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ORIGINAL ARTICLE

Increase in lumbar kyphosis and spinal inclination, declining back muscle strength, and sarcopenia are risk factors for onset of GERD: a 5-year prospective longitudinal cohort study

Shiro Imagama[1] · Kei Ando[1] · Kazuyoshi Kobayashi[1] · Masaaki Machino[1] · Satoshi Tanaka[1] · Masayoshi Morozumi[1] · Shunsuke Kanbara[1] · Sadayuki Ito[1] · Taisuke Seki[1] · Takashi Hamada[1] · Shinya Ishizuka[1] · Hiroaki Nakashima[1] · Naoki Ishiguro[1] · Yukiharu Hasegawa[2]

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Abstract

Purpose The objective was to identify risk factors for new development of gastroesophageal reflux disease (GERD) 5 years later in a prospective longitudinal cohort study.

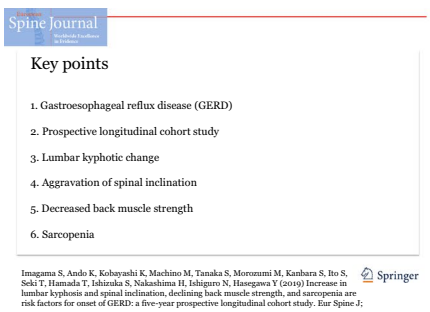
Methods A total of 178 subjects (male 72, female 106, mean age 68 years) without GERD in 2013 were examined for GERD in 2018. A Frequency Scale for Symptoms of GERD score ≥ 8 was used for diagnosis of GERD. Body mass index, spinal alignment, muscle strength, physical ability, number of oral drugs per day, sarcopenia, and frailty determined in 2013 and 2018 were compared between the GERD(+) and GERD(−) groups in 2018. Aggravation of lumbar kyphosis and spinal inclination from 2013 to 2018 was defined as a change of ≥ 5° or ≥ 10°, and weakening of back muscle strength as a change of ≥ 10 kg. QOL (SF-36) was also examined.

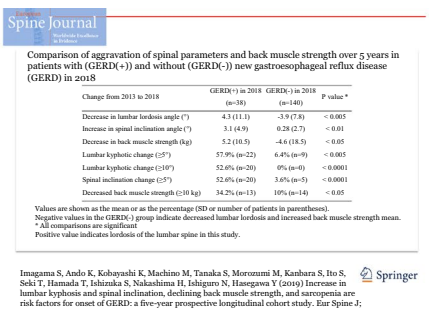
Results Of the 178 subjects, 38 (21%) were diagnosed as GERD(+) in 2018. Sarcopenia in 2018 was significantly related to a GERD(+) status ($p < 0.05$). The GERD(+) group had significantly higher rates of changes of lumbar kyphosis ≥ 5° ($p < 0.005$) and ≥ 10° ($p < 0.0001$), of spinal inclination ≥ 5° ($p < 0.0001$), and of decreased back muscle strength ≥ 10 kg ($p < 0.05$). SF-36 were also significantly worse in the GERD(+) group ($p < 0.05$).

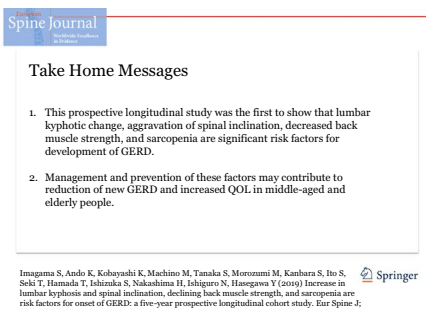
Conclusions This prospective longitudinal study firstly demonstrated that lumbar kyphotic change, aggravation of spinal inclination, decreased back muscle strength, and sarcopenia are significant risk factors for new development of GERD. Management and prevention of these factors may contribute to reduction of GERD symptoms and increased QOL in middle-aged and elderly people.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.







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Keywords Gastroesophageal reflux disease · Lumbar kyphotic change · Aggravation of spinal inclination · Decreased back muscle strength · Sarcopenia

Introduction

The number of elderly people is increasing worldwide, and maintenance or improvement of their activities of daily living and quality of life (QOL) is necessary. There has recently been greater clinical awareness of gastroesophageal reflux disease (GERD) due to its increased prevalence with aging of society [1–3] and its negative impact on QOL [4]. Vertebral column fracture and lumbar kyphosis are significantly related to GERD [5, 6], and we also showed that lumbar kyphosis and weak back muscle strength are significantly associated with GERD in middle-aged and elderly people in a cross-sectional study [7]. Additionally, in recent reports, surgical spinal correction in kyphosis patients improves GERD symptom as well as kyphotic deformity-related disorders [8, 9]. These suggest a need for orthopedic surgeons to recognize GERD symptoms related to musculoskeletal disorders such as muscle weakness or spinal alignment.

In 2012, we examined 245 subjects (mean age 67 years) in a health checkup that included evaluation of spinal balance, physical ability, and GERD symptoms [7]. This study was the first to show that lumbar kyphosis, poor sagittal balance, increased number of oral drugs taken per day, and decreased back muscle strength are important risk factors for development of GERD. However, the study was cross-sectional in design and thus was limited in defining these factors as causes of GERD. Therefore, we planned the current prospective longitudinal cohort study of subjects without GERD to identify risk factors for new GERD development after 5 years.

Materials and methods

The subjects were healthy volunteers who attended an annual health checkup in Yakumo in Hokkaido, Japan, which has been held for over 30 years and is supported by the local government (Yakumo study) [10–12]. This activity includes subjects aged ≥ 40 years who the local government recommend to receive this health checkup for maintaining good health. The study was approved by the Committee on Ethics on Human Research of our University, and informed consent was obtained from all subjects. In 2013, subjects were examined for GERD symptoms using a Frequency Scale for Symptoms of GERD (FSSG) score ≥ 8 to define GERD [13]. Patients under treatment for esophageal, gastric, and duodenal intestinal disease or with a surgical history involving these diseases, and those under treatment for spinal deformity, with fresh vertebral compression fracture, or a history of spine surgery were excluded from the study. Of 252 eligible subjects, 59 (23%) were diagnosed with GERD in 2013. Fifteen of the 193 subjects without GERD in 2013 did not attend a similar annual health checkup in 2018. Therefore, 178 subjects (male 72, female 106, mean age 68 years) without GERD in 2013 were examined for development of GERD in 2018 (Fig. 1).

Body mass index (BMI), osteoporosis, spinal alignment, back muscle strength, physical ability (3-m timed up and go test [3-m TUG]), number of oral drugs per day, sarcopenia, and frailty in 2013 were compared between the GERD(+) and GERD(−) groups in 2018. Osteoporosis was diagnosed using criteria proposed by the Japanese Society for Bone and Mineral Research [14] and was defined as a percent of the young adult mean (%YAM) < 70% in the calcaneus [15]. Spinal parameters such as thoracic kyphosis angle (T1–12), lumbar lordosis angle (L1–S1), and sacral inclination angle were measured on plain radiographs [16], and the spinal inclination angle was measured with SpinalMouse® (Idiag, Volkerswill, Switzerland) [17, 18]. The spinal inclination angle is

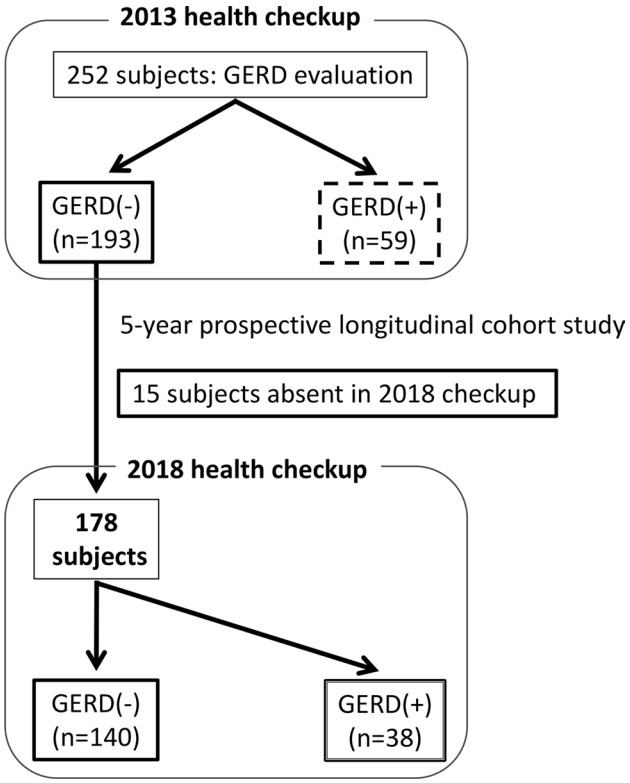

Fig. 1 Disposition of subjects in this study

defined as the angle between a straight line from T1 to S1 and the true vertical [19]. A greater spinal inclination angle indicates a bent-forward posture and poor sagittal spinal alignment [15]. A positive value indicates lordosis of the lumbar spine in this study. Back muscle strength was determined from the maximal isometric strength of the trunk muscles in a standing posture with 30° lumbar flexion using a back muscle strength meter (T.K.K.5002, Takei Co., Japan), with one examiner who was blinded to the results of other evaluations [20, 21]. The maximum strength was measured in two trials, which showed high reproducibility ($r = 0.990$, $p < 0.0001$), and the average value was recorded. QOL was evaluated using the physical component summary (PCS) and mental component summary (MCS) of the MOS 36-item short-form health survey (SF-36) [22].

Evaluation of GERD

The past literature has suggested that severity judgment based on symptoms alone should be carefully performed because symptoms may not be consistent with reflux esophagitis observed on endoscopy in some cases [23]. Therefore, evidence-based clinical practice guidelines for gastroesophageal reflux disease developed in 2015 by the Japanese Society of Gastroenterology recommended that initial diagnosis of GERD can include self-administered questionnaires with a mean diagnostic sensitivity and specificity of approximately 70%, to allow the start of treatment of GERD symptoms with a proton pump inhibitor before endoscopic diagnosis [24]. Therefore, GERD symptoms were examined using the noninvasive FSSG questionnaire [7, 13] for detection of GERD symptoms without endoscopy in this health checkup. This questionnaire is used for management of GERD in general practice, and the results correlate strongly with endoscopic findings. The questionnaire is a self-reported instrument that contains 12 questions and is written in simple and easy-to-understand language. The following questions are used to identify symptoms. (1) Do you get heartburn? (2) Does your stomach become bloated? (3) Does your stomach ever feel heavy after meals? (4) Do you sometimes subconsciously rub your chest with your hand? (5) Do you ever feel sick after meals? (6) Do you get heartburn after meals? (7) Do you have an unusual (e.g., burning) sensation in your throat? (8) Do you feel full while eating meals? (9) Does food get stuck when you swallow? (10) Do you get bitter liquid (acid) coming up into your throat? (11) Do you burp a lot? (12) Do you get heartburn if you bend over? Symptom frequency was measured on a scale of never = 0; occasionally = 1; sometimes = 2; often = 3; and always = 4. GERD was diagnosed based on a FSSG score ≥ 8, and subjects were divided into GERD(+) and GERD(−) groups.

Diagnosis of sarcopenia and frailty

Appendicular skeletal muscle mass was measured using bioelectrical impedance analysis (BIA) (Inbody 720; Biospace Co., Ltd., Seoul, Republic of Korea), which measures body composition based on differences in electric impedance among biological tissues such as fat, muscle, and bone [25]. The BIA reference values for diagnosis of muscle loss are an appendicular skeletal muscle index < 7.0 kg/m^2 and 5.8 kg/m^2 in men and women, respectively [26, 27]. Sarcopenia in the healthy volunteers in the current study was simply defined as a decrease in muscle mass, without inclusion of gait speed or grip strength in the definition. Frailty was defined as proposed by Fried et al. [28], and reviewed with modification for Japanese subjects defined by the Japanese version of the Cardiovascular Health Study [J-CHS] [29], as the presence of ≥ 3 of the following 5 criteria: unintentional weight loss (more than 2 kg in the past 6 months without any particular cause), weakness (decrease in grip strength based on Asian Working Group for Sarcopenia [AWGS] criteria [30], grip strength < 26 kg in males and < 18 kg in females), low walking speed (usual gait speed < 1.0 m/s), self-reported exhaustion, and self-reported low physical activity.

Statistical analysis

Data are shown as mean ± SD. An unpaired t test or Chi-square test was used to evaluate differences between the GERD(+) and GERD(−) groups in 2018. As lumbar kyphotic angle, spinal inclination angle, and back muscle strength were significant risk factors for GERD in our previous study, aggravation of lumbar lordosis ≥ 5° and ≥ 10°, spinal inclination ≥ 5°, and a decrease of back muscle strength ≥ 10 kg were compared between the GERD(+) and GERD(−) groups. $p < 0.05$ was considered to be significant in all tests.

Results

The characteristics in 2013 and 2018 of the 178 subjects without GERD symptoms in 2013 (at a mean age of 63 years, range 40–83 years) are shown in Table 1. Over 5 years, the mean values for BMI, osteoporosis, spinal parameters, back muscle strength, gait ability, number of oral drugs per day, and rates of sarcopenia and frailty did not change significantly. In 2018, 38 of the 178 subjects (21%) were diagnosed as GERD(+) (Fig. 2). No parameters measured in 2013 were significantly related to a diagnosis of GERD(+) in 2018 (Table 2), and only the rate of sarcopenia

Table 1 Characteristics in 2013 and 2018 of 178 subjects without gastroesophageal reflux disease (GERD) symptoms in 2013

Variables	Value (2013)	Value (2018)
Age (years)	63.3 (8.2)	68.3 (8.2)
Gender (male) (%)	40.4% ($n=72$)	40.4% ($n=72$)
Body mass index (kg/m^2)	23.4 (2.8)	23.4 (3.0)
Bone mineral density; (% YAM)	81.2 (14.3)	80.6 (13.7)
Osteoporosis (+) (%)	21.9% ($n=39$)	22.5% ($n=40$)
Thoracic kyphosis angle (°)	40.3 (9.4)	45.0 (8.7)
Lumbar lordosis angle (°)	43.8 (12.3)	41.0 (10.1)
Sacral inclination angle (°)	34.2 (10.6)	31.5 (10.5)
Spinal inclination angle (°)	2.1 (3.0)	3.1 (3.2)
Back muscle strength (kg)	76.6 (29.2)	80.4 (32.2)
3-m timed up and go test (s)	6.3 (0.88)	6.2 (1.1)
Number of oral drugs taken per day	3.2 (3.8)	3.4 (3.9)
Sarcopenia (+)	15.2% ($n=27$)	15.7% ($n=28$)
Frailty (+)	6.7% ($n=12$)	7.3% ($n=13$)

Values are shown as the mean or as the percentage (SD or number of patients in parentheses)

YAM young adult mean

Positive value indicates lordosis of the lumbar spine in this study

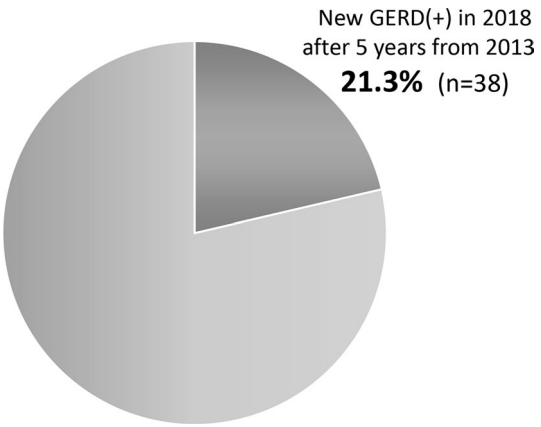

Fig. 2 New GERD(+) subjects in 2018 among those without GERD in 2013

among variables measured in 2018 was significantly associated with a GERD(+) status ($p<0.05$) (Table 3, Fig. 3). However, the mean values of spinal parameters and back muscle strength in 2013 and 2018 were worse in GERD(+) cases in 2018.

In contrast, changes in spinal parameters and back muscle strength over 5 years (from 2013 to 2018) were significantly related to diagnosis of GERD(+) in 2018 (Table 4). Increases in lumbar kyphotic angle ($p<0.005$) and spinal inclination angle ($p<0.01$) and the decrease in back muscle strength ($p<0.05$) were all larger in GERD(+) cases. Similarly, the rates of aggravation of lumbar kyphosis ≥ 5° ($p<0.005$) and ≥ 10° ($p<0.0001$), of spinal inclination ≥ 5° ($p<0.0001$), and of decreased back muscle strength ≥ 10 kg ($p<0.05$) were also higher in GERD(+) subjects (Table 4, Fig. 4), The SF-36 physical and mental component summaries measured in 2018 were significantly worse in the GERD(+) group ($p<0.05$) (Table 5).

Representative case (a patient who developed new GERD(+) after 5 years)

In 2013, a 70-year-old male was in the GERD(−) group, with FSSG scale 3, BMI 23.0 kg/m^2, without sarcopenia, lumbar lordosis angle of 40° (Fig. 5a), spinal inclination angle of 1.0°, and back muscle strength of 50.5 kg. Five years later, in 2018, at age 75 years, he had developed GERD, with FSSG scale 10, BMI 20.3 kg/m^2, sarcopenia, lumbar lordosis angle of 26° (a decrease of 14° in 5 years, indicating a lumbar kyphotic change) (Fig. 5b), spinal inclination aggravated to 10.4° (an increase of 9.4° in 5 years), and back muscle strength of 41.0 kg (a decrease of 9.5 kg in 5 years). His QOL scores in 2018 were PCS 32.6 and MCS 37.5, indicating poor QOL.

Discussion

This study is the first to evaluate GERD development after 5 years in subjects who originally did not have GERD, and to examine factors related to new GERD development. In a cross-sectional study in 2012, we found that a decrease in lumbar lordosis angle, poor sagittal balance, an increased number of oral drugs, and decreased back muscle strength are important risk factors for GERD [7].

The current longitudinal study showed the importance of changes in spinal parameters and muscle strength and muscle mass as causes of new GERD. Averaged over all 178 subjects in the study, there were no significant changes in BMI, osteoporosis, spinal parameters, muscle strength, gait ability, and rates of sarcopenia and frailty from 2013 to 2018, and only the rate of sarcopenia in 2018 was significantly associated with new GERD development in 2018. These findings may be a result of the subjects being relatively healthy volunteers, and also because of the exclusion of 59 subjects with GERD in 2013, who had poor spinal alignment, weak muscle strength, and took more oral drugs taken per day, as shown in our cross-sectional cohort study. Given the health of the subjects in this study, the rate of new GERD of 21% after 5 years in middle-aged and elderly people is surprising and cannot be neglected. This result suggests a need to focus on GERD symptoms in this population to the same as extent as that in orthopedic patients with musculoskeletal symptoms.

Table 2 Comparison of variables in 2013 in patients with (GERD(+)) and without (GERD(-)) new gastroesophageal reflux disease (GERD) after 5 years (2018)

Variables in 2013	GERD(+) in 2018 ($n=38$)	GERD(−) in 2018 ($n=140$)	p value
Age (years)	61.4 (9.4)	63.8 (7.5)	NS
Gender (male) (%)	34.2% ($n=13$)	42.1% ($n=59$)	NS
Body mass index (kg/m^2)	23.7 (2.9)	23.2 (2.8)	NS
Bone mineral density (% YAM)	83.5 (17.5)	80.5 (13.6)	NS
Osteoporosis (+) (%)	31.6% ($n=12$)	19.3% ($n=27$)	NS
Thoracic kyphosis angle (°)	39.5 (9.9)	40.4 (9.7)	NS
Lumbar lordosis angle (°)	38.8 (12.9)	44.1 (11.6)	NS
Sacral inclination angle (°)	29.6 (11.8)	34.9 (12.7)	NS
Spinal inclination angle (°)	1.9 (2.6)	1.7 (3.1)	NS
Back muscle strength (kg)	72.8 (26.9)	75.5 (28.6)	NS
3-m timed up and go test (s)	6.5 (1.1)	6.2 (0.82)	NS
Number of oral drugs taken per day	3.3 (4.1)	3.1 (3.7)	NS
Sarcopenia (+)	23.7% ($n=9$)	12.9% ($n=18$)	NS
Frailty (+)	10.5% ($n=4$)	5.7% ($n=8$)	NS

Values are shown as the mean or as the percentage (SD or number of patients in parentheses)

YAM young adult mean, *NS* not significant

Positive value indicates lordosis of the lumbar spine in this study

Table 3 Comparison of variables in 2018 in patients with (GERD(+)) and without (GERD(-)) new gastroesophageal reflux disease (GERD) in 2018

Variables in 2018	GERD(+) in 2018 ($n=38$)	GERD(−) in 2018 ($n=140$)	p value
Body mass index (kg/m^2)	23.7 (3.4)	23.3 (2.9)	NS
Bone mineral density (% YAM)	81.8 (16.9)	79.6 (12.1)	NS
Osteoporosis (+) (%)	31.6% ($n=12$)	19.3% ($n=27$)	NS
Thoracic kyphosis angle (°)	45.9 (9.1)	45.4 (8.9)	NS
Lumbar lordosis angle (°)	39.2 (14.0)	42.7 (10.9)	NS
Sacral inclination angle (°)	29.1 (10.1)	33.9 (9.8)	NS
Spinal inclination angle (°)	3.5 (4.2)	2.7 (2.7)	NS
Back muscle strength (kg)	72.2 (28.4)	81.1 (31.3)	NS
3-m timed up and go test (s)	6.3 (0.97)	6.2 (1.2)	NS
Number of oral drugs taken per day	3.6 (4.5)	3.5 (3.9)	NS
Sarcopenia (+)	36.8% ($n=14$)	10% ($n=14$)	<0.05*
Frailty (+)	10.5% ($n=4$)	6.4% ($n=9$)	NS

Values are shown as the mean or as the percentage (SD or number of patients in parentheses)

YAM young adult mean, *significant, *NS* not significant

Positive value indicates lordosis of the lumbar spine in this study

Aging has been suggested to be a risk factor for GERD [31, 32], but age was not significantly related to new GERD in our study population of healthy volunteers with no GERD in 2013. Given the lack of an effect of age, we were able to examine risk factors for GERD in two-group comparisons. Regarding spinal parameters, lumbar kyphosis and spinal inclination have been related to GERD in past studies, and we have suggested that the mechanism may involve an increase in intra-abdominal pressure caused by lumbar kyphosis or a bent-forward spine [6, 7, 33], with subsequent cranial compression of the esophagus and stomach. These changes may then induce decreased lower esophageal sphincter (LES) pressure and hiatus hernia, leading to regurgitation of gastric contents, including gastric acid, and finally causing GERD [7]. Due to exclusion of GERD(+) subjects in 2013, the 178 subjects in this study had relatively good spinal alignment, and the spinal parameters in 2013 and 2018 were not related to GERD development. However, aggravation of lumbar kyphosis and spinal inclination over 5 years were significant risk factors for new GERD in subjects who did not have GERD 5 years ago. This result is not due to aging. We found a 2.59 times higher risk of GERD

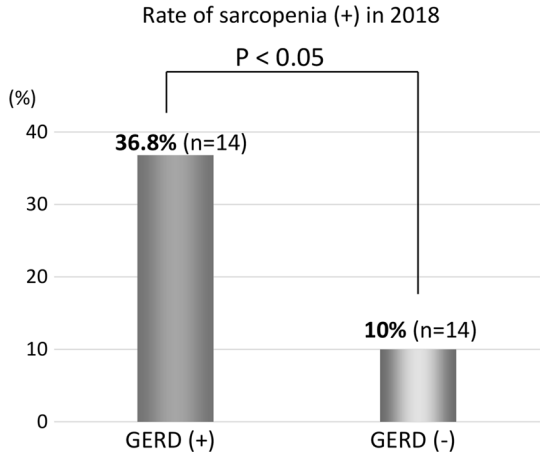

Fig. 3 Risk factors for development of GERD. The rate of sarcopenia in 2018 was significantly associated with a GERD(+) status

development with a decrease in lumbar lordosis of 10° in our cross-sectional study [7], and the current study also indicated that aggravation of lumbar kyphosis of 5° or 10° and of spinal inclination of 5° may be risk factors for new GERD. Miyakoshi et al. have reported that every additional 1° of lumbar kyphosis increased the chance of having GERD by factor of approximately 1.1 [5]. Therefore, changes in spinal alignment should be considered as important causes of GERD symptoms, as well as pain and neural deficit, in an aging society. Prevention of aggravation of lumbar kyphosis and spinal inclination may reduce development of new GERD, but a surgical procedure only to improve or prevent GERD symptoms should not be recommended.

Our study in 2012 was the first to show a relationship between reduced back muscle strength and the incidence of GERD [7]. No subsequent report has related GERD to back muscle strength and abdominal pressure, but a decrease in muscle mass (defined as sarcopenia) was identified as another risk factor for development of GERD in the current study. This suggests that a relationship of muscle strength and volume with GERD is likely. These results suggest that muscle exercise or training and treatment of sarcopenia may contribute to a reduction of GERD symptoms. However, it should also be noted that strenuous exercise induces significant reflux and related symptoms [34]; therefore, exercise for prevention of GERD should be selected carefully. Physical exercise once a week such as jogging, cross country skiing, and swimming was associated with a significant decrease in the risk of GERD by 50% compared with individuals who did no organized physical exercise of at least 30 min duration [35]. The mechanism of this protective effect is thought to involve strengthening the GER barrier function of the striated muscle of the crural diaphragm. We plan to evaluate the relationship and mechanism of muscle strengthening for prevention of GERD in a prospective intervention study.

The limitations of the study are as follows. First, the number of subjects was relatively small, and the spinal parameters and back muscle strength in 2013 and 2018 may have been significant factors for GERD symptoms in 2018 if the study had included more subjects because their mean values differed. However, the design allowed a high quality prospective longitudinal study with a high follow-up rate to be conducted, which allowed identification of significant risk factors for development of GERD. Second, this study focused on sagittal spinal alignment and did not examine coronal alignment. A recent article reported that left thoracolumbar/lumbar scoliosis was a significant risk factor for GERD and that the risk increased with a curve > 30° [36]. We also note the relationship between GERD and scoliosis in this further examination. Third, the subjects are relatively active and healthy volunteers engaged in agriculture and fishing, and so the results may differ from those in urban subjects, who may have more osteoporosis and frailty. These conditions may be risk factors for

Table 4 Comparison of aggravation of spinal parameters and back muscle strength over 5 years in patients with (GERD(+)) and without (GERD(−)) new gastroesophageal reflux disease (GERD) in 2018

Change from 2013 to 2018	GERD(+) in 2018 ($n=38$)	GERD(−) in 2018 ($n=140$)	p value *
Decrease in lumbar lordosis angle (°)	4.3 (11.1)	−3.9 (7.8)	< 0.005
Increase in spinal inclination angle (°)	3.1 (4.9)	0.28 (2.7)	< 0.01
Decrease in back muscle strength (kg)	5.2 (10.5)	−4.6 (18.5)	< 0.05
Lumbar kyphotic change (≥5°)	57.9% ($n=22$)	6.4% ($n=9$)	< 0.005
Lumbar kyphotic change (≥10°)	52.6% ($n=20$)	0% ($n=0$)	< 0.0001
Spinal inclination change (≥5°)	52.6% ($n=20$)	3.6% ($n=5$)	< 0.0001
Decreased back muscle strength (≥10 kg)	34.2% ($n=13$)	10% ($n=14$)	< 0.05

Values are shown as the mean or as the percentage (SD or number of patients in parentheses)

Negative values in the GERD(−) group indicate decreased lumbar lordosis and increased back muscle strength mean

*All comparisons are significant

Positive value indicates lordosis of the lumbar spine in this study

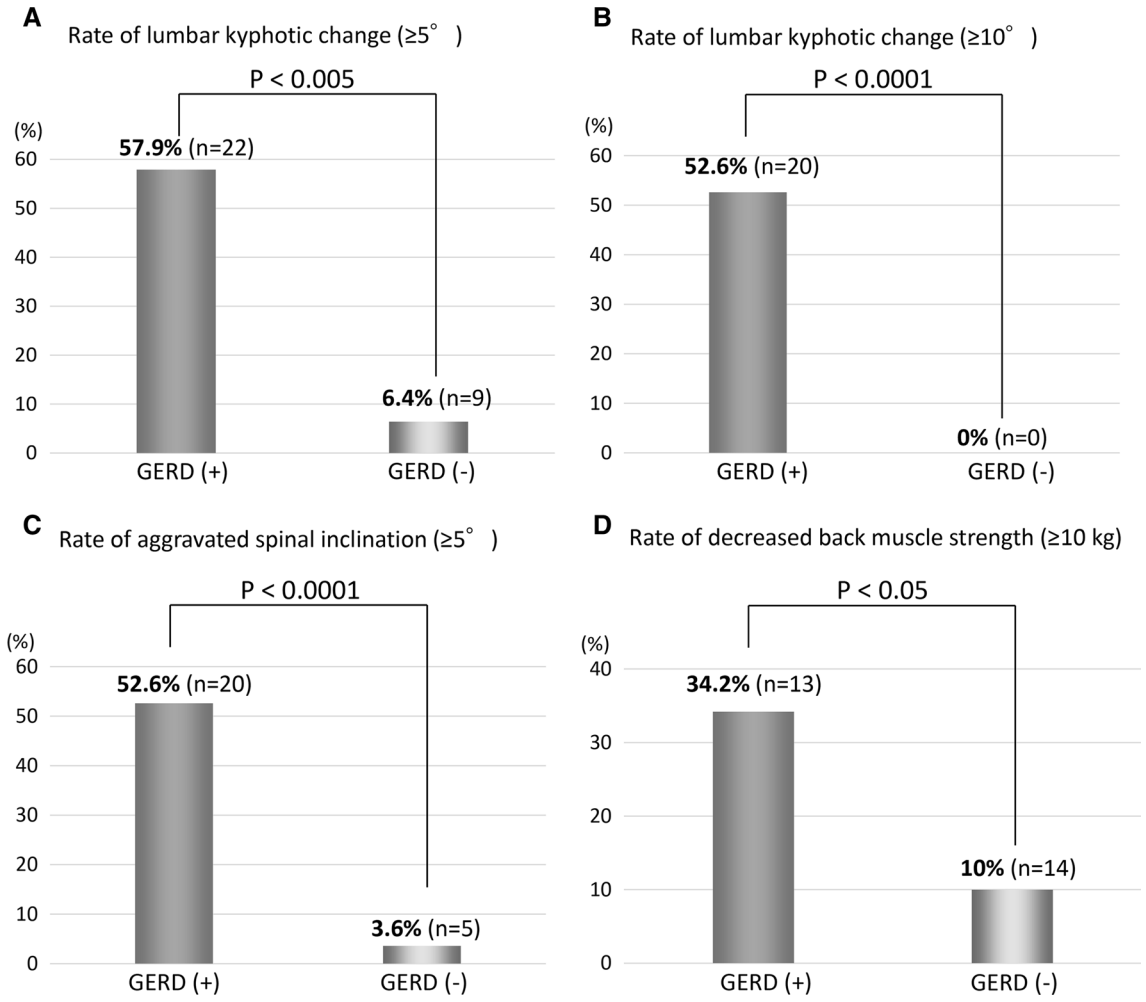

Fig. 4 Changes in spinal parameters and back muscle strength over 5 years as the risk factors for development of GERD. A GERD(+) status in 2018 was significantly related to high rates of aggravation of lumbar kyphosis ≥ 5° (**a**) and ≥ 10° (**b**), of spinal inclination ≥ 5° (**c**), and of decreased back muscle strength ≥ 10 kg (**d**)

Table 5 Comparison of quality of life (SF-36) in patients with (GERD(+)) and without (GERD(−)) new gastroesophageal reflux disease (GERD) in 2018

Variables	GERD(+) in 2018 ($n=38$)	GERD(−) in 2018 ($n=140$)	p value *
Physical component summary	46.2 (9.7)	50.6 (8.9)	< 0.05
Mental component summary	48.6 (9.9)	52.1 (8.8)	< 0.05

Values are shown as the mean (SD in parentheses)

*Both comparisons are significant

GERD depending on the study population. However, in our healthy subjects, 21% developed new GERD in 5 years, which indicates the importance of a focus on GERD in middle-aged and elderly people. Fourth, sarcopenia in this study is simply defined as a decrease in muscle mass, without inclusion of gait speed or grip strength in the definition. The definition of sarcopenia is still unclear and is likely to be modified and updated based on an international consensus for inclusion of gait speed and grip strength [37]. However, the results of this study are important in demonstrating that a simple decrease in muscle mass may also have an impact on new development of GERD symptoms. Lastly, we did not examine smoking and alcohol intake habits because these were not risk factors for GERD

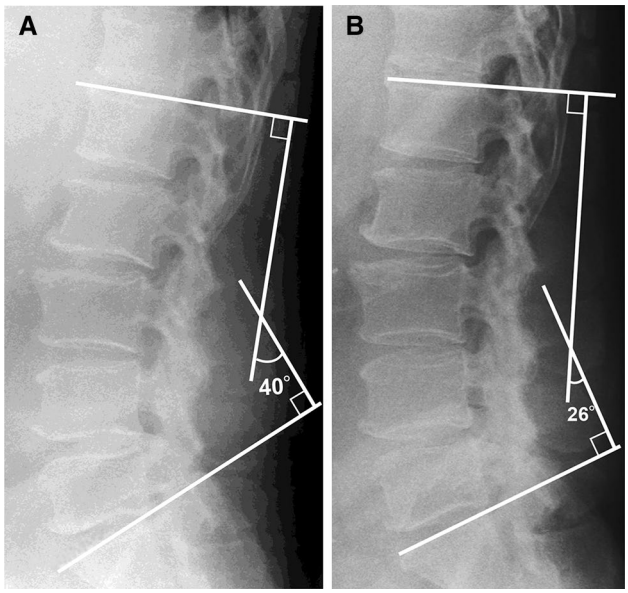

Fig. 5 Representative case of development of new GERD(+) after 5 years in a male aged 70 years in 2013. His lumbar lordosis angle decreased from 40° to 26° (lumbar kyphotic change of 14° in 5 years), and he developed new GERD(+) with a change in FSSG scale from 3 to 10 in 5 years

in our previous study in healthy volunteers [7]. Smoking seems to carry a risk for GERD symptoms and smoking cessation improved both GERD and QOL [38], while the relationship of alcohol intake with GERD is unclear [35, 39]. These issues require further investigation in another population.

In conclusion, this prospective longitudinal study was the first to show that lumbar kyphotic change, aggravation of spinal inclination, decreased back muscle strength, and sarcopenia are significant risk factors for development of new GERD. Management and prevention of these factors may contribute to reduction of new GERD and increased QOL in middle-aged and elderly people.

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Compliance with ethical standards

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Affiliations

Shiro Imagama[1] · Kei Ando[1] · Kazuyoshi Kobayashi[1] · Masaaki Machino[1] · Satoshi Tanaka[1] · Masayoshi Morozumi[1] · Shunsuke Kanbara[1] · Sadayuki Ito[1] · Taisuke Seki[1] · Takashi Hamada[1] · Shinya Ishizuka[1] · Hiroaki Nakashima[1] · Naoki Ishiguro[1] · Yukiharu Hasegawa[2]

✉ Shiro Imagama
imagama@med.nagoya-u.ac.jp

[1] Department of Orthopaedic Surgery, Nagoya University Graduate School of Medicine, 65, Tsurumai, Showa-ku, Nagoya, Aichi 466-8550, Japan

[2] Department of Rehabilitation, Kansai University of Welfare Sciences, 3-11-1, Asahigaoka, Kashiwara, Osaka 582-0026, Japan