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TIBIOFEMORAL AND PATELLOFEMORAL JOINT FORCES DURING DEEP SQUATTING AND KNEELING

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SUMMARY

Based upon an inverse dynamics model of the lower limb, the tibiofemoral and patellelofemoral joint forces were calculated for the different postures of squatting and kneeling. Ten males (age: 41.6 ± 11.3 yrs, body weight: 79.5 ± 11.7 kg) agreed to participate in this study. Using motion capturing, two force plates, and a pressure sensitive pad, the motion data was collected during different tasks in kneeling and squatting positions. The knee joint forces achieved a range between 0.5 and 0.7 x BW for the tibiofemoral joint and 0.9 to 1.1 x BW for the patellofemoral joint. Besides the effect of multiple ground contact points of the foot and shank, the soft-tissue contact of the dorsal part of the thigh and shank had a strong impact on the reduction of the knee joint forces.

INTRODUCTION

The high stress forces occuring at the knee joint associated with rising or lowering from kneeling or squatting is well known. However, very little is known about the loading during the static postures of deep squatting and kneeling. Kneeling and deep squatting are common activities in daily living and are typical postures especially in social-cultural and religious contexts in Asia and the Middle East. Various epidemiological studies suggest that prolonged squatting and kneeling is a risk factor for the development of osteoarthritis [1]. The compressive joint force during squatting and kneeling is under consideration as a potential pathomechanism. However, profound studies which could support this hypothesis are still missing. Therefore the goal of the present study was to develop a biomechanical measurement and modeling approach suitable for the estimation of the tibiofemoral and patellofemoral joint forces arising during squatting and kneeling in various contexts of daily activities and occupational tasks.

METHODS

A model of the lower limb in the sagittal plane consisting of the three segments, namely foot, shank, and thigh was configured for calculation of the knee joint forces arising during kneeling and squatting tasks. The anatomical data of the knee joint and its surrounding muscles and tendons used were from derived anatomical models reported in literature [2,3]. Special issues that need to be considered in squatting and kneeling are the multiple points of ground contact during kneeling and the thigh-calf-contact at full knee flexion. A 12-camera Vicon-system running at 100 Hz was coupled with two Kistler force plates (600x400 mm²), a pressure sensitive pad (250 × 120 mm², Paromed) attached at the dorsal surface of the thigh, and a 4-channel EMG system (sampling rate = 1 kHz). Based on inverse dynamics and applying the reduction method, the net knee moments, muscle forces, and tendon forces of the knee extensors and knee flexors were calculated. Finally the compressive joint forces in the tibiofemoral and patellofemoral joints were computed. The surface EMG activity of the quadriceps muscle (%MVC) served as qualitative validation of the muscle force predictions. Ten healthy males (age: 41.6 ± 11.3 yrs, body weight: 79.5 ± 11.7 kg) agreed to be a part of this study. Each participant performed different tasks of deep squatting and kneeling. For comparison the movements of lowering and rising from these static positions was analyzed as well.

RESULTS AND DISCUSSION

In squatting, kneeling, and deep kneeling, the knee flexion moment had a mean range of 0.23 to 0.28 $N \cdot m \cdot kg^{-1}$. Corresponding to this, the maximum quadriceps muscle activity had a mean range of 5 to 11% MVC. The quadriceps muscle force calculations yielded a maximum of 0.9 to 1.0 BW on average and had a tendency of containing greater variability for kneeling. The maximum tibiofemoral compressive joint force achieved a mean range of 0.4 to 0.7 BW (Figure 1). The maximum patellofemoral joint forces ranged from 0.8 to 1.1 BW. During lowering to squat, or rising from squat and deep kneeling, the knee flexion moment had a mean peak of 0.93 ± 0.16 $N \cdot m \cdot kg^{-1}$. The maximum tibiofemoral compressive joint force achieved 2.6 ± 0.39 BW and the patellofemoral joint force 3.4 ± 0.56 BW.

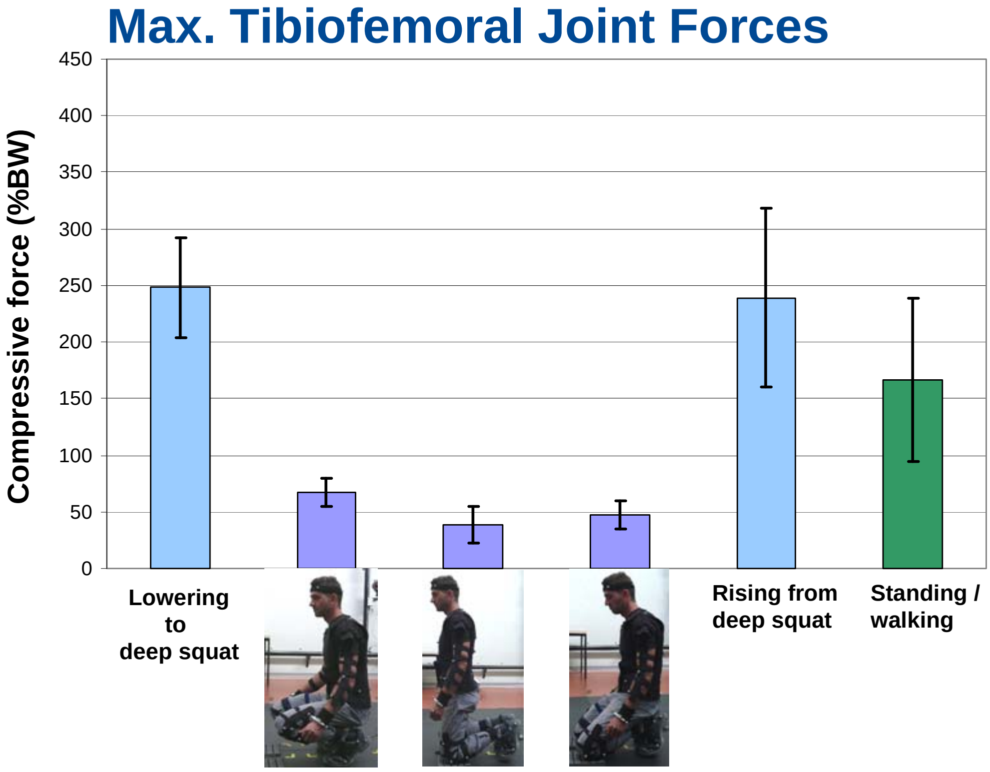

Figure 1: Maximum tibiofemoral joint forces during different motion tasks and static postures.

The overall low knee joint loadings in the terminal static postures of kneeling and squatting can be partially explained by the distribution of the ground reaction force on the foot and the proximal part of the shank. In addition to this, the thigh-calf contact force at full knee flexion has a major effect on the internal knee joint loading. The EMG recordings of the quadriceps muscle supported the model predictions. Compared to other studies [4,5,6], the present measuring approach is more comprehensive as all external forces are measured simultaneously in a single procedure with the motion capturing and EMG. The model also predicts muscle and knee joint forces of the tibiofemoral and patellofemoral joint.

CONCLUSIONS

In the debate on the knee joint loading associated with kneeling, squatting, and knee bending, the present study proposes various quantitative measures for a more comprehensive assessment of these tasks. The study's outcome suggests that for the static postures at rest of squatting, kneeling, and deep kneeling, the compressive knee joint forces are lower than has been suggested by earlier studies. These results indicate the importance of the extensive use of measurement equipment. However in the case of persons with limited knee joint mobility, the results can be expected to be notably different. Particularly among patients with endoprosthetic knee joints, the conditions may be completely different, and therefore the above mentioned results from cannot be transferred.

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