

# KNEE KINETICS DURING THE DEEP SQUAT

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## INTRODUCTION

A large portion of the world population performs deep squatting as part of normal activities of daily living (ADL). Past studies (Dyrby, 1998) have tried to quantify the rotational components of motion in the knee during dynamic ADL's. These ADL's include walking, stair climbing and performing a deep squat. Recent studies (Stiehl et al., 1995) have reported that the knee lifts off during squatting. However, these studies are based on planar fluoroscopic measurements and did not measure if forces are present to produce liftoff. The purpose of this paper is to quantify the forces and moments about the knee during the deep squat. In particular, this study focused on net adduction moment, net quadriceps moment, anterior shear force and medial and lateral knee contact forces applied to the tibia.

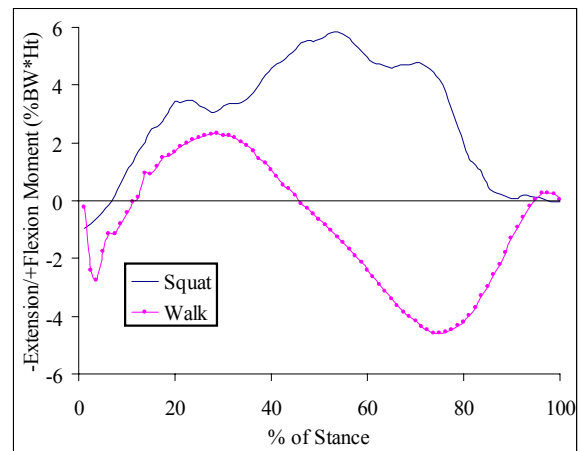
## MATERIALS AND METHODS

Eleven adults (5 female, 6 male) with no musculoskeletal impairments were studied. The subjects ( $28 \pm 8$  yrs.,  $169 \pm 8$  cm.,  $635 \pm 115$  N) performed walking and deep squat activities. Measurements were obtained using an optoelectronic system for motion analysis (CFTC) and forceplate (Bertec) (Andriacchi et al., 1997). External knee flexion and adduction moments and net anterior knee force were obtained using an inverse dynamics approach (Andriacchi et al. 1997). Medial and lateral compartment knee forces were obtained using a statically determinate knee model (Schipplein and

Andriacchi, 1991). Student's t-test were used at a significance level of  $\alpha = 0.05$ .

## RESULTS AND DISCUSSION

The knee flexion moment during the squat was almost three times as large as that seen during walking ( $p < 0.001$ , Table 1, Figure 1). Conversely the adduction moment during squatting was significantly lower ( $p=0.02$ , Table 1) than during level walking. This combination of changes in the external loading produced a more uniform balance between the force on the medial and lateral compartments than during level walking (Table 1). Walking produced significant differences in the medial and lateral compartment loading ( $p < 0.001$ ) while the deep squat showed no difference.



**Figure 1:** External knee flexion extension moments. The maximum knee flexion moment for the squat is nearly times that of walking.

Comparison of net anterior shear forces demonstrated an increase for the deep squat though this result was not significant ( $p = 0.06$ , Table 1).

## DISCUSSION

This study demonstrated that there was an increase in the net quadriceps moment and a decrease in the adduction moment during the squat relative to level walking. This external loading is more likely to load the knee more uniformly (medial to lateral) than during level walking. Thus, it is less likely that liftoff would occur during squatting than during level walking. This finding is in contrast to the study reported by Stiehl et al. (1995) that described liftoff in subjects performing deep squatting. Given the stabilizing influence by the larger force generated by the quadriceps muscles and the lower adduction moment, it is not likely that the knee would experience liftoff during squatting.

This study also demonstrates an increase in the anterior shear force during squatting. This force would be sustained by the posterior cruciate ligament (PCL) or its substitute. This shear force would be added to the substantial force generated by the quadriceps in deep flexion that must be

sustained by the PCL, since in deep flexion the patellar tendon pulls the tibia posteriorly. Designs that incorporate any mechanical constraints on motion, i.e. a cam to substitute for a sacrificed PCL should consider the high net anterior shear forces sustained during the deep squat.

## REFERENCES

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**Table 1:** Comparison of the deep squat and walking.

	Deep Squat	Walking	p-value
Knee Flexion Moment (%BW*Ht)	<b>6.6 (1.2)</b>	<b>2.3 (1.2)</b>	<b>&lt;0.001</b>
Knee Adduction Moment (%BW*Ht)	<b>1.4 (0.8)</b>	<b>2.3 (0.6)</b>	<b>0.01</b>
Peak Lateral Compartment Knee Force (N)	<b>1417 (616)</b>	<b>772 (279)</b>	<b>0.002</b>
Peak Medial Compartment Knee Force (N)	1468 (405)	1343 (247)	0.27
Peak Net Anterior Shear Force (%BW)	42.8 (6.7)	36.6 (5.7)	0.06

Note: **Bold** indicate significant differences. Standard deviation in parenthesis.