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Foot rotation—A potential target to modify the knee adduction moment

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Summary Isolating the particular joints/limb segments associated with knee adductor moment variability may provide clinically important data that could help to identify strategies to reduce medial tibiofemoral joint load. The aim of this study was to examine whether or not foot and thigh rotation during human locomotion are significant determinants of knee adductor moment variability.

Three-dimensional gait analyses were performed on 32 healthy adult women (mean age 54 ± 12 years, mean BMI $25 \pm 4\,\mathrm{kg\,m^{-2}}$) with radiologically normal knees. The relationships between foot rotation, thigh rotation and the external knee adduction moment were examined during early and late-stance phases of the gait cycle.

The degree of foot rotation correlated significantly with the magnitude of the peak knee adduction moment during late stance ($r = 0.40$, $p = 0.024$). No significant associations were apparent between thigh rotation and the peak knee adduction moment.

The association between foot rotation and the knee adduction moment in this study suggests that women who walk with external rotation at the foot reduce their knee adduction moment during late stance. This result implies that changes in foot kinematics can modify the medial tibiofemoral load during gait, which may be important in the prevention and management of knee osteoarthritis.

Introduction

There has been an increasing interest in the contribution of biomechanical factors in the pathogenesis of knee osteoarthritis (OA). Increased regional load across articular cartilage is argued to be an impor-

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tant factor contributing to knee OA,[1] and affected people walk with larger than normal knee adduction moments.[2,3] This increased force amplifies medial tibiofemoral joint load, and is associated with longitudinal progression of knee OA.[4]

Although the knee adduction moment influences the distribution of medial tibiofemoral load and the pathogenesis of knee OA,[2–8] few studies have examined the factors that contribute to knee adductor moment variability. Lower-limb alignment, and in particular the mechanical axis of the lower-limb, are the only well-established determinants of the knee adduction moment.[4,7,8] Several studies have also demonstrated that the magnitude of the toe-out angle, which is a measure of the angle between the long axis of the foot and the straight-forward line of progression of the body, is inversely associated with the external knee adductor moment during the late-stance phase of gait.[7–9] That is, the greater the degree of toe-out, the smaller the external knee adductor moment. Nevertheless, the toe-out angle, which may arise from the summation of combined movement at the hip, knee and foot, does not identify which specific joints or joint segments predominantly account for knee adductor moment variability. We hypothesised that both isolated thigh and foot rotation could account for knee adductor moment variability.

To explore these possibilities, we examined the relationship between foot and thigh rotation with the knee adduction moment in 32 healthy adult women.

Methods

Subjects

Thirty-two healthy women aged 23–71 years who were taking part in other studies within our department were invited to participate in this study. Subjects were initially recruited through the Jean Hailes Centre (a women's health clinic) and local media advertisements for studies examining healthy aging. The investigation was approved by the Alfred Hospital, Caulfield Hospital and La Trobe University ethics committees. All subjects gave written informed consent to participate in the study.

Subjects were excluded if they had a history of lower-limb OA, pain in the month prior to testing, significant limb pain or symptoms requiring medical treatment, were currently using analgesic or anti-inflammatory medications and presented with any neurological, cardiovascular or orthopaedic conditions affecting gait. All subjects were required to have no signs of malalignment or degenerative knee joint change, including joint space narrowing, osteophytes and subchondral sclerosis on radiological assessment.

Apparatus and procedure

Gait analyses were conducted in the gait laboratory at the Musculoskeletal Research Centre, La Trobe University, Australia. A six-camera Vicon motion analysis system (Oxford Metrics Ltd., Oxford, UK) was used to capture three-dimensional kinematic data during four walking trials on the dominant leg. Each subject's preferred kicking leg was nominated as their dominant leg. Ground reaction forces were measured by a Kistler 9281 force-platform (Kistler Instruments, Winterthur, Switzerland). Inverse dynamic analyses were performed using PlugInGait (Oxford Metrics, Oxford, UK) which is based on a previously proposed model,[10] to obtain joint moments calculated about an orthogonal axis system located in the distal segment of a joint. PlugInGait (Oxford Metrics, Oxford, UK) records three distinct Cardan angles, representing the sequence of rotations about axes fixed in the moving segment. This method aligns the axis of the proximal segment with the axis of the distal segment.

Reflective markers and a knee alignment device (KAD) were placed in accordance with the specifications recommended by the VICON Clinical Manager's User Manual. Markers were placed on the left and right anterior superior iliac spine, thigh (lower lateral third), ankle (lateral malleoli), shank (lower third), forefoot (second metatarsal head on the midfoot side of the equines break between the forefoot and midfoot), heel (such that a line joining the forefoot markers reflected the long axis of the foot) and sacrum.

Thigh rotation was measured about the long axis of the thigh segment and was calculated between the sagittal axis of the thigh and the sagittal axis of the pelvis projected into the plane perpendicular to the long axis of the thigh.

Foot rotation was measured about an axis perpendicular to the foot vector and the ankle flexion axis. It is defined as the angle between the foot vector and the sagittal axis of the shank, projected into the foot transverse plane. This differs from the toe-out angle, which is measured from the long axis of the foot, relative to the line of progression of the body. The foot is defined by the single vector joining the ankle joint center to the 5th toe. The relative alignment of this vector and the long axis of the foot