Sagittal imbalance and symptoms of depression in adults: Locomotive Syndrome and Health Outcomes in the Aizu Cohort Study (LOHAS)

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Abstract

Purpose With spinal deformities, mental health can deteriorate due to sagittal imbalance of the spine. The purpose of this study was to clarify the relationship between sagittal imbalance and symptoms of depression among local residents in the community.

Methods This study used data from the Locomotive Syndrome and Health Outcomes in Aizu Cohort Study (LOHAS) in 2010. The sagittal vertical axis (SVA) was identified as an indicator of sagittal imbalance. Symptoms of depression were assessed using the 5-item version of the Mental Health Inventory. Participants were classified into three categories based on the SVA balance as normal (< 40 mm), moderate imbalance (40–95 mm), and severe imbalance (> 95 mm). To evaluate the relationship between sagittal imbalance of the spine and symptoms of depression, the adjusted risk ratio (RR) and the 95% confidence interval (CI) were calculated using a generalized linear model with Poisson link.

Results There were 786 participants included in the statistical analysis. Overall, the mean age was 68.1 y (standard deviation, 8.8 y), and 39.4% were men. The prevalence of symptoms of depression by SVA category was 18.6% for normal, 23.8% for moderate, and 40.6% for severe. On multivariate analysis, the RR of SVA for symptoms of depression compared to the normal category was 1.12 (95% CI 0.7–1.70) for the moderate category and 2.29 (95% CI 1.01–5.17) for the severe category.

Conclusion In local community residents, sagittal imbalance had a significant association with symptoms of depression.

Keywords Adult spinal deformity · Sagittal imbalance · Depression · Quality of life · LHOAS

Introduction

Adult spinal deformity is one of the major problems that can impact the health-related quality of life (QOL) of an elderly population [1, 2]. Of the spinal deformities, sagittal imbalance of the spine had been shown to significantly correlate

with worse health status [3, 4] and can cause pain and affect physical performance when associated with kyphosis of the spine [5]. In addition to the physical aspect, mental health can deteriorate due to spinal deformity in adults [1]. Among patients with spinal deformity, as well as other spinal disorders, 25% had preoperative depression, which was related to severe deformity, lower QOL, and greater back pain [6, 7]. Although the relationship between severe spinal deformity with sagittal imbalance and depression has been demonstrated in the clinical setting, it remains unclear in the community setting. In addition, it remains unclear whether the depression or depressive mood is related to the spinal deformity itself or from the pain and disability due to the deformity. The purpose of this study was to clarify the relationship between sagittal imbalance and symptoms of depression among local residents in the community.

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Materials and methods

Study participants

The study protocol was approved by the ethics committee of our institution, and all participants provided written, informed consent. This study design was cross sectional and used data from the Locomotive Syndrome and Health Outcomes in Aizu Cohort Study (LOHAS), which was a cohort study from 2008 to 2010 and involved residents, aged 40 to 80 y, who participated in the annual health checkup of two communities (i.e., Tadami and Minamiaizu) in Fukushima Prefecture, Japan. The study participants were adults aged over 40 y who participated in the health checkup and underwent X-ray spinal assessment in 2010. Participants with a history of spinal surgery were excluded. The details of the LOHAS are available in a previously reported study [8].

Spinal deformity assessment

The participants underwent standing whole-spine radiography assessment. The sagittal vertical axis (SVA) was identified as the indicator of sagittal imbalance and was measured by two investigators (RT and YK) as the distance between the vertical lines that ran through the center of the C7 vertebral body and the posterosuperior corner of the sacrum, using the Surgimap software (Nemaris, Inc., New York, NY, USA). In this study, intraobserver reliability was 0.984, and interobserver reliability was 0.998. The first half of the measurements of investigator RT and the second half of the measurements of investigator YK were used for analysis.

Assessment of symptoms of depression

Symptoms of depression were assessed using the 5-item version of the Mental Health Inventory (MHI-5), which belongs to the “Mental Health” domain of the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36). According to the previous large population-based study [9], the MHI-5 was highly reliable and was validated in a general population; patients with psychiatric disorders and an MHI-5 score ≤ 60 can be considered to have moderate or severe depression. Therefore, in this study, this score was defined as the cutoff point for having symptoms of depression.

Assessment of other potential confounding factors

The potential confounding factors assessed in the present study were sociodemographic characteristics, including: age and sex; status of employment (yes/no); living alone (yes/no); and body pain on a self-reported questionnaire. The

3-min Timed Up & Go (TUG) test [10] was used to assess comprehensive physical function, including gait ability, total lower extremity muscle strength, balance, and mobility. Body pain was assessed using the bodily pain subscale of SF-12 [11], which consists of one question with five levels of possible responses.

Statistical analysis

Participants with no missing data were included in the statistical analysis. For the purpose of this analysis, participants were classified into three categories based on the SVA balance as normal (< 40 mm), moderate imbalance (40–95 mm), and severe imbalance (> 95 mm), along with the clinical presentation [12]. All confounding factors in each SVA category are presented as means and [standard deviation (SD)] for continuous variables and as numbers and proportion (%) for categorical variables. To evaluate the association between sagittal imbalance and symptoms of depression, the adjusted risk ratio (RR) and 95% confidence interval (CI) were calculated using the Poisson regression model with robust variance. The dependent variable was the prevalence of symptoms of depression, as defined previously. The independent variable was the SVA category, with the normal category being the reference. All confounding factors described above were included in the statistical model. Furthermore, to evaluate the additive association of female sex and severe SVA imbalance with symptoms of depression, the patients were subdivided according to six categorical variables, based on sex (male or female) and SVA category (normal, moderate, or severe). The adjusted RR of each group was calculated using the “male and normal balance” group as the reference. The RR in the “female and normal balance” group (RR_{female}) indicated the magnitude of the association between female sex and symptoms of depression, and the RR in the “male and severe imbalance” group (RR_{severe}) indicated the magnitude of the association between severe sagittal imbalance and symptoms of depression. When the RR in the “female and severe imbalance” group ($RR_{\text{female,severe}}$) did not depart from the $RR_{\text{female}} + RR_{\text{severe}} - 1$, which meant the absence of interaction between female sex and severe sagittal imbalance, each factor was considered to be associated with symptoms of depression through separate mechanisms. In contrast, when the $RR_{\text{female,severe}}$ departed from the $RR_{\text{female}} + RR_{\text{severe}} - 1$, which meant the presence of interaction between female sex and severe sagittal imbalance, each factor was considered to be associated with symptoms of depression through the same mechanism. This approach was implemented based on the concept of biologic interaction [13] and allowed interpretation of the magnitude of interaction by evaluating the departure of combined risk ($RR_{\text{female,severe}}$) from the sum of separate risks ($RR_{\text{female}} + RR_{\text{severe}}$). Moreover, the statistical

interaction was evaluated by including the product term (sex $\times$ SVA categories) in the statistical model. The significance of the product term was analyzed by the Wald test. All analyses were conducted using STATA v. 13.1 (StataCorp, College Station, TX). A two-tailed p value of <0.05 was considered significant.

Results

Of the 908 study participants in the LOHAS 2010 who underwent X-ray assessment, 75 who had missing data for symptoms of depression or SVA and 47 who had at least one confounding variable missing were excluded. A total of 786 (86.6%) participants were included in the statistical analysis in this present study (Fig. 1). Overall, the mean age of the participants was 68.1 [SD, 8.8] years, and 39.4% were men. Of these participants, 21.0% were identified

as having symptoms of depression, and the SVA imbalance was normal in 67%, moderate in 28.9%, and severe in 4.1%. The baseline characteristics in each SVA category are shown in Table 1.

The prevalence of symptoms of depression by SVA category was 18.6% for normal, 23.8% for moderate, and 40.6% for severe (Table 2). On multivariate analysis with adjustment for age, sex, employment status, living alone, body pain, and TUG test, the RR of SVA for symptoms of depression compared to the normal category was 1.12 (95% CI 0.7–1.70) for the moderate category and 2.29 (95% CI 1.01–5.17) for the severe category (Fig. 2). In the analysis for the additive association of female sex and severe sagittal imbalance with symptoms of depression (biologic interaction), $RR_{\text{female,severe}}$ (1.99) did not depart from RR_{female} (1.17) + RR_{severe} (1.57) – 1 (Table 3). On examination of the statistical interaction, the product term of female sex and severe sagittal imbalance was not significant ($p = 0.85$).

Fig. 1 Of the 908 study participants in LOHAS 2010 who underwent X-ray assessment, 786 (86.6%) were included for statistical analysis in this present study

Table 1 Characteristics of the study participants based on the three categories of sagittal vertical axis

	Total (<i>n</i> = 786)	Sagittal imbalance		
		Normal (<i>n</i> = 527)	Moderate (<i>n</i> = 227)	Severe (<i>n</i> = 32)
		< 40 mm	40–95 mm	> 95 mm
		(Sagittal vertical axis)		
	Mean [SD], N (%)			
Age (y)	68.1 [8.8]	66.9 [9.2]	70.3 [7.8]	72.1 [8.7]
Sex				
Male	310 (39.4)	207 (39.3)	90 (39.7)	13 (40.6)
Female	476 (60.6)	320 (60.7)	137 (60.4)	19 (59.4)
Employment				
Yes	277 (35.2)	196 (37.2)	74 (32.6)	7 (21.9)
Living alone	89 (11.3)	54 (10.3)	31 (13.7)	4 (12.5)
Timed Up & Go test (s)	7.4 [2.1]	7.2 [1.8]	7.8 [2.6]	8.7 [2.6]
Body pain	2.0 [1.1]	1.9 [1.0]	2.1 [1.2]	2.3 [1.2]

Table 2 Prevalence of symptoms of depression among the three categories of sagittal vertical axis

Sagittal imbalance	Symptoms of depression Prevalence %
Normal	18.6 (98/527)
Moderate	23.8 (54/227)
Severe	40.6 (13/32)

Fig. 2 Poisson regression model with robust variance adjusted for age, sex, employment, family arrangement, Timed Up & Go Test, and body pain. The RR of SVA for symptoms of depression compared to the normal category is 1.12 (95% CI 0.7–1.70) for the moderate category and 2.29 (95% CI 1.01–5.17) for the severe category

Discussion

The results of this study showed that sagittal spinal imbalance was associated with symptoms of depression in residents of a local community. This finding suggests that people

Table 3 Additive association of sex and sagittal imbalance with symptoms of depression

Sagittal imbalance	Adjusted risk ratio (95% CI) for symptoms of depression	
	Male	Female
Normal	Reference	1.17 (0.80–1.71) *
Moderate	0.87 (0.51–1.48)	1.39 (0.92–2.10)
Severe	1.57 (0.76–3.22)†	1.99 (1.19–3.43) ‡

*This risk ratio means RR_{female}

†This risk ratio means RR_{severe}

‡This risk ratio means $RR_{\text{female,severe}}$

Estimated from a Poisson regression model with robust variance adjusted for age, sex, employment, family arrangement, Timed Up & Go test, and body pain

with a sagittal imbalance may have symptoms of depression even before they need medical treatment. In addition, female sex and severe sagittal imbalance had no interaction with symptoms of depression. The clinical implication of these findings was that, regardless of sex, people in the community with severe sagittal imbalance should be evaluated for the possibility of having symptoms of depression.

With regard to the relationship between spinal deformity and psychiatric symptoms, the prevalence of psychosocial problems related to body image in patients with scoliosis was reported to be higher in adolescents than in adults [14]. In young individuals, patients with idiopathic scoliosis were shown to manifest symptoms of depression because of their deformity [15]. Lonner et al. reported that, compared with patients with idiopathic scoliosis, adolescent patients with Scheuermann

kyphosis had lower QOL, including mental health, and there was a negative correlation between QOL and thoracic kyphosis [16]. Thus, in young patients with spinal deformity, sagittal deformity has been particularly implicated in psychosocial problems, including depression, perhaps through body image. On the other hand, adult spinal deformity including patients was shown to have relatively low preoperative mental health, in addition to worse pain, self-image, and physical function [1, 17, 18]. However, another study showed that, compared with the US total population, adult spinal deformity patients had a significantly lower score in the physical component summary of the SF-36, but not in the mental component summary [4]. Therefore, it remains unclear whether mental health deteriorates with the deformity itself or because of deformity-related symptoms, such as pain and dysfunction. In the present study, severe sagittal imbalance was associated with symptoms of depression independent of pain, physical function, social status such as employment and living alone, and age and sex in the community setting. Although women have been well known to have a higher risk for symptoms of depression than men [19], the present results from the analysis of the biologic interaction suggest that female and severe sagittal imbalance were independently associated with symptoms of depression through separate mechanisms.

In the previous study, trunk deformity, including kyphosis, as evaluated by photographs, was related to a decrease in outdoor activities, including going out, shopping, depositing and withdrawing money, and visiting friends in community-dwelling elderly persons [20]. Combining this finding with the present results, sagittal imbalance may make elderly persons withdraw from society because of depression and decreasing activity. Therefore, we should focus on the link between sagittal spinal imbalance and depression in the community and intervene early in order to keep them active and improve their quality of life.

For the treatment of adult spinal deformity with sagittal imbalance, although surgical treatment is reported to have successful results, there are many problems, including the invasive nature of the procedure, long operation time, large amount of bleeding, high incidence of several major complications, and high cost of instrumentation and reoperation [21]. In addition, depression has been reported as one of the most important psychiatric problems related to the poor outcomes of spine surgery, including correction surgery for adult spinal deformity [6, 7]. Recent studies also showed that preoperative depression is related to various postoperative complications and reoperation [22]. Therefore, we should be very careful when considering surgical treatment for adult spinal deformity patients with symptoms of depression. Previously, surgical correction of adolescent idiopathic scoliosis or kyphosis of ankylosing spondylitis was reported

to provide significant improvements of anxiety and depressive mood [23, 24]. In adult spinal deformity patients, the associated symptoms of depression should be improved by correction of the sagittal deformity and imbalance as well. To predict surgical outcomes, it seems important to evaluate before surgery whether the symptoms of depression are related to the sagittal imbalance or are manifestations of a mental disease. However, at the moment, improvement of symptoms of depression by surgery is difficult to predict preoperatively. As mentioned above that there are many problems with surgical treatment, we should pay more attention to conservative therapy or even prevention of sagittal imbalance in the community before the patients need surgery. Although exercise is one of the promising conservative therapies [25], development of methods to prevent the deformity and sagittal imbalance is still a challenge for the future.

There were several limitations in this study. First, this study was cross-sectional in design. Therefore, a longitudinal study is needed to clarify whether the sagittal imbalance itself induced the symptoms of depression. Second, this study was conducted in a local mountainous area. Therefore, in order for the results to be generalizable to the general population, the same study design should be performed in another area, such as in a modern city, where the lifestyle and activities are different. The third limitation was the definition of sagittal imbalance. In this study, the participants were divided according to the SVA criteria in Schwab's classification [12], which has been widely accepted worldwide and was probably reasonable to use in this study. However, the use of population-adjusted sagittal modifiers was reported to more accurately classify spinal deformity [26]. In the future study, the use of a deformity classification created for Japanese patients might be necessary. Fourth, this study did not examine the pathogenesis of sagittal imbalance. Different pathologies may be included in this study, degenerative kyphosis with or without a compensatory mechanism, rigid deformities such as ankylosing spondylitis, or diffuse idiopathic skeletal hyperostosis, sarcopenia, and so on. The association of sagittal imbalance with depression may vary depending on the pathogenesis of the condition. The present study did not evaluate spinopelvic parameters, and it is unclear whether compensatory mechanisms are at work or not.

In conclusion, this study showed that sagittal imbalance was independently related to symptoms of depression in local community residents. We should pay more attention to the potential presence of symptoms of depression in people with severe sagittal imbalance.

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Code availability Not applicable.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Availability of data and material The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval The study protocol was approved by the Ethics Committee of Fukushima Medical University.

Consent to participate All participants provided written, informed consent.

Consent for publication All participants provided written informed consent.

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