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# Forward lunge knee biomechanics before and after partial meniscectomy

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ABSTRACT

*Background:* Patients following meniscectomy are at increased risk of developing knee osteoarthritis in the tibiofemoral compartment and at the patellofemoral joint. As osteoarthritis is widely considered a mechanical disease, it is important to understand the potential effect of arthroscopic partial meniscectomy (APM) on knee joint mechanics. The purpose of this study was to evaluate changes in knee joint biomechanics during a forward lunge in patients with a suspected degenerative meniscal tear from before to three months after APM.
*Methods:* Twenty-two patients (35–55 years old) with a suspected degenerative medial meniscal tear participated in this study. Three dimensional knee biomechanics were assessed on the injured and contralateral leg before and three months after APM. The visual analogue scale was used to assess knee pain and the Knee Injury Osteoarthritis Outcome Score was used to assess sport/recreation function and knee-related confidence before and after APM.
*Results:* The external peak knee flexion moment reduced in the APM leg compared to the contralateral leg (mean difference (95% CI)) −1.08 (−1.80 to −0.35) (Nm/(BW × HT)%), $p = 0.004$. Peak knee flexion angle also reduced in the APM leg compared to the contralateral leg −3.94 (−6.27 to −1.60) degrees, $p = 0.001$. There was no change in knee pain between the APM leg and contralateral leg ($p = 0.118$). Self-reported sport/recreation function improved ($p = 0.004$).
*Conclusions:* Although patients self-reported less difficulty during strenuous tasks following APM, patients used less knee flexion, a strategy that may limit excessive patellar loads during forward lunge in the recently operated leg.



## 1. Introduction

Osteoarthritis is a common disease that is considered by the World Health Organisation as one of the ten leading causes of disease burden in high-income countries [1]. The knee joint is the most commonly affected lower limb joint [2]. A meniscal tear is a potent risk factor to develop knee osteoarthritis [3] and both the patellofemoral and medial tibiofemoral compartments are commonly affected by osteoarthritis following meniscectomy [4]. Degenerative tears in middle-aged adults are associated with greater risk of knee osteoarthritis than traumatic meniscal tears in younger individuals [3]. Following the removal of meniscus tissue, studies have reported a decrease in articulating contact area and an increase in contact stress [5,6]. As knee osteoarthritis is considered at least in part, a mechanically driven disease where higher abnormally distributed forces are thought to play a role [7], it is important to discern the effect of arthroscopic partial meniscectomy (APM) on knee joint biomechanics.

The forward lunge is a challenging, functional exercise, which couples eccentric contractions and concentric contractions (also known as stretch-shortening cycle). This is pertinent as eccentric contractions typically precede concentric contractions, in the majority of daily living activities (e.g. stepping, walking) [8]. The forward lunge is also commonly used in rehabilitation programmes to improve physical function and knee muscle strength. Self-reported difficulty with strenuous tasks and knee muscle weakness has been described in people with degenerative meniscal tears pre-operatively [9] and within three months post-operatively [10,11]. Understanding the effect of a meniscal tear and subsequent APM on knee biomechanics during a task commonly prescribed as a rehabilitation exercise to improve muscle strength and physical function is warranted.

Studies investigating the squat and forward lunge have reported increased patellar contact force and stress with increased knee flexion angle [12,13] and medial tibiofemoral joint contact force is influenced by the external knee flexion moment during gait [14]. Furthermore, a higher external knee adduction moment during gait relates to knee

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pain onset [15] and disease progression in people with established knee osteoarthritis [16,17]. Aberrant knee mechanics have been reported before and after APM [18], albeit inconsistently [19]. In particular, the knee flexion moment is reportedly reduced compared to healthy controls during gait before and six months after APM [18]. However, these few studies are limited by the lack of discrete measures and heterogeneous samples. As such, it remains largely unknown if altered knee joint mechanics are present pre-operatively, and importantly if these measures alter as a potential consequence of APM in middle-aged individuals with degenerative meniscal tears at high risk of knee osteoarthritis.

The aim of this exploratory study was to compare changes in knee joint biomechanics from before to after APM between the injured and contralateral leg during a forward lunge. We hypothesized that knee joint biomechanics would alter in the injured leg compared to the contralateral leg as a potential result of APM.

## 2. Materials and methods

### 2.1. Patients

Individuals with a medial degenerative meniscal tear eligible for APM were recruited from Odense University Hospital, Odense, Denmark and Lillebaelt Hospital, Kolding, Denmark and Orthopedic Clinic Fyn, Odense, Denmark. Patients were considered to have a degenerative meniscal tear based on age (35–55 years) and how their knee pain developed. Patients were asked 'how did the knee pain/problems for which you are now having surgery develop?' and provided with the following options: a) the pain/problem evolved slowly over time; b) as a result of a specific non-violent incident (i.e., kneeling, sliding and/or twisting or similar); and c) as a result of a violent incident (i.e., during sports, a crash or similar). Patients who responded either a) or b) were considered to have a degenerative meniscal tear and were eligible. Exclusion criteria included: previous knee surgery, injuries/problems limiting physical activity within the last 30 days, very low activity level (e.g. walking restricted to indoors only), and radiographic osteoarthritis defined as Kellgren–Lawrence grade 2 or above [20]. Ethical approval was provided by the Regional Scientific Ethics Committee of Southern Denmark (ID: S-20120006). Patients provided written informed consent.

### 2.2. Forward lunge analysis

Patients were assessed before (~2 weeks) and after (~12 weeks) APM. Kinematic (100 Hz) and ground reaction force data (1000 Hz) were synchronously collected using a 6 MX03-camera motion analysis system (Vicon, Oxford, UK), one force plate (AMTI 0R6-7 Series Inc., Watertown, MA, USA) and a standard plug-in-gait marker set [21,22]. Following standardised instruction and familiarisation, patients performed a forward lunge equivalent to their leg length [23]. Patients were instructed to perform a forward lunge onto the force plate whilst barefoot, with the aim to flex the leading knee to 90° and return to a standing position. Patients were asked to maintain their trunk in an upright position during the forward lunge and ensure the contralateral leg maintained floor contact throughout the duration of the lunge. With the order of leading leg randomised, patients were instructed to perform three trials in a smooth motion, for each leg, at a self-selected speed. We considered the use of self-selected lunge speed appropriate as patients were undergoing surgery.

In accordance with Thorlund et al. [23], stance was defined as the period from foot strike to toe-off and the loading phase was defined from foot strike to 80% of the peak ground reaction force (Fig. 1). Kinematic data were filtered using a Woltring filter (mean square error of 15 $mm^2$) and ground reaction force data were filtered using a 40 Hz low-pass fourth order zero lag filter. External knee moments and impulse were calculated using inverse dynamics (Vicon Plug-In-Gait; Vicon) and were normalised to the product of body weight (N) and body height (m). Loading rate was defined as the rate of change of vertical ground reaction force during loading and was normalised to body weight (N). Biomechanical dependent variables included: knee adduction moment (peak during stance and impulse during loading), peak knee flexion moment (during stance), peak loading rate, and knee flexion angle (peak during stance and excursion during loading).

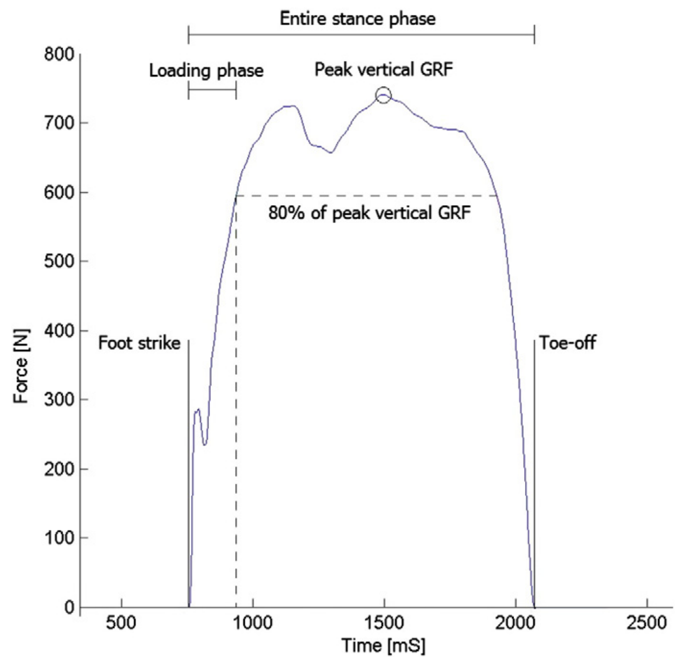


**Fig. 1.** Representative vertical ground reaction force curve for one patient illustrating the loading phase (defined from foot strike to 80% of vertical ground reaction force) and entire stance phase.

### 2.3. Self-reported measures

Before testing, patients scored their knee pain in both the injured and contralateral leg on a 100 mm visual analogue scale (VAS) with terminal anchors of 'no pain' and 'worst pain possible' [24]. Patients completed the Knee Injury Osteoarthritis Outcome Score (KOOS) item, 'how troubled are you with the lack of confidence in your knee' in the quality of life subscale and the KOOS sport and recreation subscale to determine knee-related confidence and difficulties with strenuous tasks [25] before and after APM.

### 2.4. Statistics

Paired t-tests and Wilcoxon signed rank tests were used to compare biomechanical dependent variables preoperatively between the injured and contralateral leg as appropriate. Change scores were calculated for the dependent variables by subtracting the pre-operative scores from post-operative scores. In the event where change scores did not conform to the Gaussian distribution, data were squared and log-transformed prior to analysis. A mixed linear model was used to evaluate the difference in the change scores between legs with 'participant' entered as a random effect and 'leg' (i.e., injured and contralateral leg) as a fixed effect in the model. Paired t-tests were used to compare VAS pain between the APM leg and contralateral leg before and after APM, and also to compare the change between legs from before to after surgery. A chi squared test and a Wilcoxon signed rank test were used to compare knee confidence and self-reported function before and after APM, respectively. Stata 13.1 (Statacorp, College Station, TX, USA) was used for statistical analyses and significance was set $p < 0.05$.