The Impact of Lumbar Spinal Stenosis, Knee Osteoarthritis, and Loss of Lumbar Lordosis on the Quality of Life: Findings from the Katsuragi Low Back Pain Study

Yuyu Ishimoto1), Mamoru Kawakami1), Elizabeth Curtis2),3), Cyrus Cooper2),4), Nicholas C. Harvey2),5), Leo Westbury2), Masatoshi Teraguchi1), Kayoko Horie1) and Yukihiro Nakagawa1)

1) Spine Care Center, Wakayama Medical University Kihoku Hospital, Wakayama, Japan
2) MRC Lifecourse Epidemiology Unit, University of Southampton, Southampton, UK
3) Arthritis Research UK/MRC Centre for Musculoskeletal Work and Health, Southampton General Hospital, Southampton, UK
4) National Institute for Health Research (NIHR) Oxford Biomedical Research Centre, University of Oxford, Oxford, UK
5) NIHR Southampton Nutrition Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, UK

Abstract:
Introduction: Musculoskeletal diseases and spinal malalignment are associated with poorer quality of life (QOL) in the elderly. However, to date, few general population cohort studies have focused on these conditions together. Our objectives were to clarify the associations between musculoskeletal degenerative diseases and/or spinal malalignment with QOL measures in a group of Japanese older adults.

Methods: In this cross-sectional study, we analyzed data from 334 individuals recruited from the local population (120 men, 214 women; mean age 62.7 years; range 40-75). Low back pain (LBP) was assessed by questionnaire, and lumbar spinal stenosis (LSS) was diagnosed using a validated lumbar spinal stenosis support tool. Knee osteoarthritis (KOA) was diagnosed by the presence of clinical knee pain plus radiographic KOA. Spinal radiographs were used to assess the degree of lumbar lordosis (LL) and sagittal vertical alignment (SVA). QOL assessment was performed using the Oswestry Disability Index (ODI). A score of 12 was used as a cut-off point for poor QOL.

Results: Overall, 107 (32.0%) participants had an ODI > 12 (cases), and the remaining 227 individuals were designated controls. LBP, LSS, KOA, and LL were associated with poorer QOL, both in basic models and models adjusted for age, sex, and BMI. Associations persisted after adjustment for other musculoskeletal outcomes.

Conclusions: In a free-living Japanese population, the poor QOL odds are increased by LBP, LSS, KOA, and certain spinal radiographic features, loss of LL, and increased SVA. Poor QOL odds were greatest in those diagnosed with LSS or KOA. From spinal radiographs, decreased LL and increased SVA were also predictors of poor QOL.

Keywords:
Locomotive syndrome, low back pain, lumbar spinal stenosis, knee osteoarthritis, spinal alignment

Spine Surg Relat Res 2019; 3(2): 157-162
dx.doi.org/10.22603/ssrr.2018-0051

Introduction

As a result of aging populations and increasing life expectancy in many countries, including Japan, susceptibility to musculoskeletal disorders is increasing1). Musculoskeletal disorders are the fourth largest contributor to disease burden in older people worldwide, after cardiovascular disease, malignant neoplasms and chronic respiratory diseases2). Both osteoarthritis and conditions affecting the spine, such as lumbar spinal stenosis (LSS), are widely reported to be associated with poorer quality of life (QOL), disability, and mortality3). Knee osteoarthritis (KOA), LSS, and osteoporosis (OP) are the three major musculoskeletal diseases which can lead to a condition known as the “ locomotive syn...
drome,” characterized by pain, a limitation of the range of joint mobility, deformation, reduced balance capability and slower walking pace\(^6\). The socioeconomic impact of these diseases is substantial; at present, 4.5 million elderly (aged 65 or older) people in Japan require nursing care services\(^6\), and this is set to increase dramatically: by 2055, the elderly are predicted to account for 40.5% of the country’s population\(^6\).

Few general population cohort studies to date in Japan have studied the conditions of knee osteoarthritis and lumbar spinal stenosis at the same time, and quantified their contribution to poor QOL. Studies quantifying the link between QOL and the degree of spinal malalignment, through loss of lumbar lordosis (LL) and increasing thoracic kyphosis, are also lacking. Thoracic kyphosis predicts an increased risk of mortality, low back pain (LBP), back muscle strength, difficulties with daily living activities, and other adverse health outcomes such as abdominal compression and impaired pulmonary function\(^7\). We believe that it is critical to develop a comprehensive understanding of these conditions - not only through treating geriatric musculoskeletal disorders, but also by understanding how these diseases complicate or lead to each other, and impact the QOL of affected individuals.

The Katsuragi Low Back Pain Study is a population-based cohort established in a region of Japan with a large number of elderly residents. Through this study, we aimed to clarify the relationship between poor QOL and LBP, LSS, KOA, and spinal radiographic features including LL, thoracic kyphosis (TK) and sagittal vertical axis (SVA).

### Materials and Methods

#### Participants

Participants are residents of Katsuragi Town in Wakayama Prefecture. Annual health examinations for older people are organized by the local government, including a physician consultation. All residents are notified by letters from the government, and approximately 25% (about 4,500) participate in the annual health examinations. From this group, 353 people provided written informed consent to join a cohort study organized by our university hospital in August 2014. From this existing population cohort, we recruited participants to the Katsuragi Low Back Pain Study.

The 353 participants underwent careful phenotyping for musculoskeletal health, in addition to cardiovascular risk assessment, cognitive and depression assessments, and QOL assessments. All assessments took place on the same day. For all participants we obtained physical measurements (body height, weight, blood pressure, body fat ratio), an interview-based confirmation of occupation and past medical history, and dual-energy X-ray absorptiometry (Prodigy for Bone Health; GE Healthcare Japan Corp. Tokyo) to assess lumbar spine and proximal femur bone mineral density (BMD). In this study, osteoporosis (OP) was defined according to the World Health Organization definition of T=-2.5 SD. In Japan, lumbar spine OP was defined as L2-4 BMD of < 0.714 g/cm\(^2\). In Japan, OP at the femoral neck was defined as a BMD of < 0.546 g/cm\(^2\) and < 0.515 g/cm\(^2\) for male and female\(^{10}\).

The study was conducted with the approval of the university ethics committee.

#### The oswestry disability index (ODI)

The ODI is an index derived from the Oswestry Low Back Pain Questionnaire\(^7,8\), used by clinicians and researchers to quantify the level of disability in LBP. The index scores range from 0 (lowest level of disability) to 100 (highest level of disability). A score of 12 was used as a cut-point for poor QOL. In a study of 1200 Japanese people with an ODI value of 12 were previously shown to separate individuals with LBP with disability from those without\(^{10}\). We therefore used a cut-point of 12 on the ODI to differentiate those with or without poor QOL.

#### Assessment of low back pain/knee pain

An orthopedic surgeon (YI) asked the following questions regarding LBP and knee pain, respectively, to which participants responded “yes” or “no”\(^9\). “In the past month, have you had LBP on most days?” “In the past month, have you had knee pain on most days?”

In order to further assess LBP, the same orthopedic surgeon used a visual analogue scale (scale 1-100) to assess the most intense LBP experienced during the past month.

#### Radiographic assessment

LL (L1-5), TK (T1-12), and SVA were measured using a whole spinal lateral standing radiograph\(^11\). Radiographic KOA was scored by an experienced orthopedic surgeon (MT). The severity of radiographic KOA was determined according to Kellgren-Lawrence (KL) grading\(^12\) as follows: KL0, normal; KL1, slight osteophytes; KL2, definite osteophytes; KL3, joint or intervertebral space narrowing with large osteophytes; KL4, bone sclerosis, joint or intervertebral space narrowing, and large osteophytes. The same observer re-assessed a random sample of 50 of the X-rays after more than a period of one month, blinded to the original rating.

SVA is a widely accepted measure of spinal alignment, and was measured from spinal radiographs using the method described by Schwab et al\(^{11}\). SVA is defined as the horizontal offset from the postero-superior corner of S1 to the vertebral midbody of C7.

The intra-observer reliability with intraclass correlation coefficients (ICCs) were 0.85 for LL, 0.77 for TK, and 0.80 for SVA; kappa was 0.81. Moreover, the inter-observer reliability with ICCs were 0.81 for LL, 0.89 for TK, and 0.91 for SVA; kappa was 0.79.

#### Assessment of LSS and KOA

In order to assess LSS, the same orthopedic surgeon evaluated all participants using a validated LSS support...
Participants with leg symptoms who were scored seven or higher were determined to have LSS. In order to diagnose KOA, both knee pain and radiographic KOA scoring 2 or higher on the KL scale were required.

### Statistical analysis

Participants’ demographic characteristics were summarized using means (SDs) and counts (n, %) separately for those graded as having poor QOL (ODI > 12, (cases)) and those with good QOL (ODI < 12, (controls)). Differences in categorical and continuous variables between cases and controls were analyzed using chi-squared and t-tests, respectively. The effects of predictors such as LBP, LSS, KOA, and radiographic features on ODI were assessed, using logistic regression modeling, before and after adjusting for demographics and predictors and were summarized by odds ratios (ORs) and 95% confidence intervals (CIs). ORs were adjusted for potential confounders (age, sex, and BMI) in addition to the other musculoskeletal predictors. Statistical analyses were performing using JMP version 10 (SAS Institute Japan; Tokyo, Japan).

#### Results

The overall prevalence of LBP, LSS, and KOA was 33.2%, 6.6%, and 22.7% respectively. KOA presence was higher in women (Men: 12.5%, Women: 17.8%, P=0.006). Overall OP prevalence was 2.3%. In terms of radiographic spinal features, there was no significant difference in the degree of TK between the sexes, but the severity of LL was significantly greater in women compared to men, whereas the SVA was significantly greater in men than women.

In total, 107 (32.0%) of participants were demonstrated to have poor QOL according to our criteria (ODI ≥ 12 (cases)); the remaining 227 individuals were used as controls in our analysis (Table 1). The musculoskeletal outcomes (LBP, LSS, KOA, LL, and SVA), which differed significantly between cases and controls, were used as predictors.

Table 2 shows the association between LBP, LSS, KOA, and radiographic features, including LL and SVA, and QOL status. In the unadjusted analyses (Model 1), LBP (OR 3.79, p < 0.0001), LSS (OR 4.46, p 0.0007), and KOA (OR 4.24, p < 0.0001) were significantly associated with increased odds of poor QOL. In terms of spinal radiographic features, decreasing LL (OR 1.02 per 1° decrease in LL, p=0.047 and increasing SVA (OR 1.09 per 1 cm increase in SVA, p= 0.013) significantly increased the odds of poor QOL. Adjustment for sex, age and BMI increased the strength of the association between LSS and poor QOL to OR 4.46 (95% CI 1.87, 11.4) to OR 4.77 (95% CI 1.93, 12.7). After adjustment for the other musculoskeletal predictors, as well as sex, age, and BMI, the associations between all predictors other than SVA remained significant (Model 3). In particular, SVA and KOA were associated with over a four-fold increase in risk (LSS: OR 4.1 95% CI 2.54, 9.94) after adjustment for age, sex, BMI, and all other predictors. Associations between LBP and LSS and poor QOL were attenuated by adjustment for the other

#### Table 1. Study Participant Data.

|                  | Cases (N=107) | Controls (N=227) | Pvalue |
|------------------|---------------|------------------|--------|
| Sex              |               |                  |        |
| Males            | 33 (30.8%)    | 87 (38.3%)       | 0.183  |
| Females          | 74 (69.2%)    | 140 (61.7%)      |        |
| Age [mean (SD)] (years) | 64.4 (7.9)  | 61.9 (8.9) | 0.014  |
| BMI [mean (SD)] (kg/m²) | 23.4 (3.7)  | 22.1 (3.2) | 0.002  |
| LBP              |               |                  |        |
|                 | 58 (54.2%)    | 54 (23.8%)       | <0.0001|
| LSS              | 15 (14.0%)    | 8 (3.5%)         | 0.004  |
| KOA              | 32 (30.2%)    | 21 (9.3%)        | <0.0001|
| BMD (g/cm³)      |               |                  |        |
| Femoral Neck     | 0.88 (0.14)   | 0.88 (0.15)      | 0.82   |
| Lumbar           | 1.12 (0.23)   | 1.10 (0.21)      | 0.44   |
| Radiographic features |           |                  |        |
| LL (L1-5) (°)    | 33.8 (12.4)   | 36.9 (13.0)      | 0.047  |
| TK (T1-12) (°)   | 36.7 (12.6)   | 36.6 (10.7)      | 0.91   |
| SVA (cm)         | 2.59 (3.8)    | 1.6 (3.1)        | 0.013  |

LBP: low back pain, LSS: lumbar spinal stenosis, KOA: knee osteoarthritis, BMD: bone mineral density, LL: lumbar lordosis, TK: thoracic kyphosis, SVA: sagittal vertical axis

#### Table 2. Associations between Predictors and Risk of Being a Case (ODI>12).

| Predictors         | Model 1 |                  | Model 2 |                  | Model 3 |                  |
|--------------------|---------|------------------|---------|------------------|---------|------------------|
|                    | OR      | 95% CIs          | P       | OR               | 95% CIs | P                |
| LBP                | 3.79    | 2.34-6.21        | <0.0001 | 3.78             | 2.29-6.30 | <0.0001 | 3.2             | 1.86-5.65 | <0.0001 |
| LSS                | 4.46    | 1.87-11.14       | 0.0007  | 4.77             | 1.93-12.7 | 0.001 | 4.1             | 1.56-11.29 | 0.003 |
| KOA                | 4.24    | 2.31-7.91        | <0.0001 | 4.2              | 2.26-8.00 | <0.0001 | 4.97             | 2.54-9.94 | <0.0001 |
| Radiographic features |       |                  |         |                  |         |                  |
| LL (L1-5) (°)      | 1.02    | 1.00-1.04        | 0.047   | 1.02             | 1.00-1.04 | 0.038 | 1.02             | 1.00-1.05 | 0.021 |
| SVA (+1cm)         | 1.09    | 1.02-1.18        | 0.013   | 1.09             | 1.01-1.18 | 0.025 | 1.07             | 0.98-1.16 | 0.138 |

LL: lumbar lordosis, SVA: sagittal vertical alignment

aOdds ratio per 1° decrease in LL, bOdds ratio per 1cm increase in SVA

Model 1: unadjusted

Model 2: adjusted for sex, age and BMI

Model 3: adjusted for the other predictors as well as sex, age and BMI
predictors (including KOA), whereas associations between KOA and poor QOL was strengthened by this adjustment.

Discussion

In a study of 334 Japanese older people (mean age 62.7 (8.65) years), we have shown that LBP, LSS, KOA, and decreasing LL were significantly associated with poor QOL as defined by the ODI. In this cohort, we found that people with poorer QOL tended to be older and have higher BMI. LSS was associated with an over four-fold, and KOA with almost five-fold increased odds of poor QOL as compared to those without, after adjustment for potential confounding factors such as sex, age, BMI, and other musculoskeletal conditions. BMD and TK were not shown to be associated with QOL in this population. SVA was not shown to be an independent predictor of poor QOL following adjustment for all the same confounders.

Certain limitations to this study should be acknowledged. First, this is a cross-sectional study, meaning causal attributions cannot be made between musculoskeletal health outcomes such as LBP, LSS, KOA, or radiographic features of reduced LL and poor QOL. Second, since we recruited consenting members of the population getting an annual health check to take part in a research study, random sampling cannot be ensured. This may limit the generalizability of these findings through selection bias since those enrolling in a healthcare-based study may not have been representative of the population. Third, owing to the small study sample size (n=334), the effect estimates are of low precision and could have occurred through chance, information or selection bias. Fourth, ODI does not always reflect the whole QOL but the influence of LL to determine the relationship with QOL in a population-based cohort including both genders. A further study by Imagama et al. reported that exercise designed to improve sagittal balance by improving back muscle strength and thoracic ROM improved QOL measures in men. Miyakoshi et al. showed that worsening back muscle strength was the most important factor contributing to a decline in spinal range of movement in postmenopausal women, indicating the importance of both back muscle strength and lumbar range of movement in determining QOL.

Evidence from randomized controlled trials also associate back muscle strength training with a significant improvement in QOL. Studies have linked LL to the quantity of lumbar muscle, which contributes a high percentage of overall back muscle. This may explain why exercise interventions have been shown to improve LL and QOL.

Many reports have associated LBP with lumbar degenerative changes. Disc space narrowing is the most commonly used marker of lumbar disc degeneration. One study suggested that individuals with a degenerative disc may be at greater risk of poor health. Savinainen et al. reported that the musculoskeletal capacity in subjects with a higher workload was poorer than that in the subjects with a lower workload. A difference in trunk extension strength was detected between these two groups, which is known to be associated with decreasing LL. Heavy manual work is also significantly associated with disc degeneration. Katsuragi is a rural city, and the patient population comprises a high percentage of farmers, hence heavy manual work may have affected spinal health in our population. There may have been occupational effects on QOL measures in our population; unfortunately, the study questionnaire was not specifically designed to characterize occupational risk factors for QOL. Similarly, the questionnaire did not allow us to assess nutritional risk factors for musculoskeletal measures and QOL outcomes.
In conclusion, we have demonstrated, in a population of older men and women, to our knowledge for the first time, associations between several musculoskeletal diseases, spinal radiographic features, and QOL. We have shown that the odds of poor QOL appear strongest in those with LSS or KOA among the musculoskeletal diseases. Among the spinal radiographic measures, decreasing LL was also a significant predictor of poor QOL. Further research is required to examine whether targeted exercise and nutritional interventions, aimed at improving muscle strength and reducing the burden of occupational activity, may reduce the risk of LBP, LSS and KOA, hence reducing the burden of these conditions on QOL for future generations.

Disclaimer: Mamoru Kawakami is the Editor of Spine Surgery and Related Research and on the journal’s Editorial Committee. He was not involved in the editorial evaluation or decision to accept this article for publication.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

Sources of Funding: The study was supported by a Lilly Research Grant Program for Bone & Mineral Research (B25860448) 2013 and an AO Spine 2015 Japan Research Grant.

Acknowledgement: The author would like to thank Mr. Makoto Oura, Mrs. Nami Moriguchi, Mr. Nozomu Narikawa and other members of Wakayama Medical University Kitahoku Hospital for their assistance in locating and scheduling participants for examinations.

Author Contributions: YI wrote and prepared the manuscript, YI and LW performed the statistical analysis. YI and EC contributed to the analysis and interpretation of the results and EC corrected the English. All authors have read, reviewed, and approved the article.

References
1. Yoshimura N, Muraki S, Oka H, et al. Is osteoporosis a predictor for future sarcopenia or vice versa? Four-year observations between the second and third ROAD study surveys. Osteoporos Int. 2017;28(1):189-99.
2. Prince MJ, Wu F, Guo Y, et al. The burden of disease in older people and implications for health policy and practice. Lancet. 2015;385(9957):549-62.
3. Picavet HS, Hoeymans N. Health related quality of life in multiple musculoskeletal diseases: SF-36 and EQ-5D in the DMC3 study. Ann Rheum Dis. 2004;63(6):723-9.
4. Nakamura K. The concept and treatment of locomotive syndrome: its acceptance and spread in Japan. J Orthop Sci. 2011;16(5):489-91.
5. Yoshimura N, Oka H, Muraki S, et al. Reference values for hand grip strength, muscle mass, walking time, and one-leg standing time as indices for locomotive syndrome and associated disability: The second survey of the ROAD study. J Orthop Sci. 2011;36(16):1312-9.
6. Muraki S, Akune T, Oka H, et al. Health-related quality of life with vertebral fracture, lumbar spondylosis and knee osteoarthritis in Japanese men: the ROAD study. Spine. 2011;5:91-9.
7. Fairbank JC, Couper J, Davies JB, et al. The Oswestry low back pain disability questionnaire. Physiotherapy. 1980;66(8):271-3.
8. Fairbank JC, Pye, PB. The Oswestry Disability Index. Spine. 2000;25(20):2940-52.
9. Tonosu J, Takeshita K, Haru N, et al. The normative score and the cut-off value of the Oswestry Disability Index (ODI). Eur Spine J. 2012;21(8):1596-602.
10. Muraki S, Oka H, Akune T, et al. Prevalence of radiographic lumbar spondylosis and its association with low back pain in elderly subjects of population-based cohorts: the ROAD study. Ann Rheum Dis. 2009;68(9):1401-6.
11. Schwab F, Patel A, Ungar B, et al. Adult spinal deformity-postoperative standing imbalance: how much can you tolerate? An overview of key parameters in assessing alignment and planning corrective surgery. Spine. 2010;35(25):2224-31.
12. Kellgren JH, Lawrence JS. eds. The epidemiology of chronic rheumatism: atlas of standard radiographs of arthritis. Philadelphia, PA: Oxford Blackwell Scientific, 1963.
13. Konno S, Hayashino Y, Fukushima S, et al. Development of a clinical diagnosis support tool to identify patients with lumbar spinal stenosis. Eur Spine J. 2007;16(11):1951-7.
14. Vogt MT, Cawthon PM, Kang JD, et al. Prevalence of Symptoms of Cervical and Lumbar Stenosis Among Participants in the Osteoporotic Fractures in Men Study. Spine. 2006;31(13):1445-51.
15. Yoshimura N, Muraki S, Oka H, et al. Prevalence of knee osteoarthritis, lumbar spondylosis, and osteoporosis in Japanese men and women: the research on osteoarthritis/osteoporosis against disability study. J Bone Miner Metab. 2009;27(5):620-8.
16. Murata Y, Takahashi K, Yamagata M, et al. The knee-spine syndrome. J Bone Jt Surg. 2003;85(1):95-9.
17. Imagama S, Matsuyama Y, Hasegawa Y, et al. Back muscle strength and spinal mobility are predictors of quality of life in middle-aged and elderly males. Eur Spine J. 2011;20(6):954-61.
18. Imagama S, Hasegawa Y, Matsuyama Y, et al. Influence of sagittal balance and physical ability associated with exercise on quality of life in middle-aged and elderly people. Arch Osteoporos. 2011;6:13-20.
19. Miyakoshi N, Hongo M, Maekawa S, et al. Back extensor strength and lumbar spinal mobility are predictors of quality of life in patients with postmenopausal osteoporosis. Osteoporos Int. 2007;18(10):1397-403.
20. Hongo M, Ito E, Sinaki M, et al. Effect of low-intensity back exercise on quality of life and back extensor strength in patients with osteoporosis: a randomized controlled trial. Osteoporos Int. 2007;18(10):1389-95.
21. Marras WS, Jorgensen MJ, Granata KP, et al. Female and male trunk geometry: size and prediction of the spine loading trunk muscles derived from MRI. Clin Biomech. 2001;16(1):38-46.
22. Wang Y-XJ, Griffith F, Zeng X-J, et al. Prevalence and gender difference of lumbar disc space narrowing in elderly Chinese men and women: Mr. OS (Hong Kong) and Ms. OS (Hong Kong) studies. Arthritis Rheum. 2013;65(4):1004-10.
23. Savinainen M, Nygård CH, Ilmarinen J. A 16-year follow-up study of physical capacity in relation to perceived workload among ageing employees. Ergonomics. 2004;47(10):1087-102.
Spine Surgery and Related Research is an Open Access journal distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License. To view the details of this license, please visit (https://creativecommons.org/licenses/by-nc-nd/4.0/).