

# CRUCIATE LIGAMENT FORCE DURING THE WALL SQUAT AND ONE-LEG SQUAT

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## INTRODUCTION

One leg squat and wall squat exercises are used in both athletic training and during knee rehabilitation programs. However, it is currently unknown how cruciate ligament tensile force change among one leg and wall squat exercises as a function of knee angle. The purpose of this study was to compare PCL/ACL tensile forces as a function of squat exercises and knee angle (0-90° during knee flexing phase and 90-0° during knee extending phase, where 0° = full knee extension). It was hypothesized that PCL tensile forces would increase as knee flexion increased and would be greater in the wall squat long (feet further from wall and knee not translating beyond the toes at maximum knee flexion) compared to the wall squat short (feet closer to wall) and the one leg squat, both exercises in which the knee translates beyond the toes at maximum knee flexion.

## METHODS

Eighteen subjects (9 males and 9 females) were used with an average age, mass, and height of 29±7 y, 77±9 kg, & 177±6 cm for males and 25±2 y, 60±4 kg, & 164±6 cm for females. Each subject performed the wall squat long (knees over ankles at maximum knee flexion) and the wall squat short (knees translate beyond toes at maximum knee flexion). A one leg squat was also performed, in which the knees also translate beyond toes at maximum knee flexion. Intensity was normalized for each exercise by having each subject their 12 repetition

maximum intensity, which were 55±9 kg for males and 36±9 kg for females for the wall squat and 15±3 kg for males and 10±3 kg for females for the one leg squat. Surface electrodes were placed over the vasti muscles, rectus femoris, medial and lateral hamstrings, and gastrocnemius. Reflective markers were positioned over landmarks on the foot, ankle, knee, hip, and shoulder.

Video (60 Hz), EMG & force platform (960 Hz) data were collected during 3 repetitions of each exercise (0-90° knee flexion) and averaged. EMG data were normalized by maximum voluntary isometric contractions (MVIC).

Cruciate ligament tensile forces were calculated using a biomechanical knee model (Zheng et al., 1998) with input variables consisting of resultant knee forces and moments and the muscle force function  $F_{m(i)} = c_i k_i A_i \sigma_{m(i)} [EMG_i / MVIC_i]$ , where  $k_i$  was a muscle force-length variable,  $A_i$  was physiological cross sectional area (PCSA) per muscle,  $\sigma_{m(i)}$  was MVIC force per unit PCSA,  $EMG_i$  and  $MVIC_i$  were EMG window averages, and  $c_i$  was a weight factor adjusted in a computer optimization program. Cruciate ligament tensile force as a function of exercise (wall squat long, wall squat short, one leg squat) and knee angle (every 10° from 0-90° and 90-0°) were assessed by a two-way repeated measures analysis of variance ( $p < 0.01$ ).

## RESULTS AND DISCUSSION

Cruciate ligament tensile forces for the wall squat long, wall squat short, and one leg squat are shown in Figure 1. Between 0-60° during the

knee flexing phase, PCL tensile force was significantly greater in the wall squat long compared to the wall squat short and one leg squat, and significantly greater in the wall squat short compared to the one leg squat. Low ACL tensile forces (<50 N) were generated in the one leg squat between 0-40° during the knee flexing phase. Between 70-90° during the knee flexing phase, PCL tensile force was significantly greater in the wall squat long compared to the wall squat short and one leg squat. Between 90-50° and 10-0° during the knee extending phase, PCL tensile force was significantly greater in the wall squat long compared to the one leg squat. Between 90-70° during the knee extending phase, PCL tensile force was significantly greater in the wall squat short compared to the one leg squat. At 70° and between 40-0° during the knee extending phase, PCL tensile force was significantly greater in the wall squat long compared to the wall squat short.

It is interesting that PCL tensile force was lower and ACL tensile force was higher in the one leg squat and wall squat short compared to

the wall squat long. In the wall squat short and one leg squat the knees translated beyond the toes at maximum knee flexion. Increased anterior translation of the knees appears to decrease PC tensile force and increase ACL tensile force.

### SUMMARY/CONCLUSIONS

PCL tensile force was greater during the wall squat long compared to the wall squat short and one leg squat throughout most of the knee flexing and knee extending phases. In addition, PCL tensile force was greatest at maximum knee flexion for all exercises. Low ACL tensile force was generated during the one leg squat between 0-40° knee flexion.

### REFERENCES

Zheng et al. (1998), *Journal of Biomechanics*, **31**, 963-967.

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Figure 1. Mean (SD) PCL tensile force during the one leg squat and the wall squat.

