Eur Spine J (2011) 20:954–961
DOI 10.1007/s00586-010-1606-4

ORIGINAL ARTICLE

Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males

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Received: 27 April 2009 / Revised: 18 August 2010 / Accepted: 17 October 2010 / Published online: 31 October 2010

Abstract With aging of society, clarification of the relationship between QOL and abnormal posture in the elderly may allow improvement of QOL through any preventive methods and training. However, sagittal balance has not been studied widely and most studies have focused on postmenopausal patients with osteoporosis. In this report, we provide the first evaluation of the simultaneous effects of degenerative changes on radiograph, spinal range of motion (ROM), sagittal balance, and back muscle strength, and examine the influence of these effects on QOL of the middle-aged and elderly male subjects. The subjects were 100 Japanese males who underwent a basic health checkup. Lumbar lateral radiograph, sagittal balance and spinal mobility determined with SpinalMouse® and back muscle strength were measured. The thoracic/lumbar angle ratio (*T*/*L* ratio) was used as an index of sagittal balance. SF-36 physical component summary (PCS) scores showed a significant negative correlation with age ($r = -0.377$), osteophyte score ($r = -0.246$) and *T*/*L* ratio ($r = -0.214$), and a significant positive correlation with lumbar lordosis angle ($r = 0.271$), thoracic ROM ($r = 0.282$), and back muscle strength ($r = 0.549$). Multiple regression analysis indicated that thoracic spinal ROM ($r = 0.254$, $p < 0.01$) and back muscle strength ($r = 0.488$, $p < 0.0001$) were significantly associated with SF-36 PCS ($R^2 = 0.403$). In conclusion, QOL of the middle-aged and elderly male subjects was related to sagittal balance, lumbar lordosis angle, spinal ROM, and back muscle strength. Exercise including muscle strength and spinal ROM may be able to influence these primary factors related to QOL. Back muscle strength and thoracic ROM impact on improvement of QOL in the middle-aged and the elderly.

Keywords Quality of life · Middle-aged and elderly males · Back muscle strength · Spinal mobility · Sagittal balance

Introduction

The need for independence of the elderly and improvement of their quality of life (QOL) has arisen with the rapid increase in the elderly population in recent years. The percentage of people aged 65 years old or older among the total population is currently 12.3 and 21% in the US and Japan, respectively, and is increasing yearly. Medical and nursing care costs will increase with an increase in the number of elderly with difficulty in maintaining independence in their activity of daily life (ADL), causing serious social problems.

Spinal compression fracture and femoral neck fracture in patients with osteoporosis are common and negative factors associated with a decrease in QOL [1, 2]. However, many elderly people have abnormal posture, represented by hyperkyphosis, without pain or a history of such fractures. Recent studies demonstrates that many older adults who are mostly affected by hyperkyphosis do not have vertebral fractures [3], and other postulated causes of hyperkyphosis include postural changes [4], degenerative disc disease [5],

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muscular weakness [6, 7], ligamentous degeneration [8], and genetic predisposition [9]. Such abnormal posture may be associated with multiple adverse health outcomes, including gait disorder, becoming bedridden. Abdominal compression, impaired pulmonary function, fractures, and possibly increased risk for death [3, 10–12]. Therefore, clarification of the relationship between QOL and abnormal posture in the elderly may help to improve QOL through preventive methods and exercise.

However, sagittal balance has not been studied widely and most studies have focused on postmenopausal patients with osteoporosis or thoracic kyphosis associated with spinal compression fracture [13, 14]; thus, elderly male patients have largely been excluded from these studies. However, the aging of society requires studies on elderly male patients. The objective of this study was to evaluate age-related changes in the lumbar spine, sagittal balance, spinal mobility, and back muscle strength in middle-aged and elderly males, and to determine the relationship with QOL.

Subjects and methods

The subjects were Japanese healthy volunteers who attended a "basic health checkup" supported by a local government in 2007. This checkup has been held in Y town for 27 years annually and is well known among local people, many of whom attend every year. The current study was performed in 100 males who received examinations with SpinalMouse®(Idiag, Volkerswill, Switzerland) for sagittal balance and spinal mobility among 315 (male, 110; female, 205) who underwent lumbar radiograph. The average age of the 100 male subjects was 70 years (54–91). Ten males were excluded from the study because two had a history of spinal surgery, three had a history of spinal compression fracture, and five did not agree to the study. None had either rheumatoid arthritis or hemodialysis.

Lumbar lateral standing radiograph, SpinalMouse®, back muscle strength, and QOL were examined as described below. The study protocol was approved by the Committee on Ethics in Human Research of Nagoya University.

Radiographic evaluation

The lumbar lordosis angle (L1–S1) and sacral inclination angle were measured using lumbar lateral standing radiograph, and osteophyte formation and disc height were determined as markers of degeneration. Osteophyte formation was evaluated using the Nathan classification (0–4) and the total score (osteophyte score, 0–20) for L1/2–L5/S1 in this classification was also determined [15]. The degree of disc height narrowing was scored based on the scale of Miyakoshi et al. [16], in which 0, 1 and 2 reflect a 0–20, 20–50 and >50% reduction in disc height compared with the L1–L2 disc, and the total score from the L2–L3 to the L5–S1 discs was defined as the disc score. A disc score of 0 corresponds to no disc degeneration.

To assess the effect of potential interobserver error in grading disc narrowing and osteophytes, 20 radiographs with images of 100 discs and intervertebral osteophytes were evaluated independently by 5 spinal surgeons. The intraclass correlation coefficients in this analysis were 0.96 for disc height narrowing and 0.93 for osteophytes, and both were highly significant.

Evaluation of SpinalMouse®

Spinal range of motion (ROM) and spinal angle were measured using SpinalMouse®, which is an electronic computer-aided device that measures sagittal spinal ROM and intersegmental angles noninvasively using the so-called surface technique. Intraclass coefficients of 0.92–0.95 have been determined for curvature measurement with SpinalMouse® [17]. In the current study, each angle was measured three times in a neutral standing position, maximum bending position, and maximum extension position, and average data were used. The evaluation items included the thoracic kyphosis angle, lumbar lordosis angle, sacral inclination angle, thoracic ROM, lumbar ROM and total spinal ROM. The thoracic kyphosis and lumbar lordosis angles are expressed as positive values in this study. Correlations of the lumbar lordosis angle and sacral inclination angle with lumbar radiograph were examined to confirm the reproducibility of SpinalMouse® measurements. The value obtained by dividing the thoracic kyphosis angle (neutral position), a marker of posture with the head bent forward, by the lumbar lordosis angle (neutral position) was defined as the thoracic/lumbar angle ratio (T/L ratio) and used as an index of sagittal balance. Jackson defined the T/L ratio as reflecting the sagittal balance and suggested that this ratio ranges from 0.15 to 0.75 [18–20]. We also investigated the T/L ratio in Japanese volunteers and found that values between 0.4 and 1.1 reflect "congruent sagittal alignment" [21, 22]. An examination of the whole spine radiograph is strictly required to evaluate sagittal balance. However, we cannot check the whole spine radiograph in a basic health checkup, and therefore we used the SpinalMouse® for evaluating spinal balance.

Back muscle strength

Back muscle strength was determined from the maximal isometric strength of the trunk muscles in a standing posture with 30° lumbar flexion using a digital back muscle strength meter (T.K.K.5402, Takei Co., Japan) [23]. The average force from two trials was recorded. The maximum strength in each trial was measured and these values showed high reproducibility ($r = 0.990$, $p < 0.0001$). All subjects were assessed by one examiner who was blinded to the results of other evaluations.

QOL

The SF-36 (Japanese version 2.0) was used for evaluation of QOL [24]. Support was provided so that the subjects could answer all questions by themselves. The eight scales and two summary measures of the SF-36, the Physical Component Summary (PCS) and the Mental Component Summary (MCS), were evaluated and their correlation with other factors was examined.

Statistical analysis

All data are shown as means ± standard deviation (SD). Correlations between variables were analyzed using Pearson's correlation coefficient and simple regression analysis. Further analyses using multiple regression were conducted to determine which variables best correlated with QOL. Probability values of less than 0.05 were considered to be statistically significant.

Results

Evaluation of the SpinalMouse® data revealed a significant correlation of lumbar radiographic data with the lumbar lordosis angle ($r = 0.672$, $p < 0.0001$) and sacral inclination angle ($r = 0.551$, $p < 0.0001$). This confirmed the reliability of the SpinalMouse® measurements of these angles and the data were then used in further analysis.

The mean values of age and measured variables in the subjects are listed in Table 1 and correlations between variables are shown in Table 2. Age was significantly negatively correlated with lumbar lordosis angle and back muscle strength, and significantly positively correlated with total osteophyte score and *T*/*L* ratio. The total osteophyte score and disc score confirmed in the radiograph were correlated negatively with the lumbar lordosis angle and positively with the *T*/*L* ratio. The *T*/*L* ratio showed a significant negative correlation with lumbar lordosis angle, thoracic ROM, lumbar ROM and back muscle strength, and total spinal ROM had a significant positive correlation with lumbar ROM and back muscle strength, but no correlation with thoracic factors. A significant correlation of back muscle strength was found with all items except for thoracic kyphosis angle, thoracic ROM, and sacral inclination angle.

Regarding QOL, SF-36 PCS showed a significant negative correlation with age, osteophyte score and *T*/*L* ratio, a high positive correlation with back muscle strength, and a significant positive correlation with lumbar lordosis angle and thoracic ROM. SF-36 MCS showed a significant positive correlation with back muscle strength only. Correlations between each SF-36 scale and the measured variables were also evaluated (Table 3). Physical functioning (PF), which largely affects SF-36 PCS, showed a significant negative correlation with *T*/*L* ratio and other factors. Lumbar lordosis angle, thoracic ROM, lumbar ROM and total spinal ROM showed a significant positive correlation with PF or Role-Physical (RF). Among all the factors, only back muscle strength showed a significant positive correlation with all SF-36 scales, but all factors except for thoracic kyphosis angle and sacral inclination angle had correlations with some SF-36 scales. Based on these results, age, total osteophyte score, lumbar lordosis angle, *T*/*L* ratio, thoracic spinal ROM, and back muscle strength were selected as independent variables in a multiple regression model for SF-36 PCS.

Multiple regression analysis of the factors potentially associated with SF-36 PCS showed that thoracic spinal ROM and back muscle strength were significant contributors to the SF-36 PCS score (Table 4). None of the other

Table 1 Data for the study subjects

Variables	Mean	SD	Range
Age (years)	70.2	7.1	54–91
Osteophyte score (total)	7.91	3.9	0–16
Disc score (total)	1.1	1.5	0–6
Thoracic kyphosis angle (°)	39.0	10.9	4–68
Lumbar lordosis angle (°)	18.3	10.5	−13 to 38
Sacral inclination angle (°)	5.6	7.4	−13 to 23
T/*L* ratio	4.1	5.4	0.31–29.5
Thoracic spinal ROM (°)	23.6	11.8	3–51
Lumbar spinal ROM (°)	48.3	14.2	18–80
Total spinal ROM (°)	113.3	19.5	63–158
Back muscle strength (kg)	92.0	30.0	32–168.5
SF-36			
PF	84.2	13.9	50–100
RP	80.9	23.1	12.5–100
BP	70.1	22.4	31–100
GH	61.5	16.9	20–100
VT	67.4	18.6	25–100
SF	87.1	17.8	25–100
RE	83.4	22.2	25–100
MH	75.8	16.3	40–100
PCS	50.0	12.0	9.65–63.7
MCS	53.1	8.0	36.3–68.5

T/*L ratio* thoracic/lumbar angle ratio, *ROM* range of motion, *PF* physical functioning, *RP* role-physical, *BP* bodily pain, *GH* general health perception, *VT* vitality, *SF* social functioning, *RE* role-emotional, *MH* mental health, *PCS* physical component summary, *MCS* mental component summary

Table 2 Correlations between measured variables

Variables	Age (years)	Osteophyte score (total)	Disc score (total)	Thoracic kyphosis angle (°)	Lumbar lordosis angle(°)	Sacral inclination angle (°)	*T/L* ratio	Thoracic spinal ROM (°)	Lumbar spinal ROM (°)	Total spinal ROM (°)	Back muscle strength (kg)	SF-36 PCS	SF-36 MCS
Age (years)		0.317***	0.177	−0.077	−0.351*****	−0.181	0.242*	−0.152	−0.053	−0.163	−0.380*****	−0.377***	−0.035
Osteophyte score (total)			0.258*	−0.024	−0.256*	−0.133	0.318***	−0.169	−0.199	−0.137	−0.222*	−0.246*	−0.005
Disc score (total)				0.003	−0.250*	−0.107	0.357****	−0.047	0.041	0.007	−0.316***	−0.193	−0.004
Thoracic kyphosis angle (°)					0.331***	−0.012	0.028	−0.109	−0.021	−0.051	−0.118	−0.041	−0.010
Lumbar lordosis angle (°)						0.708*****	−0.556*****	−0.018	0.240*	0.182	0.304***	0.271*	−0.044
Sacral inclination angle (°)							−0.544*****	0.028	0.225*	0.004	0.137	0.172	−0.096
T/L ratio								−0.204*	−0.289**	−0.073	−0.332***	−0.211*	0.099
Thoracic spinal ROM (°)									−0.128	−0.150	0.126	0.282**	−0.043
Lumbar spinal ROM (°)										0.359*****	0.219*	0.198	0.128
Total spinal ROM (°)											0.218*	0.127	0.080
Back muscle strength (kg)												0.549*****	0.236*
SF-36 PCS													0.215*
SF-36 MCS													

T/L ratio thoracic/lumbar angle ratio, *ROM* range of motion, *PCS* physical component summary, *MCS* mental component summary

Data are Pearson's correlation coefficients (*r*). *$p < 0.05$; **$p < 0.01$; ***$p < 0.005$; ****$p < 0.001$; *****$p < 0.0005$; or ******$p < 0.0001$

variables in this model were significantly associated with SF-36 PCS. The coefficient of determination (R^2) in the multiple regression model was 0.403, indicating that 40.3% of the variability in SF-36 PCS score was explained by all the variables.

Discussion

Some reports have shown a decrease in ADL and QOL in association with compression fracture and spinal deformity in osteoporosis patients [25–31]. Recently, Miyakoshi et al. [13, 32, 33] investigated spinal ROM in postmenopausal patients with osteoporosis aged 50 years or older and found that a decrease in spinal ROM had negative effects on QOL, and that deterioration of back muscle strength was the most important factor decreasing spinal ROM, indicating that maintenance of back muscle strength and lumbar ROM are important for QOL. Hongo et al. [14] also showed that back muscle training caused a significant improvement of QOL in a randomized controlled study. However, these studies have focused on postmenopausal patients with osteoporosis so the aging of society requires studies on elderly male patients. Therefore, our interest grew on the influence of spinal aging on QOL of elderly males. The current study is the first to evaluate the influence of degenerative change on radiograph, spinal ROM, sagittal balance and back muscle strength and to determine the relationship with QOL.

SpinalMouse®

The SpinalMouse® provides a simple and noninvasive test that has been shown to be reliable in many reports [17, 34–36]. In this study, SpinalMouse® data showed a significant correlation with lumbar radiograph. However, the reliability of the test decreases in persons with thick soft tissues or for lower lumbar vertebra data, and measurement is also difficult in patients with surgical resection of the spinous process. We also found that SpinalMouse® measurements were significantly related to radiological measurements, but the correlation was not high. However, the SpinalMouse® is suitable for ROM evaluation based on differences in measurement and comparison of alignments, and can be used for evaluation of total spinal mobility over a short period of time with no side effects. In a health checkup, it is particularly difficult to evaluate a functional radiograph or a whole spine radiograph due to cost and limited time. Thus, the SpinalMouse® is a useful tool for measurement of spinal mobility and alignment.

Sagittal balance in the elderly

Our results suggest that with aging the *T/L* ratio increases with a decrease in lumbar lordosis angle and back muscle

Table 3 Correlations between SF-36 scales and other variables in the study subjects

Variables	PF	RF	BP	GH	VT	SF	RE	MH
Age (years)	−0.303***	−0.343***	−0.132	−0.147	−0.161	−0.129	−0.285**	−0.171
Osteophyte score (total)	−0.222*	−0.195	−0.241*	−0.104	−0.041	−0.088	−0.186	−0.083
Disc score (total)	−0.213*	−0.161	−0.208*	−0.107	−0.018	−0.008	−0.112	−0.096
Thoracic kyphosis angle (°)	0.038	−0.043	−0.074	0.100	−0.088	−0.032	−0.096	0.009
Lumbar lordosis angle (°)	0.339***	0.276**	0.120	0.140	0.063	0.063	0.143	0.065
Sacral inclination angle (°)	0.199	0.157	0.078	−0.082	0.013	0.059	0.081	−0.009
T/L ratio	−0.267**	−0.166	−0.130	−0.073	0.015	−0.028	−0.086	0.037
Thoracic spinal ROM (°)	0.218*	0.256*	0.162	0.147	0.009	0.149	0.216*	0.026
Lumbar spinal ROM (°)	0.123	0.276**	0.247*	0.061	0.183	0.136	0.183	0.193
Total spinal ROM (°)	0.217*	0.195	0.110	0.094	0.108	−0.014	0.028	0.203
Back muscle strength (kg)	0.506******	0.558******	0.450******	0.351****	0.415******	0.398*****	0.408******	0.280**

T/L ratio thoracic/lumbar angle ratio, *ROM* range of motion, *PF* physical functioning, *RP* role-physical, *BP* bodily pain, *GH* general health perception, *VT* vitality, *SF* social functioning, *RE* role-emotional, *MH* mental health

Data are Pearson's correlation coefficient (*r*). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$; **** $p < 0.001$; ***** $p < 0.0005$; or ****** $p < 0.0001$

Table 4 Multiple regression analysis of factors associated with SF-36 PCS in the study subjects

Variables	Coefficient (*r*)	Significance (*p*)
Age (years)	−0.069	0.4938
Osteophyte score (total)	−0.074	0.4375
Lumbar lordosis angle (°)	0.209	0.0756
T/L ratio	0.165	0.1612
Thoracic spinal ROM (°)	0.254	0.0063
Back muscle strength (kg)	0.488	<0.0001

PCS physical component summary, *T/L ratio* thoracic/lumbar angle ratio, *ROM* range of motion

strength, which results in sagittal imbalance. Generally, an increase in the thoracic kyphosis angle causes lumbar hyperlordosis to maintain sagittal balance [21, 22]. In this study, the thoracic kyphosis angle was not particularly large, perhaps because the subjects were males with no history of thoracic compression fracture. However, decreases in the lumbar lordosis angle and sacral inclination angle due to aging-related changes such as osteophyte formation or disc degeneration resulted in an increased *T/L* ratio, causing a posture with the head bent forward (Fig. 1). The *T/L* ratio can be close to 1 to maintain sagittal balance, even when the lumbar lordosis angle and sacral inclination angle decrease, provided that the thoracic kyphosis angle undergoes a compensatory decrease [21, 22]. However, we found a significant negative correlation between thoracic ROM and *T/L* ratio, and deterioration of sagittal balance was apparent in persons with low thoracic ROM. Regardless of the presence of thoracic compression fracture and thoracic kyphosis, the thoracic spine of elderly persons with low spinal mobility cannot bear decreased lumbar lordosis, and the thoracic kyphosis angle does not decrease, causing a posture with the head bent forward and sagittal imbalance (Fig. 1). In addition, our results showed that sagittal balance was maintained well in subjects with both good thoracic ROM and good lumbar ROM and back muscle strength, which indicates that these factors are also related to maintenance of sagittal balance. Sagittal imbalance can cause abnormal posture, gait disorder and a high risk of falling [11], and may be linked to spinal compression fracture due to forward loading on spinal vertebrae, resulting in increased falling in persons with a posture with the head bent forward and deterioration of ADL and QOL. To avoid this vicious circle, it is important for the elderly to maintain sagittal balance by exercise for spinal ROM and back muscle strength. Recent reports also demonstrated that spinal flexibility exercises reduced hyperkyphosis in older persons [37, 38].

Effects of sagittal balance, spinal ROM, and back muscle strength on QOL of males

Previous reports have shown that maintenance of back muscle strength, spinal ROM, and especially lumbar ROM

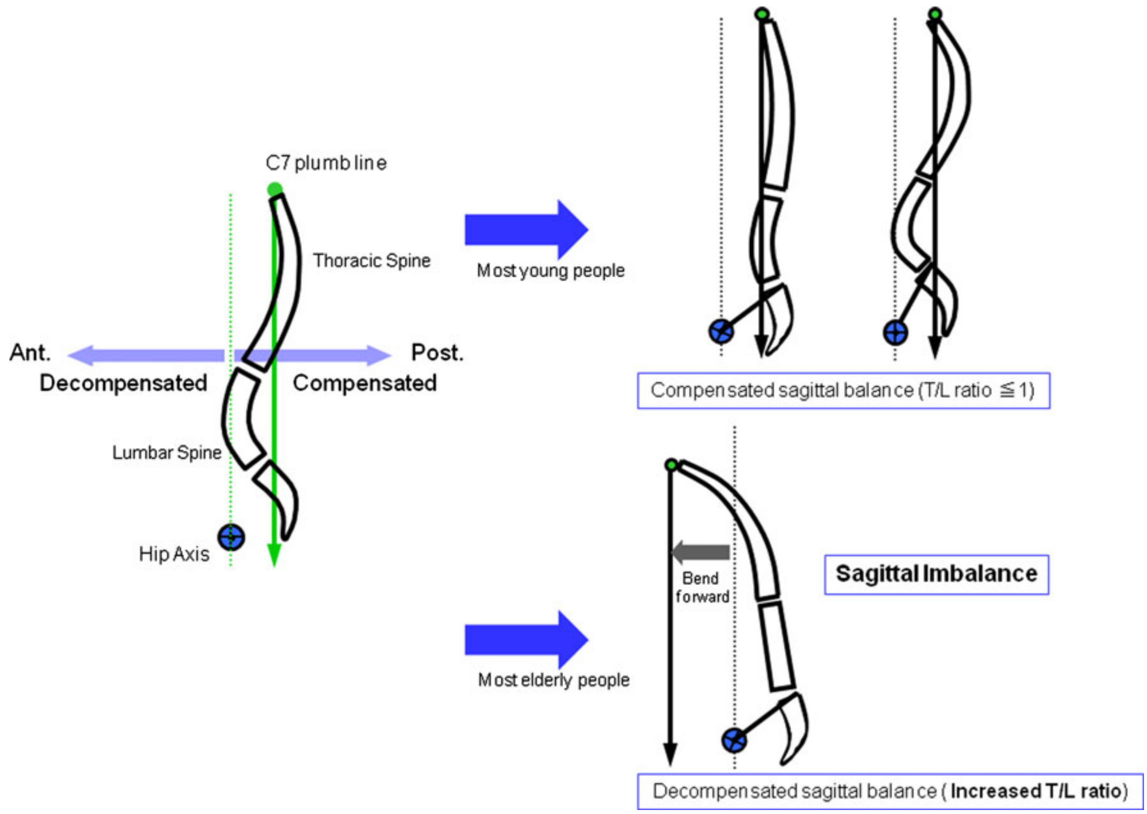

Fig. 1 The relationship between increased *T*/*L* ratio and decompensated sagittal balance. When lumbar lordosis increases or decreases in young people, thoracic kyphosis is changed to maintain sagittal balance and the *T*/*L* ratio is adjusted to remain lower than 1. However, in the elderly, lumbar lordosis decreases with aging, but kyphosis cannot be decreased to maintain sagittal balance due to inflexibility of the spine. Therefore, the *T*/*L* ratio is increased and this leads to bending forward. This phenomenon results in decompensated sagittal balance with increased *T*/*L* ratio in the elderly

improves QOL of postmenopausal patients with osteoporosis [33]. In this study, QOL had a significant positive correlation with lumbar lordosis angle, maintenance of sagittal balance, spinal ROM and back muscle strength, suggesting that these factors are important for maintenance of QOL of males. Among these factors, only back muscle strength had a significant correlation with both SF-36 PCS and SF-36 MCS scores, indicating that back muscle strength has a strong effect on QOL. In multiple regression analysis of factors associated with SF-36 PCS, the effects of both back muscle strength and thoracic ROM were significant. Thoracic ROM showed a significant correlation with the *T*/*L* ratio, but no relationship with age and back muscle strength. In previous studies, lumbar muscle provides a high percentage of back muscle [39], and thus back muscle has been shown to affect the lumbar lordosis angle and lumbar ROM [31, 40]. Therefore, the relationship of thoracic ROM with SF-36 PCS and the absence of a close relationship with back muscle strength suggest that maintenance of thoracic ROM is also important for good QOL of males, in addition to back muscle strength. Based on the results of this study, we suggest that middle-aged and elderly males can maintain their sagittal balance by exercise for back muscle strength and thoracic ROM, and that this will lead to a healthy physical and mental life.

Limitations

Comparison of the results with those for female patients with osteoporosis will be also useful, but it is difficult to obtain cooperation from all female persons because they were required to undress for measurement with the SpinalMouse®. However, we consider that the study clarified the QOL-related factors in an aging society, including back muscle strength, spinal ROM and sagittal balance of males.

Conclusion

The results of the study suggest that QOL of middle-aged and elderly males is related to factors such as sagittal balance, lumbar lordosis angle, spinal ROM, and back muscle strength. Exercise including muscle strength and spinal ROM may be able to influence these primary factors related to QOL, but this is an avenue for future research. Back muscle strength and thoracic ROM impact on improvement of QOL in the increasing population of the middle-aged and the elderly.

Conflict of interest No grant or any other funding has been received.

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