total hip arthroplasty (THA) and quantify the relationship between hip pain, weakness and biomechanical variables.

Methods: Subjects between 50 and 85 who were scheduled for THA were recruited for this study. Hip abductor muscle strength was operationally defined as the amount of force exerted during an isometric hip abduction contraction. Hip pain for the affected and unaffected limbs were measured on a numerical scale from 0-10 where the subject responded to the question “Rate your average pain over the past week from 0 to 10, where 0 is no pain and 10 is the worst imaginable pain.” Hip range of motion (ROM) was the total ROM from the Harris Hip Score. Three-dimensional motion analysis was used to quantify joint angles and joint moments during walking at self-selected speed. Peak hip adduction angle, peak external adduction moment, peak trunk angle and contralateral pelvic motion were assessed throughout the stance phase of gait for the affected and unaffected sides. Positive trunk angles were indicative of trunk lean towards the stance limb and negative trunk lean angles were indicative of trunk lean towards the swing limb. Pelvic motion was measured in the vertical direction using the iliac crest marker on the unaffected side during stance on the affected limb, and was measured on the affected side during stance on the unaffected in order to quantify pelvic drop on the side contralateral to the stance limb. Pelvic position was quantified as 1) vertical position of the iliac crest at initial contact and 2) the average slope of iliac crest height from the time of initial contact to maximal value. Because the height of the iliac crest is expected to rise during midstance as the knee and hip extend (the center of the mass becomes more superior as the limb functionally lengthens towards midstance), the slope of the line conveys information about the rate of rise of the iliac crest. A lower slope indicates that the iliac crest may be dropping during contralateral stance relative to the functional length of the stance limb. That is to say, even though the center of mass of the body is elevating, the iliac crest is doing so at a slower rate than the rest of the trunk and pelvis. Comparisons between sides were made using paired-samples t-tests and Pearson correlations were performed to determine the relationship between clinical impairments and biomechanics.

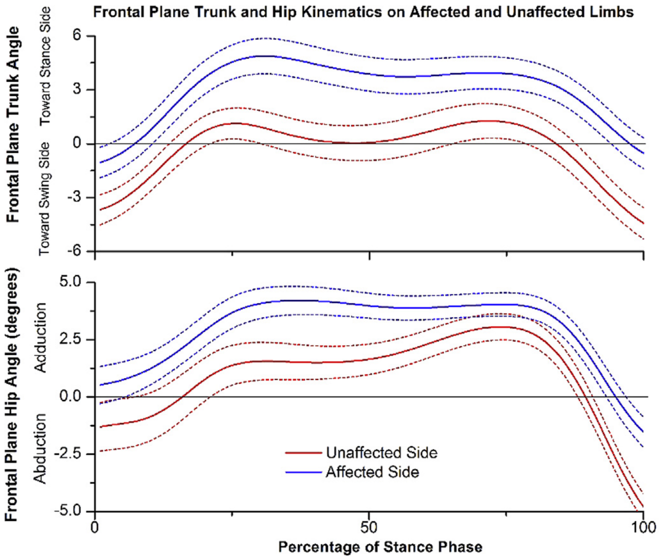
Results: Patients had significantly lower strength and greater pain on the affected side (Table 1). The affected limb had greater peak hip adduction angle during stance and greater trunk lean towards the stance side (Table 1, Figure 1). There was a trend towards greater pelvic drop at initial contact (lower iliac crest height on the contralateral side) and there was a significantly lower rate of rise of the contralateral iliac crest throughout the stance phase (slope of iliac crest) (Table 1; Figure 2). Less hip strength was nearly correlated with greater trunk lean ($r = -0.336$; $p = 0.052$) and greater pain ($r = -0.324$; $p = 0.061$). Pain was not related to any biomechanical variable.

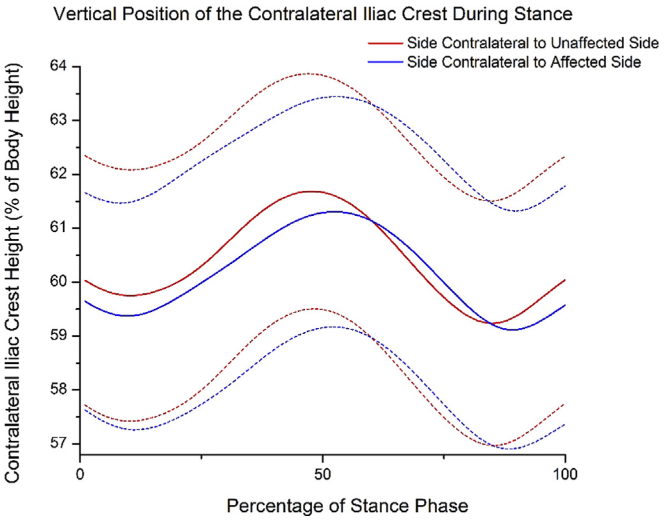
Conclusions: Excessive trunk sway towards the affected side is often cited as a method to reduce joint contact force and compensate for weak hip abductors. Our results showed no change in the hip adduction moment, but subjects did display gait patterns typified by excessive trunk lean toward the affected side and greater pelvic drop on the contralateral side. Weakness of the hip abductors may contribute to excessive trunk lean.

Table 1
Biomechanical and clinical measures for the affected and unaffected limbs

	Affected side	Unaffected side	*P*-value
Pain (0-10)	5.8 (2.6)	0.6 (1.5)	<0.001
Strength (N/kg)	0.43 (0.24)	0.58 (0.26)	<0.001
Peak hip adduction angle (degrees)	5.0 (4.7)	2.3 (3.1)	0.006
Peak hip adduction moment (Nm/kg*ht)	0.76 (0.21)	0.81 (0.15)	0.277
Peak trunk angle (degrees)	5.7 (3.5)	2.5 (3.3)	0.005
Iliac crest height at initial contact (% height)*	59.80 (2.2)	60 (2.3)	0.092
Slope of iliac crest (% height/% stance cycle)(x10-2)**	4.8 (1.4)	5.6 (1.5)	0.002

*Represents height of the contralateral iliac crest as a measure of pelvic drop; **Slope of the contralateral iliac crest.





148

PRE-OPERATIVE PREDICTORS OF CONTRALATERAL TKA FOLLOWING UNILATERAL TKA

P. Flowers, J. Zeni, L. Snyder-Mackler. *Univ. of Delaware, Newark, DE, USA*

Introduction: To identify biomechanical and clinical predictors of future contralateral TKA in persons who underwent unilateral TKA at baseline. We hypothesize that strength, pain, self-reported joint function, and peak knee flexion and adduction moments in both limbs will be predictors of contralateral TKA.

Methods: Subjects who underwent unilateral TKA for osteoarthritis (OA) were evaluated and grouped according to contralateral TKA status (Had a contralateral TKA within 2.5 years vs. Did not have a contralateral TKA within 2.5 years). Initial data collections were performed on subjects :6mos, 1yr, and :2yrs after TKA. Subjects were followed-up at least 2.5 years after initial surgery to determine incidence of contralateral TKA. Patient-reported outcomes of joint function and pain were assessed for each knee (Knee Outcomes Survey-Activities of Daily Living (KOS-ADLS), KOS-pain subscale). Quadriceps strength was assessed as a maximal voluntary isometric contraction, normalized to BMI. Active knee extension range of motion (AROMe) was measured using a long arm goniometer. Knee flexion moments at peak knee flexion (KFM at PKF) and peak knee adduction moments (PKAM) were analyzed. Hierarchical logistical regression models were used to determine which of these factors predicted contralateral TKA. Two-by-two ANOVA was performed to detect limb by group differences. Significance level was set at $p \leq 0.05$. Descriptive comparisons were made to historic pre-operative and healthy controls.

Results: Ninety-three subjects were included in this study. Sixteen subjects were lost to follow-up, resulting in 77 subjects included in the final analysis (YES: $N = 18$, 6M/12F, age = 67.11; NO: $N = 59$, 31M/28F, age = 66.80). There were significant main effects of group and limb (Table 1), with the YES group having substantially weaker knee extensors on both limbs (Fig 1). There were no significant predictors of contralateral TKA for either limb. However, the addition of operated limb quadriceps strength to the model improved the significance of the model and was nearly a significant addition to the model ($p = 0.077$).

Conclusions: Given that the subjects who had contralateral TKA were substantially weaker than those who did not, and were weaker than historical group undergoing TKA, these results suggests that quadriceps weakness may play a role in discriminating those who do and do not demonstrate symptomatic progression on the contralateral limb. Future work should evaluate rehabilitation protocols that not only restore operated limb quadriceps strength to at least pre-operative levels. Although knee adduction moment is predictive of OA progression, we did not find that in this analysis. However, previous literature suggests that non-normalized PKAM may be a more clinically relevant measure when analyzing knee OA progression. Therefore, future analyses of incidence of contralateral TKA may include non-normalized PKAM.

Table 1
Clinical & biomechanical outcomes.

Variable	YES		NO		Main Effect of Limb	Main Effect of Group	Interaction Effect
	Operated	Non- operated	Operated	Non- operated			
KOS	0.82 ± 0.13	0.89 ± 0.10	0.86 ± 0.12	0.92 ± 0.10	0.005*	0.068	0.775
Knee pain	0.83 ± 0.86	0.66 ± 0.74	0.59 ± 0.87	0.52 ± 0.73	0.439	0.216	0.745
Quad strength (N/BMI)	15.61 ± 5.97	18.87 ± 8.30	19.01 ± 7.62	21.68 ± 8.51	0.050*	0.041*	0.845
Extension ROM (°)	0.17 ± 3.88	-0.77 ± 3.22	0.44 ± 4.41	-1.91 ± 3.27	0.025*	0.553	0.332
KFM at PKF (N·m/kg·m)	0.27 ± 0.16	0.26 ± 0.21	0.34 ± 0.15	0.34 ± 0.18	0.776	0.017*	0.770
PKAM (N·m/kg·m)	-0.30 ± 0.08	-0.38 ± 0.12	-0.29 ± 0.12	-0.38 ± 0.14	0.000*	0.865	0.949

*$p \leq 0.05$ (¶ (-) = hvperextension. (+) = extension loss).

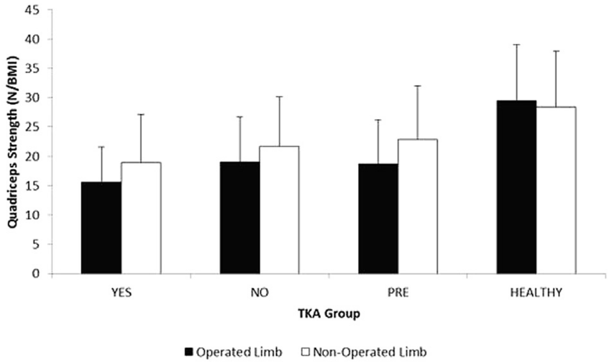


Figure 1. – Operated and Non-operated limb quadriceps strength in those that received contralateral TKA (YES), did not receive contralateral TKA (NO), at end-stage unilateral knee OA (PRE), and healthy controls (HEALTHY).

149

COMPOSITION OF THE KNEE INDEX, A THREE-DIMENSIONAL BIOMECHANICAL INDEX FOR KNEE JOINT LOAD, IN SUBJECTS WITH MILD TO MODERATE KNEE OSTEOARTHRITIS

B. Clausen [†,‡], T.P. Andriacchi [§,||], D.B. Nielsen [¶,#], E.M. Roos [†,‡], A. Holsgaard-Larsen [¶,#]. [†] *Univ. of Southern Denmark, Odense M, Denmark;* [‡] *Dept. of Sports Sci. and Clinical Biomachanics, Odense M, Denmark;* [§] *Stanford Univ., Standford; Veterans Administration, Palo Alto, CA, USA;* [||] *Dept. of Mechanical Engineering, Dept. of Orthopedic Surgery, Stanford, CA, USA;* [¶] *Univ. of Southern Denmark, Odense C, Denmark;* [#] *Dept. of Orthopaedics and Traumatology, Odense Univ. Hosp., Odense C, Denmark*

Purpose: Knee joint load is an important factor associated with progression of knee osteoarthritis. The knee adduction moment (KAM) is an indicator of medio-lateral knee load distribution. However, KAM only includes frontal plane moment and has recently been found insensitive in subjects with mild to moderate osteoarthritis. The Knee Index has been developed to include moments from all three planes (frontal, sagittal and transversal) and was able to distinguish between pain relief induced by placebo, NSAID or opioids. However, to help interpret the underlying biomechanical characteristics of the Knee Index, the respective contributions of the knee moments derived from the three planes are important to determine.

The purpose of this study was therefor to investigate how the frontal, sagittal and transversal moments contribute to the Knee Index, a novel biomechanical index of joint load for the knee, in patients with mild to moderate knee osteoarthritis.

Methods: The contribution of frontal, sagittal and transversal plane knee moments to the Knee Index was investigated in 24 subjects (13 women, age: 58 ± 7.6 years, BMI: 27.1 ± 3.0) with clinically diagnosed mild to moderate knee osteoarthritis according to the ACR criteria. Three dimensional gait analysis was performed using a 6-camera Vicon MX (Vicon, Oxford, UK) movement analysis system (100 Hz) with the Plug-in-Gait marker set. Ground reaction forces were recorded (1000 Hz) by two AMTI force-plates (AMTI, OR6-7, Watertown, MA, USA) embedded at floor level. Subjects walked barefoot at self-selected walking speed. The trial (out of 5 trials) representing the median velocity was selected for further analysis. The first peak (approximately 50 % of stance phase) magnitude Knee Index (calculated by the root mean square of frontal, sagittal and transversal knee moments (for equation, see figure 1A) and the corresponding knee moments (at the same time points) from all three planes were calculated for the knee diagnosed with OA using inverse dynamics. Percentage distribution of the contributors of the Knee Index (for equation, see figure 1B).

Results: Frontal plane kinematics contributed with 60.0% (SD 25.6) of the Knee Index while sagittal plane kinematics contributed with 40.5% (SD 26.1) and transversal plane kinematics contributed with 0.2% (SD 0.3). A substantial inter-subject variation in the relative contribution of the flexion and extension moment components to the Knee Index was observed (see figure 2).

Conclusions: Our findings in these subjects with mild to moderate knee OA support the notion that the primary contributor to the Knee Index is the frontal plane kinematics (i.e. the knee adduction moment), and secondarily the sagittal plane kinematics (i.e. the knee flexion moment). The transversal plane moment did not contribute to the Knee Index. It is hypothesized that the Knee Index's sensitivity to pain comes from the inclusion of the sagittal plane.

The present substantial inter-subject variation gives interest to investigate the relative contributions as predictive of future clinical changes. The present findings add to the knowledge of knee joint load distribution and OA.

$$\text{A.} \quad Knee\ Index = \sqrt{\left(\frac{(Frontal\ plane\ moment^2 + Sagittal\ plane\ moment^2 + Transversal\ plane\ moment^2)}{3}\right)}$$

$$\text{B.} \quad \%Frontal = \left(\frac{\left(\frac{Frontal\ plane\ moment^2}{Knee\ Index^2}\right)}{3}\right) * 100\% \qquad \%Sagittal = \left(\frac{\left(\frac{Sagittal\ plane\ moment^2}{Knee\ Index^2}\right)}{3}\right) * 100\%$$

$$\%Transversal = \left(\frac{\left(\frac{Transversal\ plane\ moment^2}{Knee\ Index^2}\right)}{3}\right) * 100\%$$

Figure 1. Equation of the Knee Index and percentage distribution.