rates, adverse events occurrences and long-term degenerative changes [3–13,9,15], this study did not find differences between medial and lateral meniscectomy groups.

No differences were found between the lateral meniscectomy group and medial meniscectomy group for frontal and sagittal knee joint moments during walking and running. Despite known differences long-term degenerative changes

**Table 2**
Mean (SD) spatiotemporal outcomes and knee kinematic and kinetic outcomes during walking for both medial and lateral meniscectomy groups.

| | Medial | Lateral | Mean difference (CI 95%) | *p* values | *g* |
|---|---|---|---|---|---|
| *Spatiotemporal outcomes* | | | | | |
| Walking speed (m/s) | 1.5 ± 0.2 | 1.4 ± 0.1 | 0.1 (0.0 to 0.2) | 0.184 | 0.51 |
| Stride length (m) | 1.5 ± 0.1 | 1.5 ± 0.2 | 0.1 (-0.1 to 0.2) | 0.492 | 0.26 |
| Stride width (m) | 0.1 ± 0.0 | 0.1 ± 0.0 | 0.0 (0.0 to 0.0) | 0.168 | 0.53 |
| Cadence (steps/min) | 114.9 ± 5.8 | 110.2 ± 8.8 | 2.9 (-1.4 to 10.7) | 0.124 | 0.59 |
| *Knee joint kinematics* | | | | | |
| Knee flexion at initial contact (°) | −0.8 ± 4.9 | 0.2 ± 4.8 | −0.9 (-4.7 to 2.9) | 0.616 | 0.19 |
| Peak knee flexion (°) | 16.2 ± 7.4 | 15.0 ± 6.2 | 1.1 (-4.2 to 6.4) | 0.670 | 0.16 |
| Peak knee adduction (°) | 1.5 ± 3.7 | 1.1 ± 4.4 | 0.3 (-2.9 to 3.6) | 0.844 | 0.07 |
| Peak knee internal rotation (°) | −26.6 ± 8.0 | −26.6 ± 10.1 | −0.1 (-7.3 to 7.2) | 0.989 | 0.01 |
| *Knee joint kinetics* | | | | | |
| Peak knee flexion moment (N.m/[BW × Height]%) | 2.7 ± 1.1 | 2.3 ± 1.2 | 0.3 (-0.5 to 1.2) | 0.428 | 0.30 |
| Peak early stance knee adduction moment (N.m/[BW × Height]%) | 2.5 ± 0.6 | 2.3 ± 1.0 | 0.2 (-0.5 to 0.9) | 0.592 | 0.20 |
| Peak late stance knee adduction moment (N.m/[BW × Height]%) | 1.6 ± 0.5 | 1.8 ± 1.0 | −0.2 (-0.8 to 0.5) | 0.577 | 0.21 |
| Peak knee external rotation moment (N.m/[BW × Height]%) | 0.8 ± 0.4 | 0.6 ± 0.3 | 0.1 (-0.1 to 0.4) | 0.310 | 0.39 |
| Peak knee internal rotation moment (N.m/[BW × Height]%) | −0.8 ± 0.3 | −0.8 ± 0.2 | −0.0 (-0.2 to 0.2) | 0.768 | 0.11 |
| Knee adduction angular impulse (N.m.s/[BW × Height]%) | 0.7 ± 0.2 | 0.8 ± 0.4 | −0.1 (-0.3 to 0.2) | 0.540 | 0.23 |

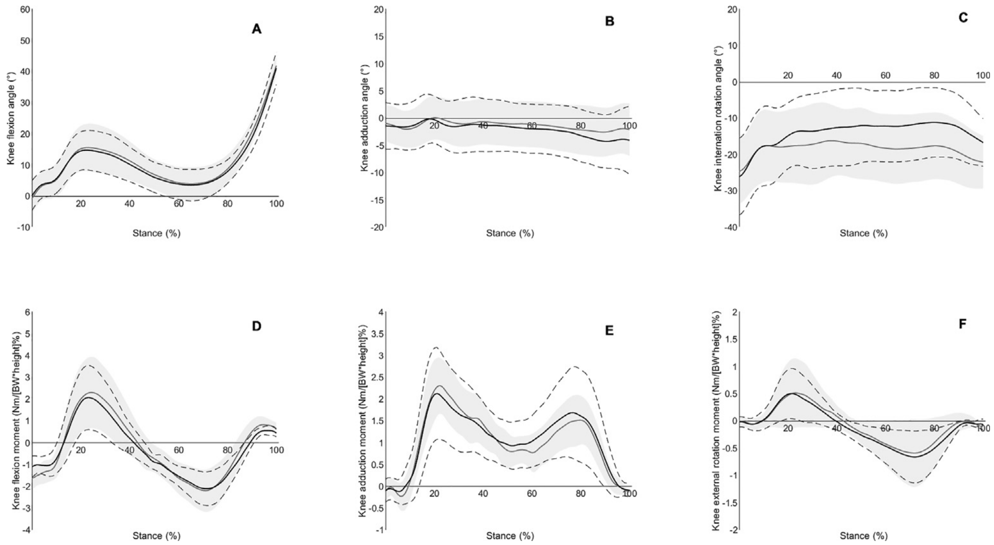


**Figure 2.** Ensemble mean (SD) for (A) knee flexion angle, (B) knee adduction angle, (C) knee internal rotation angle, (D) knee flexion moment, (E) knee adduction moment, (F) knee external rotation moment during walking for the medial meniscectomy group (grey, with shaded SD), and lateral meniscectomy group (black with dashed SD).

**Table 3**
Mean (SD) spatiotemporal outcomes and knee kinematic and kinetic outcomes during running for both medial and lateral meniscectomy groups.

| | Medial | Lateral | Mean difference (CI 95%) | *p* values | *g* |
|---|---|---|---|---|---|
| *Spatiotemporal outcomes* | | | | | |
| Running speed (m/s) | 3.6 ± 0.5 | 3.7 ± 0.8 | −1.0 (-4.7 to 2.7) | 0.944 | 0.03 |
| Stride length (m) | 2.5 ± 0.4 | 2.6 ± 0.4 | 1.2 (-3.4 to 5.7) | 0.953 | 0.02 |
| Stride width (cm) | 8.2 ± 3.3 | 9.4 ± 3.2 | 0.2 (-3.4 to 3.7) | 0.374 | 0.32 |
| Stance time (ms) | 228.7 ± 22.5 | 241.3 ± 44.8 | 0.5 (-1.9 to 2.9) | 0.382 | 0.32 |
| Cycle time (ms) | 698.8 ± 19.1 | 710.4 ± 47.0 | −0.2 (-1.7 to 1.4) | 0.382 | 0.29 |
| Cadence, (steps/min) | 171.6 ± 6.4 | 169.1 ± 12.5 | 0.0 (-0.2 to 0.2) | 0.528 | 0.23 |
| *Knee joint kinematics* | | | | | |
| Knee flexion at initial contact (°) | 7.7 ± 5.5 | 8.7 ± 3.0 | 0.0 (-0.5 to 0.5) | 0.588 | 0.22 |
| Peak knee flexion (°) | 35.3 ± 4.3 | 34.2 ± 7.2 | 0.0 (-0.3 to 0.3) | 0.602 | 0.18 |
| Peak knee adduction (°) | 0.3 ± 4.2 | 0.2 ± 4.7 | 0.0 (0.0 to 0.0) | 0.931 | 0.03 |
| Peak knee internal rotation (°) | −24.9 ± 10.6 | −22.3 ± 10.0 | −2.6 (-10.7 to 5.4) | 0.511 | 0.25 |
| *Knee joint kinetics* | | | | | |
| Peak knee flexion moment (N.m/[BW × Height]%) | 9.8 ± 1.7 | 9.3 ± 4.1 | 0.0 (0.0 to 0.0) | 0.705 | 0.14 |
| Peak early stance knee adduction moment (N.m/[BW × Height]%) | 3.3 ± 1.7 | 3.4 ± 2.1 | 0.0 (0.0 to 0.0) | 0.828 | 0.08 |
| Peak late stance knee adduction moment (N.m/[BW × Height]%) | 0.3 ± 0.2 | 0.3 ± 0.3 | 2.5 (-5.6 to 10.7) | 0.731 | 0.13 |
| Peak knee external rotation moment (N.m/[BW × Height]%) | 1.6 ± 0.8 | 1.7 (0.9) | −0.1 (-0.8 to 0.5) | 0.666 | 0.17 |

following a medial and lateral meniscectomy and the associated difference in frontal and sagittal knee joint moments our findings suggest differences in knee joint moments may not be apparent in the short-term following a meniscectomy. Although we did not measure pain, swelling or number of adverse events, both groups reported similar scores across all domains of KOOS. For this study, the time of collection for both groups were similar, with a mean time 24.7 weeks post-surgery. Although participant in this study had RTS, individuals continued to demonstrate poor perceived knee function evidenced by the low KOOS scores when compared to previous studies [21,22]. The lack of differences in knee loading could be due to the lack of differences in perceived knee function between groups and suggest similar movement patterns despite the location of surgery. Further data is required to understand the potential differences in knee loading between medial and lateral meniscectomies in the long-term as perceive knee function improves.

To our knowledge, this is the first study to compare biomechanical outcomes between medial and lateral meniscectomies to better understand the differences observed in future clinical and radiographical outcomes. Our study reported no differences between groups during walking and running when assessed within a year post-surgery. However, biomechanical changes in the knee could become more apparent over a longer time frame. Hall et al. [21,22] reported KAM and KFM increased further over 2 years when compared to short-term knee loading (3 months) during walking and jogging following a medial meniscectomy. Therefore, knee loading in individuals who had either a medial or lateral meniscectomy could diverge over time but in the short-term they exhibited similar strategies when walking or running. Future research should

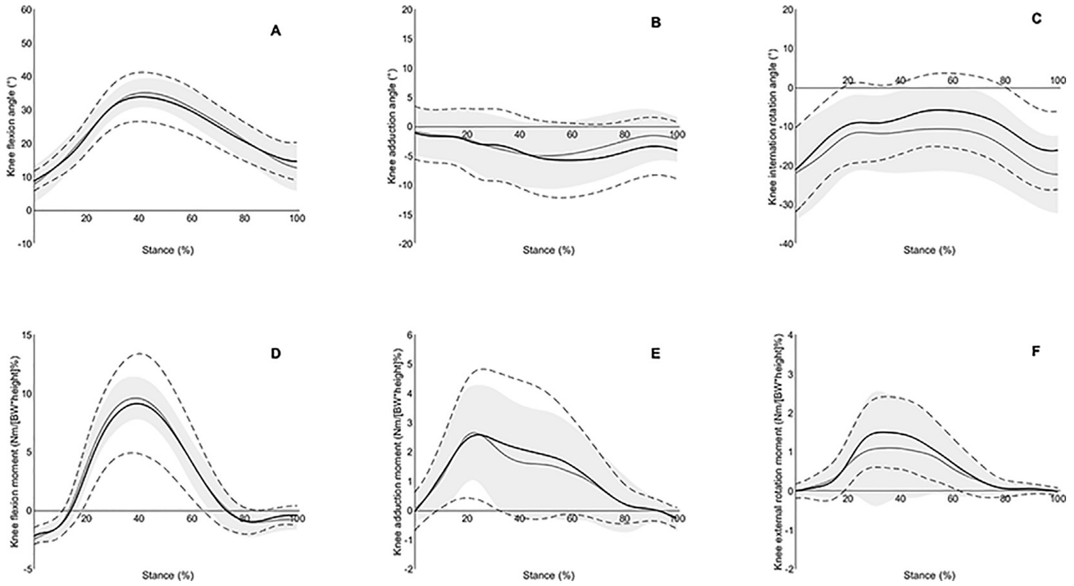


**Figure 3.** Ensemble mean (SD) for (A) knee flexion angle, (B) knee adduction angle, (C) knee internal rotation angle, (D) knee flexion moment, (E) knee adduction moment, (F) knee external rotation moment during running for the medial meniscectomy group (grey, with shaded SD), and lateral meniscectomy group (black with dashed SD).

explore differences in the progression of knee loading prospectively between individuals who had medial and lateral meniscectomy over a longer duration post-surgery to better understand the progression of knee OA in these individuals.

As with any study, we must consider the limitations that may have influenced our findings. Firstly, a relatively low sample size particularly for the medial meniscectomy group reduces the statistical power of this study increasing risk of type II error. This study provides preliminary data in comparing knee joint loading between medial and lateral meniscectomies; however, future studies are needed. We grouped individuals based on isolated meniscectomy location i.e. lateral or medial, however, we did not account for injury type, location within the lateral or medial meniscus or size of the removed meniscus which could have implications on knee loading patterns [3–12]. Recovery from meniscectomy is dependent on age [5], activity level [5], type of tear (e.g. vertical or radial) [4], proximity to the peripheral aspect of the meniscus [4] (affecting the available blood supply to aid in healing [1]) and size of meniscus removed [4,5,37]. Not controlling for these parameters could affect our outcomes by increasing heterogeneity in our sample but importantly it does allow for generalisable findings. The movements assessed in this study were reflective of movements performed in the early rehabilitation phase post-surgery, however, they do not reflect the complex sport-specific movements and therefore the knee loading experienced by individuals once they return to sport. Therefore, future studies should explore knee loading in more dynamic sport-specific movements.

## 5. Conclusions

Frontal and sagittal knee loading did not differ between individuals who had a medial meniscectomy with those who had a lateral meniscectomy. It is unclear whether knee loading diverges over a longer period which could explain long-term radiographical differences between medial and lateral meniscectomy. Therefore, future work is needed to explore knee loading following a meniscectomy as time progresses.

## Ethical approval

REC reference 18/EE/0015, IRAS: 239,135.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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