THIGH-CALF AND HEEL-GLUTEUS CONTACT FORCES IN HIGH FLEXION (EXPERIMENTAL RESULTS)

Jonisha P. Pollard
National Institute for Occupational Safety and Health, Pittsburgh Research Laboratory, Pittsburgh, PA, USA
email: JPollard@cdc.gov, web: http://www.cdc.gov/niosh/mining

INTRODUCTION

In restricted vertical working heights such as low-seam coal mines, workers are forced to assume kneeling or squatting postures to perform work. These postures are associated with increased risks for the development of significant knee pathologies such as meniscal tears and osteoarthritis [1,2].

Previous research has shown an increased applied knee flexion moment when kneeling in high flexion [3]. However, these models have been applied to flexion up to 140° which neglects contact between the thigh and calf which occurs beyond 140°. In addition to thigh-calf contact, when kneeling near full flexion there may be additional contact between the heel and gluteal muscles.

To the author's knowledge, heel-gluteus contact has not been previously investigated, but thigh-calf contact has received some attention. Zelle (2007) reported thigh-calf contact forces up to 30% bodyweight (BW) [4]. Zelle (2009) reported decreased knee forces when accounting for thigh-calf contact [5]. Caruntu (2003) reported erroneous force and moment estimations when thigh-calf contact was neglected from models to determine muscle and ligament forces [6].

In this study thigh-calf and heel-gluteus contact forces were quantified to determine their effect on the externally applied flexion moment in high flexion.

METHODS

Ten subjects were recruited (7 male; age: 34 ± 17 years; weight: 683 ± 98 N; height 169 ± 8 cm) from the National Institute for Occupational Safety and Health in Pittsburgh, PA. No subjects had a history of knee pathologies.

Subjects were instructed to stand while a clinical seating pressure assessment system (ClinSeat®, Tekscan Inc., South Boston, Massachusetts, USA) was placed along their lower right leg from the popliteal to the heel. They were then instructed to squat and pressure data was collected for 5 seconds. (Figure 1) Next, the subject kneeled on the floor at 90° flexion. The pressure sensor was again laid across their lower right leg. They then went into full flexion while data were collected for 5 seconds. During data collection, the distance from the top of the sensor to the lateral epicondyle of the femur was measured and recorded. Subjects were given no specific instructions on kneeling, and therefore assumed postures which they felt caused the least discomfort.

The supplied software (Advanced ClinSeat, Tekscan Inc., South Boston, Massachusetts, USA) was used to record the pressure distributions and calculate the centers of pressure and total forces at the thigh-calf and heel-gluteus contact areas.

Figure 1: Experimental data collection

RESULTS AND DISCUSSION

In all subjects, thigh-calf contact forces when squatting were at least 20% BW, with a mean of 39 ± 14% BW (Figure 2). Thigh-calf contact in full flexion was less than squatting with a mean of 28 ± 13% BW (Figure 3). The centers of pressure were

6.6 and 6.1 inches inferior of the epicondylar axis for squatting and kneeling near full flexion, respectively. In 7 of the 10 subjects, kneeling near full flexion resulted in heel-gluteus contact. These contact forces were less than the thigh-calf contact forces, with a mean of 11 ± 6% BW and a center of pressure 16.3 inches inferior of the epicondylar axis; approximately at the subject's heel.

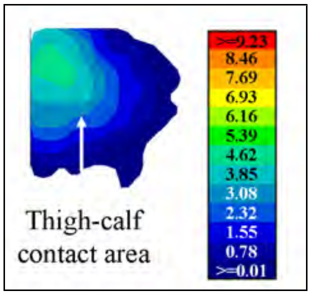

Figure 2: Typical pressure distribution (psi) for squatting.

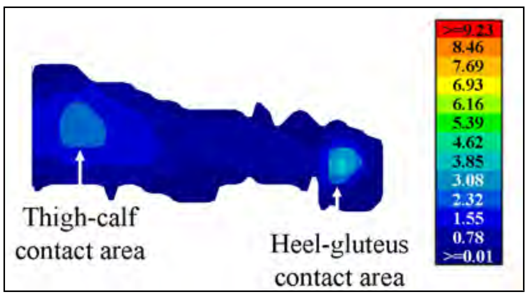

Figure 3: Typical pressure distribution (psi) for kneeling near full flexion.3

Thigh-calf and heel-gluteus contact forces created extension moments about the knee. Mean thigh-calf contact moments when squatting and kneeling near full flexion were 4% BW*Ht and 3% BW*Ht, respectively. The mean heel-gluteus contact moment was 3% BW*Ht.

The forces and moments generated by thigh-calf contact have been shown to greatly affect the muscle and ligament forces as well as the stresses in knee structures. Caruntu and colleagues (2003) found that when accounting for thigh-calf contact, quadriceps forces decreased by 700 N and medial collateral ligament forces increased by 50% [6]. Zelle (2009) found reductions in compressive knee forces by 1.99 times BW when thigh-calf contact was included. Contact stresses on the tibial post of polyethylene knee replacements also decreased by 21.2 MPa when including thigh-calf contact [5].

Having a comparable moment contribution to thigh-calf contact, it is expected that heel-gluteus contact will have similar affects on the forces and stresses in the internal knee structures.

CONCLUSIONS

Thigh-calf and heel-gluteus contact forces act in the anterior direction of the shank, thereby extending the knee and reducing the applied flexion moment. These forces act to stabilize the knee in high flexion and may significantly affect calculations in computational knee models.

Traditionally, segment contact forces have been neglected from biomechanical models. The complexity of modeling tissue deformation and pressure distributions may discourage researchers from considering these inputs. However, the magnitude of these forces were shown to be quite large, >30% BW and the moments produced by these contact forces may decrease externally applied flexion moments by as much as 9% BW*Ht.

In the future, biomechanical models should account for the thigh-calf and heel-gluteus contact as neglecting these forces may result in erroneous force and moment estimations.

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DISCLAIMER

The findings and conclusions in this paper are those of the author and do not necessarily represent the views of the National Institute for Occupational Safety and Health.