

Center of Mass Offsets During Crouched Posture Activities

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Introduction

Gait analysis and other studies of human movement often focus on lower body mechanics. The kinetics of these movements may be greatly influenced by upper body segments. The positions of the head, arms and trunk can alter the body center of mass (COM), thereby altering demands on the lower extremities to maintain upright and balanced stance. In normal gait, relative movement of COM within the body is minimal, and it can be assumed that its position is fixed relative to the pelvis [1]. During stair climbing, squats, and in cerebral palsy patients exhibiting significant crouch gait, COM is displaced anteriorly by motion of the upper body, and increased flexion at the hips, knees, and ankles [2-4]. The **purpose** of this study was to determine the location of COM as a function of knee flexion angle during a squat. It was **hypothesized** that COM moves a significant distance anterior to the center of pelvis (COP) as knee flexion angle increases. It was subsequently **hypothesized** that this shift in COM location will result in significantly reduced extension moments about the knee joint.

Statement of Clinical Significance

Failure to account for anterior-posterior shift in COM location during knee flexion can lead to incorrect assumptions and modeling of the lower extremities [5]. The strategy of shifting the COM to accommodate pathologies and overcome obstacles should be considered by clinicians when interpreting the results of these motions.

Methodology

Following Institutional Review Board approval, 11 normal males 69 ± 1 inches tall were recruited. Subjects were fitted with a full body set of 28 reflective markers [2], and a 6-camera motion capture system (Vicon 370, Oxford Metrics Ltd., Oxford, England) was used

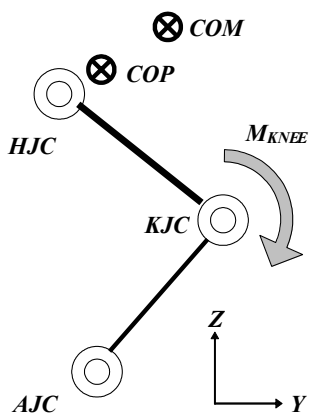


Figure 1. Lower extremity model used to calculate moments about the knee.

to track their positions. Subjects were instructed to stand upright and then squat by flexing hip, knee, and ankle joints to the greatest extent possible while keeping heels in contact with the ground. Subjects were instructed to move their upper body as necessary to maintain balance, and to move slowly to minimize inertial effects. Each subject completed seven squats. A full body biomechanical model [2] was used to calculate positions of joint centers and COM. Anterior/Posterior distance between COM and COP in the sagittal plane, defined as COM offset, was measured at knee flexion angle increments of 10° , from upright stance (0°) to full squat (140°). A COM offset of zero denoted that COM and COP were collinear, while COM offsets anterior of the COP were defined as positive, and offsets posterior as

negative. Representative squats for each subject were created by calculating mean COM offset at each knee flexion angle from all seven trials. Representative squats were then combined to calculate mean offsets and 95% confidence intervals of the means. A sagittal plane model of the knee (Fig. 1) was used to predict knee extension moments (M_{knee}) under two assumptions: COM was collinear with the COP (Eq. 1), and COM was a distinct point as calculated by the full body biomechanical model (Eq. 2). BW denotes average subject body weight and KJC_y is position of the knee joint center.

$$(1) M_{knee} = -1/2 BW (COP_y - KJC_y) \quad (2) M_{knee} = -1/2 BW (COM_y - KJC_y)$$

Results

As shown in Figure 2, COM offset distance increased with increasing knee flexion. At knee flexion angles of 10° and greater, the difference between the COM and COP was significant at the 95% confidence level. Predicted knee moments were significantly less at the 95% confidence level at knee flexion angles of 10 degrees and greater when COM position was calculated using the sagittal plane model rather than assumed collinear with the COP (Fig. 3).

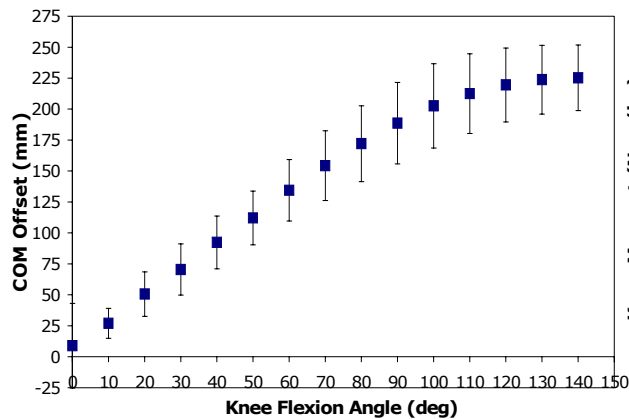


Figure 2

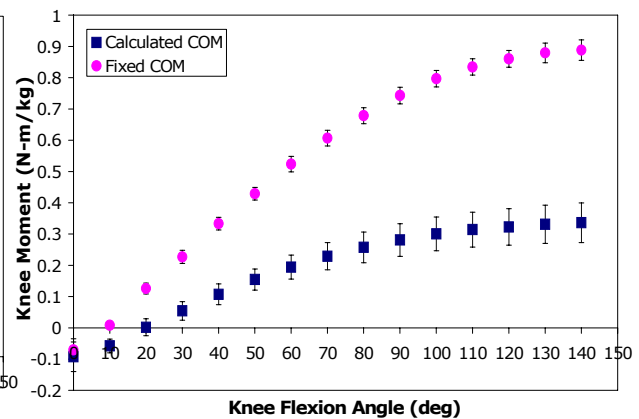


Figure 3

Discussion

Various studies have indicated that COM during normal gait remains near the center of the pelvis with little excursion [1,6,7]. This study has demonstrated that even at small knee flexion angles, trunk and upper extremity compensations may be used which significantly translate the COM anteriorly from the COP. Knee extension moments necessary to balance body weight forces are reduced by moving the COM anteriorly, reducing the moment arm. While these measurements were made during controlled squatting motions, they may also be applicable to pathological gait and other activities including sit-to-stand motions and stair climbing.

References

- [1] Whittle M, Hum Mov Sci, 16:347-355, 1997 [5] Perry, J et. al., JBJS Am., 57:961-967, 1975
 [2] Eames, M et. al., Hum Mov Sci, 18:637-646, 1999 [6] Shimba T, J. Biomech., 17:53-60, 1984
 [3] Chou, L et. al., Gait Posture, 13: 17-26, 2001 [7] Crowe, A et. al., Gait Post, 1:61-68, 1993
 [4] Gage, J, Clin Ortho Rel Res, 253, 45-54, 1990

Acknowledgements

Supported by the Shriners Hospitals for Children grant #8250