Geometrical Assessment of Age-Related Change in Range of Motion of Lower Limb Joints

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Introduction

Restriction of the range of motion (ROM) of joint, as well as muscular weakness and neurological disorder, is one of contributing factors to a decline in physical activities in aged persons (Schultz et al., 1992) and disabled patients (Bleck, 1979). The ROM is clinically defined as the maximal range of joint angle while biarticular muscles are relaxed. Consequently, it indicates only the restriction due to monoarticular muscle and connective tissues around the joint (Greene and Heckman, 1994). However, the length of biarticular muscle greatly influences the ROM of the joint. For example, the maximal hip flexion accompanying a fully extended knee joint is considerably reduced compared with that accompanying a fully flexed knee joint (James and Parker, 1989). Therefore, the interaction between two adjacent joints needs to be considered when assessing the ROM of the joint. The authors developed the geometrical method to describe and assess the interactive ROM of lower limb joints, i.e., hip and knee joint (Kuno et al., 1998). The aim of this study is to expand the geometrical method to the interactive ROM of ankle and knee joint and to examine a systematic age-related change in the interactive ROM of hip, knee and ankle joint including the effect of biarticular muscles.

Methods

Since a geometrical representation of interactive ROM of hip and knee joint has been reported in detail previously (Kuno et al., 1998), it is briefly described here. In our method, the relationship between two adjacent joint mobility due to the stretched biarticular muscle is represented the linear relationship as a first-order approximation. The sagittal ROM of hip and knee joint can be illustrated

![Figure 1](image_url)

**Figure 1**: A hexagon model of the combined range of motion of hip and knee joint defined by joint angle in different six boundary positions (a), and a pentagon mode of the combined range of motion of ankle and knee joint (b) defined by joint angle in different five boundary positions.
by a hexagon with the 6 vertices defined by hip and knee joint angle (Fig. 1a). In Fig. 1a, the position at the point 1-1 and 2-1 is maximal flexion and extension of both hip and knee joint, respectively. The points 1-2 and 1-3 represent the position at which biarticular hamstring muscles are fully stretched. The points 2-2 and 2-3 represent the position at which biarticular rectus femoris muscle is fully stretched. And the sagittal ROM of ankle and knee joint can be a pentagon with the 5 vertices defined by knee and ankle joint angle (Fig. 1b). In Fig. 1b, the position at the point 3-1 and 4-1 is maximal flexion and extension of both ankle and knee joint, respectively. The points 3-2 and 3-3 represent the position at which biarticular gastrocnemius muscle is fully stretched.

The measurements were performed on the right lower limb from 70 healthy normal males; age ranging from 20 to 75 years old. The subjects were distributed more than 10 persons in every 10 years. Photographic analysis was used for measuring the ROM of lower limb joint. The eleven postures corresponding to the six vertices of a hip-knee hexagon or five vertices of a knee-ankle pentagon were photographed. In order to determine the longitudinal axes of thigh and leg, four black round markers were placed on the skin surface at the great trochanter, the lateral epicondyle of the femur, the lateral condyle of the tibia and the lateral malleolous of the ankle. From these photographs, the angles of lower limb joints in each postures were measured. The flexion in hip and knee joint (dorsiflexion in ankle joint) were defined positive.

**Results & Discussion**

Figure 2 shows typical geometrical ROM representations of hip and knee (a) and ankle and knee (b) in two age groups (20 and 70 years old). The two sides representing the maximal flexion and extension knee joint angles in each panel remained almost unchanged over the observed age. The other sides were shifted inside with age (Fig. 2). Figure 3 illustrates scatter diagrams of the maximal flexion and extension angle of each joint as a function of age. The maximal hip joint angle decreased in flexion and increased in extension with age (Fig. 3a). Similarly, the maximal ankle joint angle decreased in dorsiflexion and increased in planterflexion with age (Fig. 3c). On the other hand, there was no significant change with age in both of the maximal knee flexion and extension angle (Fig. 3b). Since the knee joint mobility did not change, the hip joint angle at the point 1-3 is considered to reflect the influence of the stretched hamstrings. Similarly, the hip joint angle at the point 2-3 and the ankle joint angle at the point 3-3 is considered to reflect the influence of the stretched rectus femoris and gastrocnemius, respectively. The regression analysis indicated significant correlation between each joint angle and age (Fig. 4).

![Figure 2](image-url)  
**Figure 2**: Typical combined range of motion of hip and knee joint (a), and ankle and knee joint (b) in young (20 years) and elder (70 years) age groups.
These results suggested the age-related reduction of the ROMs of hip and ankle joint and age-related shortenings of three biarticular muscles, i.e., hamstrings, rectus femoris and gastrocnemius. These age-related changes seem to result from their disuse associated with decline in the physical activity levels of daily living with advancing age. The present geometrical method is considered to be useful for systematic and quantitative assessment of the ROM of the lower limb joints.

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