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Original article

Relation among the knee, sagittal spinal alignment, and the spinal range of motion: Investigation in local medical check-ups using the SpinalMouse

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Abstract

Background: This study was designed as an investigation in a local population to assess the relation between the knee joint and spinal alignment in a population-based study using the SpinalMouse.
Methods: Medical check-ups were conducted for residents of a mountain village in Japan. The study population included 107 men and 157 women (528 knees) with a mean age of 71.1 ± 6.8 years (range, 60–87 years). A questionnaire dealing with any current symptoms involving the knees was administered, and physical examinations dealing with the range of motion (ROM) of knee were conducted. The SpinalMouse was used to measure sagittal spinal alignment and spinal ROM. The parameters considered were thoracic kyphosis angle, lumbar lordosis angle (LLA), sacral inclination angle (SIA), and trunk angle of inclination (INC). The patients were divided into a group with knee flexion contracture (FC group) and a group without knee FC (non-FC group) to conduct a comparative study of both groups.
Results: With regard to static spinal alignment, LLA and SIA decreased significantly in the FC group ($p < 0.05$). With regard to spinal ROM, LLA and INC decreased significantly in the FC group ($p < 0.05$).
Conclusion: Results suggested that the knee and the spine affect each other and that the spinal ROM is also involved. The current study may explain the development of knee-spine syndrome.

Keywords: knee; sagittal spinal alignment; SpinalMouse; spinal range of motion

Introduction

Knee osteoarthritis often causes flexion contractures (FC), which affect the ability to perform daily activities.[1] Tsuji et al[2] reported a correlation between the spinal alignment and the knee joint, which they called knee–spine syndrome; however, the pathogenesis has not been clarified. In addition, previous studies have examined outpatients or simulated knee FCs, and little has been reported on the relationship between the knee and the spine. Moreover, few reports have described the relationship between the knee joint and spinal alignment as ascertained from a population-based study.

This study was designed as a population-based study using the SpinalMouse to assess the relationship between the knee joint and spinal alignment in a local population. Our hypothesis is that the knee and the spine affect each other and that the

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spinal range of motion (ROM) is involved in the pathogenesis of knee osteoarthritis.

Materials and methods

This cross-sectional study was approved by the institutional Review Board of our institution. All patients, prior to giving their consent to participate in this study, were informed that their data would be published. To help prevent lifestyle-related diseases and aid the early detection of cancer, medical check-ups were conducted in Japan for residents of a mountain village, where agroforestry and tourism are the main industries. A statistical power analysis based on the median effective dose indicated an optimal sample size as > 100 patients, with a significance level of 5% and statistical power of 0.95. The study included 107 men and 157 women (528 knees), with a mean age of 71.1 ± 6.8 years (range, 60–87 years).

A questionnaire was administered regarding the patients' age and sex. We also conducted physical examinations to determine the ROM of the knees in the supine position using a goniometer. The goniometer axis was set on the lateral epicondyle of the femur, while the proximal arm was set parallel to the long axis of the femur and the distal arm was set parallel to the long axis of the fibula and pointing at the lateral malleolus. We used the SpinalMouse (Idiag AG, Volketswil, Switzerland), an electronic computer-aided measuring device, to measure the sagittal spinal ROM and intersegmental angles noninvasively, according to a so-called surface-based technique, to determine the sagittal spinal alignment and ROM (Fig. 1).[3,4] The device was connected to a standard personal computer via an analogue-to-digital converter. The SpinalMouse was placed manually on the patient's skin surface and moved paravertebrally along the patient's spinal column from C7 to S3, while adhering to the body surface of the patient. The device was moved gently to prevent erroneous measurements. The system recorded the outline of the skin surface over the sagittal spinal column. The patient was asked to take three consecutive positions: erect, maximal flexion, and maximal extension of the spine. One measurement was taken in each position. The relevant parameters recorded in each position were as follows: all individual motion segment angles (T1/2–L5/S1), thoracic kyphosis angle (TKA; T1/2–T11/12), lumbar lordosis angle (LLA; T12/L1 to the sacrum), sacral inclination angle (SIA), and trunk angle of inclination (INC; angle subtended between the vertical and a line joining C7 to the sacrum). The intraclass coefficients for the curvature measurements obtained using the SpinalMouse were calculated to be 0.92–0.95.[3,4] To conduct a comparative study of two groups, the patients were divided into a group with knee FCs of knee extension loss > 5° (FC group) and a group without knee FCs (non-FC group). The differences between the two groups in terms of age, sex, ROM of the knee, TKA, LLA, SIA, and INC were compared using Welch *t* test and the Chi-square test. All statistical analyses were conducted using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA). Significance was inferred for $p < 0.05$.

Results

The FC group included 229 knees, and the non-FC group included 299 knees. Significant differences were found between the two groups for age (72.2 ± 6.2 years in the FC group; 70.2 ± 7.0 years in the non-FC group, $p < 0.01$), but not for sex (males accounted for 39.3% of the patients in the FC group and 41.8% of the patients in the non-FC group, $p = 0.272$; Table 1). The degree of knee flexion was significantly lower in the FC group (142.3 ± 6.9 in the FC group and 139.4 ± 9.5 in the non-FC group). With regard to static spinal alignment, the results for the FC group were TKA 37.6 ± 15.6°, LLA −18.9 ± 12.3°, SIA 10.7 ± 7.5°, and INC

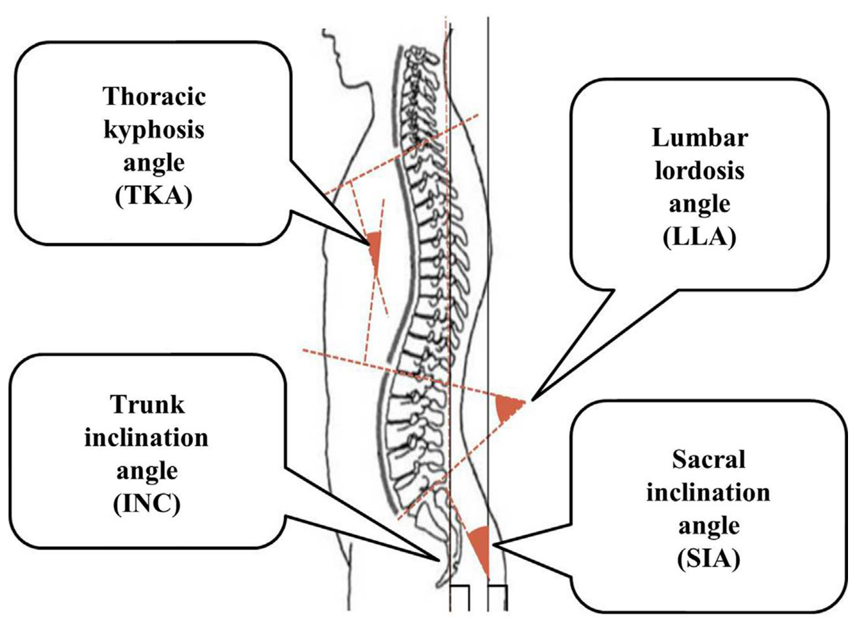

Fig. 1. An electronic computer-aided measuring device was used to measure the sagittal spinal range of motion (ROM) noninvasively. Intersegmental angles were used with a surface-based technique to measure the sagittal spinal alignment and ROM.

Table 1
Relation between the FC group and the non-FC group.

	FC group ($n = 229$)	Non-FC group ($n = 299$)	p
Age (y)	72.2 ± 6.2	70.2 ± 7.0	0.010
Sex (male:female)	90:139	124:175	0.272
Knee flexion (°)	139.4 ± 9.5	142.3 ± 6.9	< 0.001

FC = flexion contracture.

4.2 ± 5.3°, whereas the results for the non-FC group were TKA 37.2 ± 13.7°, LLA −20.9 ± 11.0°, SIA 12.1 ± 7.6°, and INC 3.6 ± 4.2°. The results showed that the LLA and SIA values were significantly lower in the FC group ($p < 0.05$; Table 2). Regarding spinal ROM, the results for the FC group were TKA 47.4 ± 18.0°, LLA 21.0 ± 14.1°, SIA 53.1 ± 17.1°, and INC 83.5 ± 17.1°, whereas the results for the non-FC group were TKA 22.5 ± 17.8°, LLA 51.0 ± 16.8°, SIA 55.9 ± 23.6°, and INC 105.9 ± 24.7°, indicating a significant decrease in the LLA and INC values in the FC group ($p < 0.05$; Table 3).

Discussion

The most important findings of this population-based study are that the knee and the spine affect each other and the spinal ROM. This is the first report of a population-based investigation of the relationship between the knee joint and spinal alignment.

Japanese society is aging rapidly, and the incidence of Japanese patients with joint disorders is increasing.[5] Therefore, elucidating risk factors affecting the incidence and progression of joint disorders is important to prevent such disorders. Degenerative changes of the knee often cause FCs, and Offierski and MacNab[6] reported that symptomatic diseases of both the hip and spine may produce a complex hip-spine syndrome. However, the standing posture alignment depends not only on the spine, but also on the hip and knee joints. Murata et al[7] reported that lordosis is significantly less common in patients with a knee extension limitation greater than 5°. Harato et al[8] reported that knee FCs significantly influence the three-dimensional trunk kinematics during relaxed standing and level walking. They inferred that the dynamic changes in trunk motion observed during walking engender changes in the spinal alignment, which may contribute to the development of spinal deformities. These observations may explain the onset of “knee-spine syndrome”. In these studies, knee extension limitation was related to a decrease in lumbar lordosis on sagittal plane radiographs or a gait analysis system, and few reports have described the relationship between the knee and spine using the SpinalMouse. Furthermore, previous studies have examined outpatients or simulated knee FCs, and little has been reported regarding the relationship between the knee and spine. Based on the current findings, lumbar lordosis was significantly less prevalent in the FC group, which confirmed the relationship between FCs and spinal alignment in this population-based study.

Table 2
Sagittal spinal alignment.

Parameter (°)	FC group ($n = 229$)	Non-FC group ($n = 299$)	p
Thoracic kyphosis angle	37.6 ± 15.6	37.2 ± 13.7	0.262
Lumbar lordosis angle	−18.9 ± 12.3	−20.9 ± 11.0	0.018
Sacral inclination angle	10.7 ± 7.5	12.1 ± 7.6	0.036
Trunk angle of inclination	4.2 ± 5.3	3.6 ± 4.2	0.072

FC = flexion contracture.

Table 3
Spinal range of motion.

Parameter (°)	FC group ($n = 229$)	Non-FC group ($n = 299$)	p
Thoracic kyphosis angle	47.4 ± 18.0	22.5 ± 17.8	< 0.001
Lumbar lordosis angle	21.0 ± 14.1	51.0 ± 16.8	< 0.001
Sacral inclination angle	53.1 ± 17.1	55.9 ± 23.6	0.121
Trunk angle of inclination	83.5 ± 17.1	105.9 ± 24.7	< 0.001

FC = flexion contracture.

The SpinalMouse is available for the noninvasive assessment of spinal alignment and movement.[3,4,9,10] The SpinalMouse makes contact with the patient's body surface and is then moved gently to prevent erroneous measurements. The intraclass coefficients for the curvature measurements obtained with the SpinalMouse have been reported to be 0.92-0.95.[3,4] In addition, previous studies have demonstrated that the thoracic and lumbar kyphosis angles and spinal ROMs measured using the SpinalMouse strongly correlate with those measured using spinal radiographs.[11] Imagama et al[12] reported that SpinalMouse data showed a significant correlation with radiological measurements in their population-based study. Because of cost considerations and the limited time allotted for this population-based study, we used the SpinalMouse to examine the patients quickly. Obtaining spinal ROM measurements is also possible using the SpinalMouse. However, there are no reports in the relevant literature describing the relationship between the knee joint and the spinal ROM. Takemitsu et al[13] reported that standing sagittal spinal malalignment results from decreasing trunk muscular strength and spinal ROM with age and that the amplitude of the quadriceps and biceps muscles of the thigh is high, as ascertained using electroneuromyography. The authors postulated that patients showing sacrum dorsal tilting stand in a knee flexion position to gain a mechanical advantage, which increases the tension of the lower muscles. They also speculated that this tendency influences the knee joint. Tsuji et al[2] reported that changing the spinal alignment causes patients to assume the knee flexion position, which subsequently increases tension in the thigh muscles. Furthermore, tight hamstrings are known to occur in patients with knee FCs. A tight hamstring decreases spinal flexibility.[14] The results of this study demonstrate that the knee joint, spine, and spine ROM mutually interact with each other. Regarding TKA, flexibility was increased in the FC group, suggesting a mechanism compensating for the loss of lumbar spine flexibility. As to the onset of knee-spine syndrome, the possible participation of a decrease in spinal ROM can be inferred from these results.

This study is associated with several limitations. First, this was a large-scale population-based study, although the baseline data were cross sectional. Therefore, it is necessary to continue research in this area to confirm the changes in alignment using a longitudinal design. Second, the FC group was markedly larger than the non-FC group. For this reason, there may have been an influence of age on the results. Third, it remains unclear whether lumbar spine or knee deformities are the primary factor for this condition. We will continue to investigate this point.

To summarize, the knee and spine affect each other. The spinal ROM is also affected in patients with disorders of the knee joint. These results suggest that the involvement of spinal ROM decreases lumbar lordosis and sacral inclination during knee FCs. The current observations may explain the development of knee–spine syndrome.

Conflicts of interest

All contributing authors declare no conflicts of interest

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