PRESSURE ON THE KNEE WHILE PERFORMING A LATERAL LIFT FROM KNEELING POSTURES

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INTRODUCTION

Mine workers are restricted to kneeling, squatting, stooping, or crawling postures throughout their entire shift in low-seam (<42") and mid-seam (43" to 60") coal mines. In 2007, the Mine Safety and Health Administration (MSHA) database reported 84 knee injuries for seam heights between 30" and 54" which translates to an estimated $1.1 million using cost data from low-seam mine injury claims [1]. Significant injury risk is apparent when performing work with prolonged kneeling with sustained high forces on the knees [2]. Forces applied to the knees may also rise and decline rapidly when working (e.g. reaching for tools, moving materials) in kneeling postures. Moreover, the measurement of static pressure does not adequately reflect the high forces experienced during dynamic kneeling work tasks [2]. To enhance understanding of occupational kneeling and provide data to be used in the design of interventions (e.g. kneepads), mean pressures on the knee were estimated for kneeling and transferring a load laterally, a common mining practice.

METHODS

Seven subjects (5 male, 2 female), with no prior kneeling experience, volunteered to simulate three kneeling postures for a lateral lifting task that required twisting at the waist. Subject age varied from 20 to 60 years with a mean age (± SD) of 36 (±18) years. Subjects were screened for knee conditions, and no subject reported ever having serious injury or knee surgery. The test postures were kneeling: in full flexion (Near Full – sitting on heels), at 90° knee flexion (Near 90), and with only the right knee down (One Knee). These postures were simulated for work performed at a 48" vertical height, which restricted the subjects' posture.

A custom-made capacitive pressure sensor with 196 sensing units (0.22" by 0.48") was used (PPS, Los Angeles, CA). The sensor was pre-shaped to the knee at 90° flexion, 7" wide by 13.8" long with an active area of 4.6" by 8.3". Gaps between sensing units ranged from 0.065" to .322" with larger gaps in the curved portion of the sensor. Pressure data were collected at a variable sampling rate of approximately 5 Hz. Subjects were instrumented with reflective markers and motion data were recorded at a frequency of 60 Hz using the motion capture system (Motion Analysis Corporation, Santa Rosa, CA). Ground reaction forces were measured at a frequency of 1020 Hz using a force plate (AMTI, Watertown, MA), read through an analog-to-digital board (National Instruments, Austin, TX), and recorded using the motion capture software (EvaRT, Motion Analysis Corporation, Santa Rosa, CA). Pressure, force and motion data were synched through the motion capture software.

This data collection process was part of a larger study in which static postures were also investigated [3]. The peak pressures observed for these lateral lifting tasks, however, far exceeded the maximum calibrated pressure (35 psi) of the individual sensing units. Thus, to estimate the mean pressure applied to the knee, the ground reaction force at the right knee was divided by the active contact area of the sensor (total area of sensing units for pressure greater than the sensor threshold of 0.4 psi). Similarly, knee pressure was estimated for a 10 second static trial.

Prior to each trial, the pressure sensor was placed in a reference position and zeroed to eliminate any pressure artifact associated with the stretching of the sensor. Subjects were instructed to reach to their right to retrieve a 25 lbs block (shaped like a stopping/cinder block), bring it in front of their body, and then set it down on their left side in one smooth motion. The block was instrumented with reflective markers to track its position.

Three stages of interest were isolated from these lifting tasks; when the block was picked up from their right side (BPU), when the block was directly in front of the subject (Block At Front - BAF), and when the block was placed down (BPD).

RESULTS AND DISCUSSION

Estimated mean pressure versus posture is shown in Figure 1 for the static trials that were collected as part of the larger study [3] and the three lifting stages. Similar results were found for the Near 90 and One Knee postures for all trials, as expected considering postural similarities. Estimated pressures increased in all postures when performing the lifting trial compared to the static trial. Drastic increases were noted in the Near Full posture during the lifting task. Highest mean pressures were seen at the BPU stage where estimated pressure exceeded 20 psi, which was more than four times the pressures estimated for the other postures. One reason for the notable differences in estimated mean pressure is smaller mean contact area. While forces for the Near Full posture were within 0.8 to 1.4 times the measured mean forces of the Near 90 and One Knee postures, the mean contact areas were 1.8 to 4.7 times *lower* for the Near Full posture. This is likely due to the contact of the tibial tubercle with the force plate when kneeling in full flexion.

When normalized to the static posture, estimated mean pressures for the Near Full posture exceeded those for the static trials by factors of 11, 8, and 5 for BPU, BAF, and BPD, respectively. An ANOVA showed posture was statistically significant ($p=0.003$) for normalized mean pressure. Differences in subject anthropometry and tubercle prominence may explain the wide variation in contact area, and thereby the variation in knee pressure for the Near Full posture.

Figure 1 also suggests the Near 90 and One Knee postures are preferred for lateral lifting. The mean pressure magnitudes during each stage of lift for these postures are similar to those during static kneeling. In considering a postural rotation strategy, these findings suggest that, in moving supplies with a lateral lift technique, workers should limit using the Near Full posture and instead use Near 90 or One Knee whenever possible. Observations have shown low-seam coal miners to most often use the Near Full posture. These miners routinely wear kneepads, which have been shown to aide in minimizing peak stresses on the knee while the mean pressure is not greatly affected [3]. Some limitations of this study included the effect on contact area estimates due to the size of the sensing units and associated gaps of the sensor and the inability to report peak pressures.

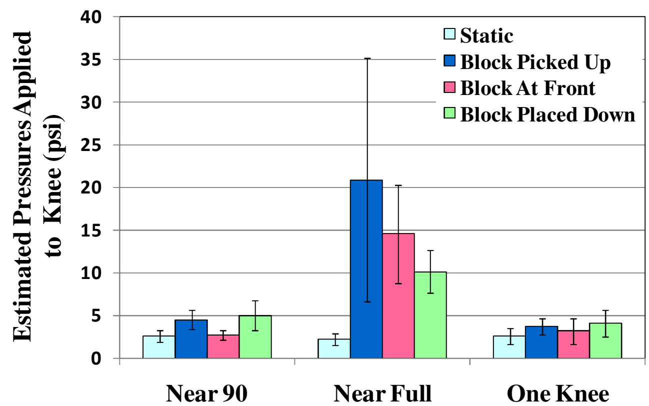

Figure 1: Estimated mean pressure for static trial and three stages of lifting task for each posture.

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DISLCAIMER

The findings and conclusions in this study are those of the authors and do not represent the views of NIOSH.