Tai chi, a traditional Chinese exercise, has been practiced for centuries in China by the elderly and young to attain agility, balance, and posture control. Its beneficial effects on health have been observed, and the maintenance of balance control in older people in particular has drawn increasing attention from scientific researchers. A number of cross sectional and longitudinal studies have provided positive evidence that tai chi practitioners (TC) not only have better cardiorespiratory function,12 but also perform better in balance control13 and falls with aging may be regular physical activity.8

Methods: By detecting the threshold of passive movement, ankle and knee joint kinaesthesis was measured in 21 elderly long term tai chi practitioners (TC group), 20 elderly long term swimmers/runners (S/R group), and 27 elderly sedentary controls (control group).

Results: Ankle joint kinaesthesis differed significantly among the three groups (p = 0.001). Subjects in the TC group could detect a significantly smaller amount of motion than those in the S/R group (p = 0.022) and control group (p = 0.001). No significant difference was found between the S/R group and the control group (p = 0.701). The threshold for detection of passive motion was significantly different in knee extension and flexion. For knee flexion, the TC group showed a significantly lower mean threshold for detection of passive motion than the control group (p = 0.026). There were no significant differences between the S/R group and control group (p = 0.312), or between the TC group and S/R group (p = 0.533). For knee extension, no significant difference was noted among the three groups (p = 0.597).

Conclusions: The elderly people who regularly practiced tai chi not only showed better proprioception at the ankle and knee joints than sedentary controls, but also better ankle kinaesthesis than swimmers/runners. The large benefits of tai chi exercise on proprioception may result in the maintenance of balance control in older people.
1.5 hours a day over the previous four years or more (TC group). Twenty subjects had swum and/or run for at least one hour a day for four or more years (S/R group). The subjects in the TC and S/R groups had not done any other regular physical activity in the previous five years. Twenty seven subjects had not engaged in any regular exercise for more than four years (control group). No significant difference was noted in sex, age, height, and weight across the three groups (table 1).

Each subject gave written informed consent before participation. The study was approved by the local medical ethics committee.

**Measurement procedures**

Joint kinaesthesia is the sensation of joint movement; it is an important technique used to evaluate proprioception. Kinaesthesia is usually determined by establishing the threshold at which passive motion is detected, an assessment of the ability to detect relatively slow passive joint motion. We used it to assess knee and ankle joint proprioception.

Testing was performed in a well lit and well ventilated room. The room was sound attenuated and isolated so as to reduce any auditory or visual interference that might distract the participants. After their weight and height had been measured, each subject participated in two separate data collection sessions: measurement of ankle joint kinaesthesia and, after a brief rest period, measurement of knee joint kinaesthesia.

**Ankle joint kinaesthesia test**

Data were collected using the instrumentation and procedures described by Lentell et al. with minor modifications. As illustrated in fig 1, the custom made device is a box with a movable platform that rotates about a single axis in two directions. With the foot resting on this platform, plantar dorsi-flexion of ankle movements can occur. This platform is moved by an electric motor which rotates the foot on an axis at a rate of 0.4˚/s. Movement can be stopped at any time by the use of a hand held switch. The angular displacement achieved by the platform is calculated by the dents that the motor rotates.

The device is also equipped with a hanging scale and a fixed pulley supported by a trestle, which is outside of the device. A thigh cuff attached to the lower end of the scale is wrapped around the lower thigh of the subject. The method of assessing knee kinaesthesia was similar to those described in previous studies. As shown in fig 2, the apparatus consists of electric motor, governor, counter transmission, and linkage system. A moveable frame can rotate around a single axis in two directions at a velocity of 0.4˚/s. Angular displacement of the frame is calculated by the dents that the motor rotates.

Each subject performed two practice tests to become familiar with the test process before completing the trials. At least six randomised trials (three trials for extension, three trials for flexion) were performed on the dominant leg according to the following protocol. The subjects were instructed to concentrate on their foot and to press the hand switch when they could sense motion and identify the direction of the movement. After two practice trials had been performed, the motor was engaged to rotate the foot into dorsiflexion or plantarflexion at a random time interval between two and ten seconds after subject instruction. The researcher recorded the rotation angles of the platform and the direction of movements as passive motion sense. At least six randomised trials were conducted: three for planterflexion, three for dorsiflexion. The mean values of the three angles sensed in one direction were calculated.

**Table 1** Characteristics of elderly tai chi practitioners (TC group), swimmers/runners (S/R group), and sedentary controls (Control group)

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TC (n=22), 12M, 9F</td>
<td>66.1 (5.2)</td>
<td>163.6 (7.9)</td>
<td>64.8 (9.9)</td>
</tr>
<tr>
<td>S/R (n=20), 12M, 8F</td>
<td>65.4 (3.0)</td>
<td>164.1 (8.6)</td>
<td>66.5 (12.4)</td>
</tr>
<tr>
<td>Control (n=27), 15M, 12F</td>
<td>65.6 (3.9)</td>
<td>163.9 (7.8)</td>
<td>68.5 (10.9)</td>
</tr>
</tbody>
</table>

Values are mean (SD). M, male; F, female.
freely over the edge of the seat 5 cm proximal to the popliteal fossa. A custom made inflatable cuff was fitted above the knee joint and inflated to 20 mm Hg to neutralise cutaneous sensation. The axis of rotation of the knee joint was aligned with the axis of rotation of the frame. Then the researcher placed the lower part of the shank of the subject on the frame. An ankle inflatable cuff was applied and inflated to 20 mm Hg to reduce multisensory afferent discharge at the shank-machine interface. To further reduce unwanted sensory input, the subjects kept their eyes closed and wore headphones with music playing to eliminate the sight and sound of the apparatus.

The starting position of each trial was 45˚ of knee flexion as measured by an electrogoniometer (Penny and Giles, Christchurch, Dorset, UK). Subjects were told that their legs could move in a flexed or extended direction beginning at a random delay of 2–10 seconds after the examiner signalled the start of the test. Once the subject detected motion of the leg, he or she pressed a hand held stop button and confirmed the direction of the motion. The rotation angles of the frame were defined as the threshold of detection for the knee joint. Mean values of three trials in one direction were used for analysis.

Data analysis

All variables are presented as mean (SD). Values for passive motion sense of ankle and knee joint in different directions were respectively compared using paired t test in each group. Because there were no significant differences between the directions of ankle movement, plantarflexion, and dorsiflexion, data were averaged to produce ankle kinaesthesia. One way analysis of variance indicated significant differences in passive motion sense in knee flexion across the three groups (p = 0.025). Further analysis showed that the TC group had a significantly lower mean threshold for detection of passive motion than the subjects in the control group (p = 0.026). There were no significant differences between the S/R group and control group (p = 0.312), or between the TC group and S/R group (p = 0.533). For knee extension, no significant difference was found among the three groups (p = 0.597) (fig 4).

DISCUSSION

Although many studies have indicated that adoption of regular physical activity can attenuate the age related decline in many physiological systems, few have examined the effects of exercise on proprioception of old people, especially...
Tai chi exercise and proprioception

The postural control system operates as a control circuit between the sensory sources, central nervous system, and the musculoskeletal system. Proprioceptors and visual and vestibular centres contribute afferent information to the central nervous system on body position and balance.8 Colledge and his colleagues21 studied the relative contributions of vision, proprioception, and the vestibular system in different age groups. They found all age groups were more dependent on proprioception than on vision for the maintenance of balance. Camicioli et al22 also showed that disruption of proprioceptive input was the most important determinant of quantitative balance performance in subjects older than 80 years. Thus proprioception may greatly influence postural stability, and a decline in proprioception with aging could be associated with the increased propensity in elderly people to fall.8 The considerable benefits of tai chi exercise on proprioception may have significance for old people in maintaining balance.

Training has been widely reported to be one of the best ways to improve balance in the elderly.12,13 However, different kinds of exercise have been shown to have different effects on balance. Gauchard et al23 chose yoga and soft gymnastics as proprioceptive exercise, which consist of slow movements performed sequentially under different postural conditions; they compared the effects of proprioceptive exercise, bioenergetic physical activities (swimming, cycling, or jogging), and no exercise on postural control in elderly people. The results indicate that muscular strength was significantly increased in the bioenergetic exercise group, while proprioceptive exercise appeared to have the greatest effect on balance control. The authors pointed out that the ritual motions of tai chi are also proprioceptive exercise. From our results showing that elderly tai chi practitioners have improved proprioception, we suggest that maintaining, or delaying the decline in proprioception is closely associated with tai chi exercise improving balance control in old people.

Tai chi exercise is a series of individual graceful movements in a slow, continuous, circular pattern. In performing tai chi, awareness of movement sequencing starts from the feet, ankles, and legs, and the strong thigh muscles are used to concentrate the movement through and around the turning of the hips and waist, with the latter acting as the axis around which all body movements are executed. The movements of tai chi are gracefully fluent and consummately precise because specificity of joint angles and body position is of critical importance in accurately and correctly performing each form.24 Acute awareness of body position and movement is demanded by the nature of the activity. Thus it is logical that the practice of tai chi has benefits for proprioception, which is confirmed by our study.

Swimming and running are two of the most common exercises practiced by elderly people; they are excellent forms of aerobic exercise, and provide good training stimuli for cardiopulmonary function and muscle strength. Compared with tai chi, swimming and running involve cyclic repetitive actions. Awareness of joint position and movement is not emphasised during these exercise forms. In addition, most elderly people exercise only to enhance health and for recreation; they usually do not pay much attention to joint position and angles during exercise, unless such awareness is required in certain forms of exercise, such as tai chi. This may help to explain why the swimmers/runners did not have better scores for knee and ankle kinaesthesia in this study.

It is of particular interest that the effects of tai chi on proprioception were different in the knee and ankle joints. The effect on ankle joint kinaesthesia was more prominent than on knee joint kinaesthesia. The passive motion sense of the ankle joint in the TC group was significantly better than in both the sedentary control group and the S/R group. However, for the knee joint, tai chi exercise only produced a better effect than in the sedentary control group. These results may be attributable to the characteristics of tai chi movements. The old tai chi proverb states, “When performing tai chi, the feet act as roots”. Although almost all tai chi forms are performed in a semi-squat position, which enhances the loading of the muscles and motion ranges of the knee joints, the continuous transformation of different postures and steps cause more changes in ankle joint movements, such as turning the toes outward or inward and raising or lowering the toes. Moreover, while making a stride, foot placement is slow and deliberate. These movements may help to retain the sensitivity of proprioceptors located in the joint capsules, ligaments, tendons, and muscles.

Ankle proprioception is very important for the elderly to maintain proper postural control. Many studies have indicated that the movement pattern for postural correction in elderly adults is different from that of young adults. The elderly rely more on hip movements, while young people rely on ankle movements to control postural stability.25 A decline in somatosensory information from the feet is a major factor in this pattern change with age.22 Therefore the considerable impact of tai chi practice on ankle proprioception is of great benefit in the retention of balance control in old people.

The decline in proprioception with age may be an important contributing factor to falls in the elderly, and this may be influenced by regular physical activity. This study shows that, compared with other common activities, long term tai chi exercise may have more benefit in retaining proprioception of the ankle and knee joints, which may be valuable for maintaining balance control in the elderly.

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