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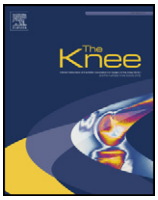

Knee joint laxity and passive stiffness in meniscectomized patients compared with healthy controls

Jonas B. Thorlund [a,*], Mark W. Creaby [b], Tim V. Wrigley [c], Ben R. Metcalf [c], Kim L. Bennell [c]

[a] Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Odense, Denmark
[b] School of Exercise Science, Australian Catholic University, Brisbane, Queensland, Australia
[c] Centre for Health Exercise and Sports Medicine, School of Physiotherapy, University of Melbourne, Melbourne, Victoria, Australia

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ABSTRACT

Background: Passive mechanical behavior of the knee in the frontal plane, measured as angular laxity and mechanical stiffness, may play an important role in the pathogenesis of knee osteoarthritis (OA). Little is known about knee laxity and stiffness prior to knee OA onset. We investigated knee joint angular laxity and passive stiffness in meniscectomized patients at high risk of knee OA compared with healthy controls.
Methods: Sixty patients meniscectomized for a medial meniscal tear (52 men, 41.4 ± 5.5 years, 175.3 ± 7.9 cm, 83.6 ± 12.8 kg, mean ± SD) and 21 healthy controls (18 men, 42.0 ± 6.7 years, 176.8 ± 5.7 cm, 77.8 ± 13.4 kg) had their knee joint angular laxity and passive stiffness assessed twice ~2.3 years apart. Linear regression models including age, sex, height and body mass as covariates in the adjusted model were used to assess differences between groups.
Results: Greater knee joint varus (-10.1 vs. $-7.3°$, $p < 0.001$), valgus (7.1 vs. 5.6°, $p = 0.001$) and total (17.2 vs. 12.9°, $p < 0.001$) angular laxity together with reduced midrange passive stiffness (1.71 vs. 2.36 Nm/°, $p < 0.001$) were observed in patients vs. healthy controls. No differences were observed in change in stiffness over time between patients and controls, however a tendency towards increased laxity in patients was seen.
Conclusions: Meniscectomized patients showed increased knee joint angular laxity and reduced passive stiffness ~3 months post surgery compared with controls. In addition, the results indicated that knee joint laxity may increase over time in meniscectomized patients.

1. Introduction

Mechanical factors play an important role in the pathogenesis of knee osteoarthritis (OA) [1,2]. One mechanical factor suggested to affect both onset and progression of OA as well as physical function is frontal plane laxity [2]. Frontal plane laxity refers to the behavior of the knee joint during passive varus–valgus rotation. Increased laxity may adversely affect knee joint mechanics, such as knee joint loading [3], and may contribute to OA onset and progression [4,5]. Laxity is typically measured as total varus–valgus angular motion when a specific torque is applied. The evidence regarding altered angular varus–valgus laxity of the OA knee using this approach, is however, inconsistent, with one large study finding of increased laxity with OA [6], and another no difference [7]. Studies with fewer participants investigating angular varus–valgus knee laxity are similarly inconsistent [8–10]. An alternative approach to quantify the passive mechanical behavior of the knee in the frontal plane, is to quantify the mechanical stiffness of the joint during varus–valgus rotation. Mechanical joint stiffness refers to the movement occurring at the joint in response to a given load. Previous reports indicate that varus–valgus stiffness is lower in women than men, and may contribute to the increased risk of anterior cruciate ligament injury (ACL) in women [11]. This measure has also been reported in those with knee OA, with reduced frontal plane stiffness reported in the midrange of the range of motion in comparison to controls [7]. This indicates that knee OA patients have less rotational support from the passive joint structures within the functionally important range of motion [7]. However, it is not known if increased laxity and reduced passive stiffness also precede the onset of OA.

Previous knee injury is considered a major risk factor for knee OA [12,13]. Most studies investigating knee joint laxity after knee surgery have investigated ACL reconstructed patients, showing increased laxity [14] and altered knee joint mechanics [15]. Less is known about these in patients with a prior meniscectomy, a group at particularly high risk of knee OA [16–18]. Studies have shown

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* Corresponding author at: Department of Sports Science and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark. Tel.: +45 6550 3894.
E-mail address: jthorlund@health.sdu.dk (J.B. Thorlund).

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that total vs. partial meniscectomy causes more instability (assessed by the Lysholm score [19]) 8 years after surgery [20]. Furthermore, anterior–posterior (AP) laxity has been reported to be increased following resection of large parts of the meniscus (i.e. more than 46%) in cadavers [21] and destabilization of the meniscus in mice [22]. However, in relation to medial compartment tibiofemoral knee OA, frontal plane laxity and/or stiffness may be of greater functional relevance and contribute to impaired knee joint mechanics, which in turn may be one of the factors in the series of events leading to knee OA in this sub-group of patients. To our knowledge, no studies have investigated in vivo varus–valgus laxity and passive knee joint stiffness using a standardized measure in meniscectomized patients at high risk of knee OA compared with controls.

The aim of this study was to investigate varus, valgus, and total angular laxity together with varus, valgus and midrange stiffness in meniscectomized patients compared with a healthy control group. We hypothesized that meniscectomized patients would display increased knee joint laxity and reduced passive stiffness compared with controls. A secondary aim of this study was to investigate if potential changes in knee joint laxity and passive stiffness over time differed between meniscectomized patients and controls.

2. Materials and methods

2.1. Participants

Participants in the present study are a sub-group of patients previously described in other cross-sectional studies focusing on magnetic resonance imaging (MRI) [23,24] and one longitudinal study [25]. This sub-group consisted of those patients and controls that had knee joint laxity and passive stiffness assessed. Sixty patients (30–55 years) who had an arthroscopic partial meniscectomy for a medial meniscal tear were identified through their surgical billing codes from orthopedic clinics in Melbourne, Australia [24]. Patients were excluded if they had: evidence of lateral meniscus resection; >33% of medial meniscus resected; >2 tibiofemoral cartilage lesions; tibiofemoral cartilage lesion(s) >10 mm in diameter or less than 50% of cartilage thickness (i.e. > International Cartilage Repair Society (ICRS) grade 2a cartilage lesion); previous knee or lower limb injury (other than current meniscectomy); history of knee pain (other than leading to meniscectomy); post-operative complications; cardiac, circulatory or neuromuscular conditions; diabetes; stroke; multiple sclerosis and contraindication to MRI.

Asymptomatic, healthy controls (30–55 years) were recruited from the local community and screened for the following exclusion criteria: current knee pain; any previous lower limb bone or joint injury; cardiac, circulatory or neuromuscular condition; diabetes; stroke; multiple sclerosis and contraindication to MRI. In the present study all patients and healthy controls that had full datasets available on knee joint laxity and passive stiffness at the baseline and follow-up assessments were included.

The operated knee was deemed the study knee for the meniscectomized participants. A randomly selected knee was deemed the study knee for the asymptomatic controls. In the meniscectomized patients, assessments were performed at 0.27 years ± 0.04 years post surgery, and 2.48 years ± 0.22 years post surgery. Control participants also completed assessments on two occasions, 2.25 years ± 0.17 years apart. Standing height and body mass were measured at baseline with a stadiometer and standard weighing scales, respectively. The University of Melbourne Human Research Ethics Committee approved the research. All participants provided written informed consent.

2.2. Varus–valgus knee joint laxity

Laxity was assessed using the Kin-Com 125-AP dynamometer (Chattecx Corp., Chattanooga, TN, USA) with customized modifications as described previously [7]. Participants were seated with the knee relaxed and flexed at 20° [6,26], the ankle secured in a 90° fixed flexion ankle-foot orthosis to a load cell on the horizontal lever arm of the dynamometer, and the tibiofemoral joint directly above, and intersected by, the lever arm axis of rotation. In this gravity-neutral position, the leg was moved passively by the dynamometer 10 times from varus to valgus at 5° per second and results were obtained as an average from these 10 movements. Varus and valgus angles were determined at the points where 12 Nm of passive resistance was reached [6].

The analog force and lever arm angle were sampled directly from the Kin-Com at 100 Hz by 16-bit analog-to-digital conversion (Micro 1401, Cambridge Electronic Design, UK) to a computer using Spike2 software (Cambridge Electronic Design, UK). Joint torque (Nm) was computed as the product of the force (Newtons) recorded at the ankle and the lever arm (meters; measured from the axis of rotation at the knee to the force transducer at the ankle). In contrast to other methods which do not record force continuously [6,9,26], a neutral lever arm angle could be identified at zero force, and on this basis, varus and valgus ranges were separated from the total lever arm angle data. Stiffness was defined as the change in joint torque divided by change in joint angle (Nm/°). End-range varus and valgus stiffness was calculated over the last 25% of the range moving in a varus and valgus direction, respectively (Fig. 1). Mid varus–valgus (VV) range stiffness was calculated from the averaged varus and valgus movements over a 2° window, 1° either side of mechanical neutral. Intra-rater reliability of the angular laxity and stiffness measures were excellent when measured a week apart in 10 people with medial tibiofemoral OA ($ICC_{2,1} = 0.87$ to 0.97).

2.3. Statistical analysis

Data were analyzed using the STATA Version 11.2 (Statacorp, College Station, TX, USA). Data were checked for normality prior to analyses. Differences in demographics and gender distributions between groups were evaluated with an independent *t*-test and chi-square test, respectively. Differences in baseline angular laxity and stiffness between groups were evaluated using linear regression analysis. An adjusted linear regression analysis including age, sex, height and body mass as covariates was also performed. Age and sex have previously been reported to have effect on the mechanical properties of tendons and ligaments [27–29] and a recent report showed that laxity indices were correlated with both body mass and height [7]. To account for the slight variation in follow-up times, change in angular laxity and stiffness were expressed as annualized change over time. Differences between groups were evaluated using linear regression models adjusted for baseline values. In addition, baseline age, sex, height and body mass were entered in the fully adjusted model as covariates. An a priori alpha level of 0.05 was set for all analyses. This was a secondary analysis of data from a longitudinal cohort study, and thus an a priori sample size calculation was not performed.

3. Results

No differences were observed in the ratio of male/females, age or height between patients and controls at baseline. However, patients were heavier and had higher body mass indices (BMIs) than controls (Table 1).

3.1. Knee joint laxity and passive stiffness at baseline

Meniscectomized patients displayed greater knee joint laxity in the varus and valgus directions separately, as well as in total laxity at baseline in both the unadjusted and adjusted models (Table 2). In addition, passive knee joint stiffness was reduced in the mid VV range of range of motion compared with controls. Unadjusted varus and valgus stiffness did not reach statistically significant differences in the unadjusted model, however after adjusting for covariates varus stiffness was lesser in the patient group compared with that in controls and a borderline significant difference was observed in valgus stiffness (Table 2).