Weight-Bearing vs Non-Weight-Bearing for dynamic CT acquisition of the knee: a preliminary study

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Summary

This study investigated the effect of weight-bearing (WB) versus non-weight-bearing (NWB) setup on lateral patellar displacement (Bisect Offset, BO) during knee flexion-extension motion, in 10 healthy people, using 256 slice dynamic CT (4DCT). BO differences between WB and NWB between 0° and 30° of knee flexion were analyzed. A significantly larger patellar displacement in WB was found compared to NWB at all angles except 0° ($p = 0.016$), with median differences of +4.6% to +9%. These findings highlight the importance of considering loading conditions in knee kinematic assessments, especially in patients with patellar instability or pain. The study emphasizes the potential of weight-bearing 4DCT for knee evaluations.

Introduction

In medical imaging, weight-bearing dynamic analysis may offer more insightful information on lower limb kinematics compared to static images taken in unloaded conditions. Dynamic CT (4DCT) is an imaging technique that enables motion capture with high temporal resolution and exceptional morphological detail. Due to the supine position necessitated by the CT scanner's design, movements have traditionally been studied in non-weight-bearing conditions. However, weight-bearing and non-weight-bearing acquisitions have shown differences in lateral patellar displacement when analysed using MRI [1]. Furthermore, muscle activation is markedly influenced by the transition from a weight-bearing to a non-weight-bearing position. The aim of this preliminary study was to compare the lateral displacement of the patella (Bisect-offset) estimated using 4DCT images, between weight-bearing (WB) and non-weight-bearing (NWB) knee motion.

Methods

Ten healthy adults (20 knees) participated in this study. To replicate constant gravitational force during horizontal dynamic CT acquisition, a novel weight-bearing device compatible with a 256-slice wide-beam CT scanner was employed [2]. Each participant performed consecutive cycles of full knee flexion-extension both in weight bearing and non-weight bearing setting (Figure 1). A 4DCT scanning protocol (16x50 cm FOV, 80 kVp, 50 mA, 6.7 s) captured images of both knees simultaneously during the task. Automatic multi-atlas segmentation and rigid registration were used to compute a transformation matrix at each time point, representing the movement of each bone (tibia, femur and patella). Bisect offset (BO) was calculated, and its difference between WB and NWB between 30° and 0° of knee flexion was analyzed. Wilcoxon one-sample test with Bonferroni correction (significance level = 0.007) was performed to determine whether there was a significant difference from the zero line.

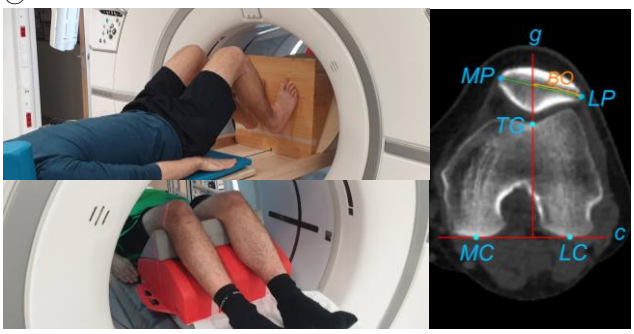

Figure 1. Left: WB (on top) and NWB (bottom) acquisition. Right: Definition of the BO metric; C: Condyle; TG: Trochlear Groove; P: Patella; M: Medial; L: Lateral.

Results and Discussion

Differences between WB and NWB are displayed in Figure 2.

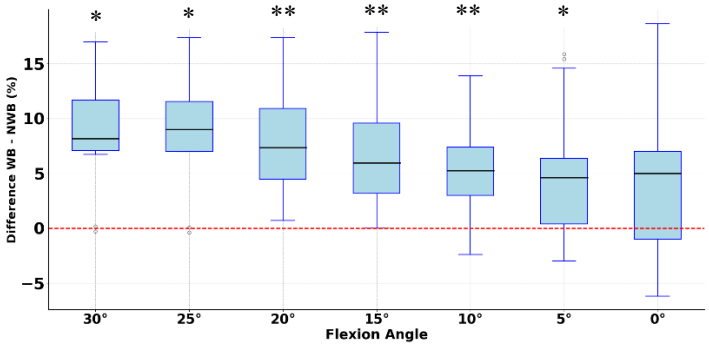

Figure 2: BO (%) difference (WB minus NWB) between 30° and 0° of knee flexion; * $p<0.007$; ** $p<0.001$.

The analysis revealed significant patellar displacement at all angles except 0° ($p = 0.016$), with median differences ranging from +4.6% to +9%. WB displacement was significantly larger compared to NWB in the last 30° of knee flexion. When pathologies like patellar instability or patellar pain are evaluated, the choice of the setup may have a significant impact in assessing patellar motion, as NWB seems to underestimate lateral displacement.

Conclusions

Differences in knee kinematics are evident when motion is captured under WB vs. NWB conditions. The loading factor should be carefully considered when assessing knee kinematics [3]. Depending on the setting and condition investigated, a WB setup may be more appropriate, achievable through weight-bearing CT images [2]. Further research in patient groups will help clarify its potential.

References

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