Age-related Decline in Proprioception

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Joint-position sense of the knee was measured in 29 subjects with normal knee joints ranging in age from 20 to 82 years. Joint-position sense was determined by two common techniques that measure the threshold to detection of motion and the ability to reproduce passive knee positioning. Joint-position sense was found to deteriorate with increasing age as measured by both tests, with a correlation coefficient that was significant at the p < 0.001 level for each test. The two tests were found to correlate at the p < 0.025 level, indicating that the same biologic parameter was being measured by both tests. Deterioration of proprioception, or joint-position sense, as measured may be a sensitive indicator of subclinical degenerative joint disease of the knee, as well as a means of quantitating proprioception in suspected neuropathic joints.

Joint-position sense in the aging human has undergone relatively little study.[10] Knowledge of normal joint-position sense as a function of age has considerable clinical importance to the orthopedic surgeon. The incidence of degenerative arthritis increases with age, particularly in weight-bearing joints. Some pathologic change in cartilage and other joint structures is thought by many to be part of normal aging, with osteoarthritis representing one end of this spectrum.[9] Troubling, and sometimes disabling, pain is a commonly recognized symptom of the disease. Other sensory modalities, particularly joint-position sense (proprioception), may be affected as well. Patients with advanced arthritis often walk with an abnormal gait pattern that is not explained or directly related to the pain they experience. Some observers have suggested a decline in proprioception as a basis for the pathologic wide-based gait often observed.[7] Gait patterns are known to change with normal aging even in the absence of any signs or symptoms of joint disease.[11] An associated decline in joint-position sense might also be hypothesized. The change in joint morphology associated with aging might be either the cause or result of declining joint sensation, as has been proposed in arthritic patients.[13] Joint-position sense has been quantified by many observers;[2,3,5,8] however, its relation to age has not been established.

Kokmen *et al*[10] evaluated the sensitivity of perception of motion in the metacarpophalangeal and metatarsophalangeal joints in young and elderly normal subjects. Although older subjects detected motion less well at low frequencies, these investigators concluded that no major decline in joint-motion sensation occurred. To investigate further the effect of age on proprioception, joint-position sense was evaluated in a group

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MATERIALS AND METHODS

Twenty-nine volunteers ranging in age from 20 to 82 years with normal knees by history and by physical examination were selected. The volunteers were engineering graduate students, medical school faculty or staff, or hospital volunteers. The subjects were evaluated for joint-position sense by two methods.

An apparatus was designed to position patients consistently and to eliminate all external cues to limb motion except those emanating from the knee and surrounding tissue (Fig. 1). The subjects were seated, reclined to 60° to encourage relaxation, with the legs hanging freely over the side of the seat 4–6 cm proximal to the popliteal fossa. Custom-made Jobst air splints were fitted above and below the knee joint and inflated to 20 mm Hg to neutralize cutaneous sensation. The inflated thigh cuff was then immobilized in malleable Orthoplast splints; Velcro straps were used to ensure the same starting position for each test repetition. Movement of the extremity was accomplished by means of a wire attached to the tip of the leg air splint. Subjects were blindfolded to remove visual input.

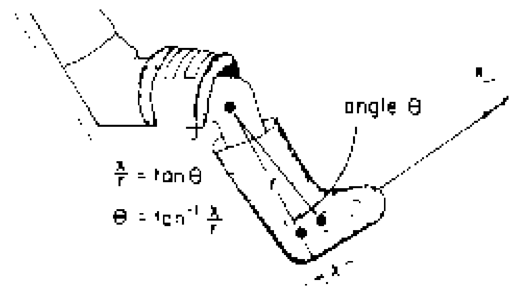

FIG. 1. Schematic representation of the proprioception apparatus.

Reproduction of Passive Positioning

Starting at a free-hanging position of 90° the examiner moved one of the legs by pulling the attached wire at a slow steady rate of approximately 10°/second. The leg was pulled along the natural line of extension of the leg, to a random angle of 5°–25° of extension from the starting position. Motion was totally passive with no assistance from the subject. The extremity was held by the examiner in this position for two to three seconds, and the subject was asked to concentrate on the present position of the leg. The knee was returned to the starting angle, and the subject was asked to return the leg to the previous position.

Since the leg is moved along a line approximately tangential to the arc of curvature of the leg, the linear displacement in millimeters can be converted to angular displacement, with maximum error calculated to be 1.3% for the relatively small angles involved. The distance from the medial joint line, through the medial malleolus, and to the heel was measured in each subject and used as the radius of curvature of the arc. The angular displacement is thus an approximation.

The test was repeated ten times, five in each leg, and a mean value was recorded for the accuracy in degrees to which the movements were reproduced.

Threshold to Passive Motion

Both leg air splints were suspended by wires attached to pulleys driven by a low-speed motor from which a long shaft extended. The position of the pulleys on the shaft was adjusted, ensuring that the legs were pulled along their natural arc of extension. A starting position of 60° as measured by a goniometer was used; the pull of gravity, thus, was already applied to the wire. This served to minimize any cues to the onset of motion. When the motor was started neither pulley was engaged, and the subject was given a control box with an on–off switch. He was informed that one of his legs would slowly change position at a random time, from five to 30 seconds after the motor was started; in this way auditory cues were eliminated. The shaft moved slowly at a precalibrated rate, which produced an angular deflection of 0.4°/second in each subject once the pulley was engaged. When the subject detected position change and pressed the button, he was asked which leg had changed position as a further control of validity of response. The linear movement of the wire was measured in millimeters and converted to angular deflection as described previously. Ten repetitions were performed in each subject, five in each leg in a random sequence. A mean value was calculated for each leg separately and for both combined.

RESULTS

Results of the measurements of reproduction for 58 knees are shown in Figure 2 as a function of age. The regression equation for the reproduction of angle test as a function of age is: reproduction (degrees) = 1.02

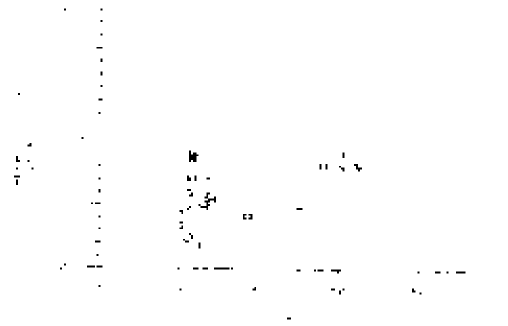

FIG. 2. Reproduction of passive positioning as a function of age. The angle on the vertical axis is the average difference between the set angle and the reproduction angle

+ 0.0590 × age (years). The correlation coefficient is 0.570, and the correlation is significant at $p < 0.001$. Figure 3 shows the variation of the measurement of threshold to detection of motion as a function of age. The correlation coefficient is 0.555, which is significant at the $p < 0.001$ level; the regression equation is: threshold (degrees) = 3.10 − 0.0456 × age (years). Threshold and reproduction were correlated, yielding a correlation coefficient of 0.293, which was significant only at the $p < 0.025$ level.

DISCUSSION

It is apparent from the results of the present study that joint-position sense is significantly related to age. The results of detection of motion were obtained at a single slow rate of knee extension. Kokmen *et al.*[10] noted a significantly lower motion-sensation threshold in young as compared with elderly groups at low speeds. This difference was lost at higher speeds, causing these investigators to conclude that position sense does not vary with age. Kokmen *et al.*[9] studied the metacarpophalangeal and metatarsophalangeal joints, which would be less likely to show the ravages of age than the weight-bearing knee joint used in the present study.

In addition, two accepted, independent tests of joint-position sense were utilized in the present study; both demonstrated a significant correlation of joint-position sense with age. The correlation of the two tests of position sense demonstrated a significant relation, showing that the same biologic parameter was being measured.

Aging is shown in the present study to be associated with a decline in joint-position sense. It is also well known that aging is associated with the arthritic changes described as degenerative joint disease.[7] Whether aging causes either the decline in joint-position sense or the degenerative joint disease is debatable. Sensory denervation of joints without motor denervation has been shown to result in degeneration of chondrocytes in the cartilage surface of joints.[4] These observations were considered to be similar to changes noted with aging by other investigators.[1] Finsterbush and Friedman[4] believed that trauma to the denervated joint was an important, although not primary, factor in the joint damage. Thus, it may be concluded that sensory denervation can cause aging changes in cartilage.

The association of diminished joint-position and pain sense has been considered important in the development of Charcot joints.[7–12] Thus, degenerative joint disease (with relatively intact pain and joint-position sense) and Charcot joint disease (with markedly diminished pain and joint-position sense) may be at opposite ends of a spectrum of symptomatic joint disease. Changes observed

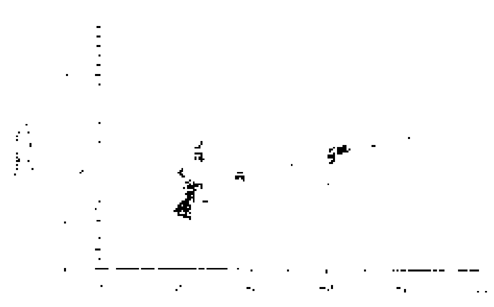

FIG. 3. The angular change in position of the knee at the threshold of detection of motion as a function of age.

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in joints with aging may be on the subclinical side of degenerative joint disease.

Results of the present study do not allow conclusions as to whether the decline in proprioception observed with aging is the cause or result of pathologic changes that occur in the joints. However, these results do suggest that proprioception as measured may be a sensitive method for detecting subclinical osteoarthritis. Furthermore, this type of proprioception measurement may become an accurate method for diagnosing neuropathic knee joint disease, which is frequently diagnosed presumptively on clinical grounds.[12]

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