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Clinical Studies

Prevalence of global spinal malalignment and the influence on LBP and HR-QOL in a healthy, nonelderly population. A cross sectional analysis, including bone mineral density, skeletal muscle mass index, and back muscle extensor strength

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ABSTRACT

Background: In healthy, nonelderly populations, prevalence of 3 modifiers of global spinal malalignment (GS-MalAlign) (PT ≧20°, PI-LL≧10°, SVA≧40 mm) remains unknown. The clinical significance has not been determined. The purposes are to disclose the prevalence of the 3 modifiers of GS-MalAlign, and evaluate the influence on LBP, and HR-QOL related to bone mineral density (BMD), skeletal muscle mass index (SMI), and back muscle extensors strength (BMES) in a healthy, nonelderly population.
Methods: A mono-centric, cross-sectional survey. Three hundred and 2 participants (18< age <65 years) without ADL disturbance were consecutively enrolled. Sagittal parameters of the spine and the pelvis were measure on whole spine radiograms. BMD and SMI were determined using DEXA. BMES was defined as a maximum extension force at the T4 to T7 level and measured by a strain-gauge dynamotor. LBP was checked through interview. HR-QOL was ascertained by score of Medical Outcome Study Short-Form 36-Health Survey (SF-36v2).
Results: The final analysis could be done in 84 females and 179 males. PT≧20°, PI-LL≧10°, and SVA≧40 mm were found in 12% (31/263), 11% (31/263), and 6% (16/263), and each mean value was 25.0 ± 4.0°, 15.3 ± 5.9°, and 52.7 ± 12.2 mm (Mean ± S.D.). Prevalence of LBP was significantly higher in the participants with PI-LL≧10° than with PI-LL<10°; 43% (12/28) versus 21% (49/235) (p<.05). PI-LL≧10° only had an association with LBP (OR: 3.0435, 95% CI, 1.1378–8.141, p<.05). Four 2% of participants (4/263) associated with all 3 modifiers had LBP and a significantly lower mental component summary score of SF-36v2 (p<.05).
Conclusions: Some of individuals are associated with GS-MalAlign even in healthy, nonelderly populations. There is a possibility that PI-LL ≧10° results in LBP within a degree of no ADL disturbance, and it is speculated that coexistence of all 3 modifiers of GS-MalAlign would lead to a poor mental HR-QOL.

Background

Physiological curvature in the sagittal plane and straight architecture in the coronal plane are required for maintaining activities of daily living (ADL). In 1994, Dubousset et al. described a unique concept called the "Cone of Economy," which was characterized by an ergonomically favorable, erect position of the spine. Once the global spinal alignment in the sagittal plane (GS-Align) was set out in the "Cone of Economy," muscular demand, fatigue, and pain easily develop [1].

It is well recognized that GS-Align is very closely linked to health-related quality of life (HR-QOL) and exhibits clinical symptoms of patients with osteoporosis, sarcopenia, and adult spinal deformity (ASD). Low back pain (LBP), walking disturbance due to back fatigue and pain, and increased potential of falls are dominant symptoms in aged patients

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with global spinal malalignment in the sagittal plane (GS-MalAlign). Depressive mood and/or syndrome secondary to LBP and unsatisfied feelings of self-body image often develop in the same patients [1–3]. Gastroesophageal reflux, dysphagia, and respiratory disorders can also be anticipated in patients with GS-MalAlign [4]. Therefore, restoration of normal GS-Align is very essential to be healthy individuals.

Numerous numbers of articles about GS-Align have been published. As radiological parametres of GS-Align, C7 sagittal vertical axis (SVA), thoracic kyphosis (TK), lumbar lordosis (LL), sacral slope (SS), pelvic incidence (PI), mismatch between pelvic incidence and lumbar lordosis (PI-LL), and pelvic tilt (PT) including cervical lordosis (CL) gain a consensus of clinical validity and are used in the studies of health-related epidemiology and planning of corrective surgeries for spinal disorders.

In 2012, especially as it concerned ADS, the Scoliosis Research Society demonstrated radiographic parameter thresholds that were predictive of an Oswestry Disablity Index score of 40. According to the guideline, the thresholds are PT of 22°, PI-LL of 11°, and SVA of 46 mm, respectively. At the same time, as normal sagittal modifiers of GS-Align; PI-LL<10°, SVA<40 mm, and PT<20° are proposed based on the data of Caucasian populations with symptomatic ASD [5]. Contrast to the validity in symptomatic patients, prevalence and significance of GS-MalAlign modifiers; PT≧20°, PI-LL≧10°, and SVA≧40 mm, have not been disclosed in healthy, nonelderly populations (18< age <65 years).

In 1988, Takemitsu et al. already demonstrated that patients who had a forward bending posture while walking and/or an exhausted status had established categories of lumbar degenerative kyphosis caused by decreased back muscle extensor strength and atrophy in elderly populations [2]. Bone mineral density (BMD), skeletal muscle mass index (SMI), back muscle extensor strength (BMES), and GS-Align are intricately related. In general, low BMD, SMI, and weak BMES are risk factors for LBP and poor HR-QOL [6,7]. Thus, GS-Align should be simultaneously evaluated with BMD, SMI, and BMES when treating patients with degenerative spinal disorders. There are many studies about BMD, SMI, BMES, LBP, and HR-QOL with GS-Align in elderly populations. Meanwhile, associations among GS-MalAlign modifiers, BMD, SMI, and BMES have not been specifically analyzed in healthy, nonelderly populations.

Therefore, 3 purposes were set in the current survey. The first purpose is to disclose a prevalence of GS-MalAlign modifiers (PT≧20°, PI-LL≧10°, and SVA≧40 mm), the second was to evaluate associations among radiological parametres of GS-Align, including BMD, SMI, and BMES, and the third was to detect whether the 3 modifiers have influence on LBP and HR-QOL in relation with BMD, SMI, and BMES in a healthy, nonelderly population.

Methods

Cooperation and consent to the current survey could be obtained in a robust medical factory in our city. The whole population of the city was 74.175 in 2015. A total number of employees of the medical factory was 1,489, and the employees lived in the same city. Their ethnicity was singular and Mongoloid heritage. Three hundred and 2 participants out of 1,489 individuals who had regular jobs and no ADL disturbance were randomly selected and evaluated at our hospital during the period of 2015 to 2016.

This survey was approved by the ethics committee of our institute on 7 August 2015, according to the 1964 Helsinki Declaration. No economic incentive had been paid to the participants.

All of them were asked to give their consent to participate, including a risk of very low radiation exposure in the current survey. Age, gender, body height, weight, and status of QOL were ascertained in the questionnaire.

The inclusion criteria were as follows: age 18< age <65 years old; no ADL disturbance due to spinal and other joint pain; neither previous nor current treatment of spine; no previous diagnosis of spinal disorders.

Assessment of physical status including LBP

Past histories of the 302 participants were taken by interview. Physical and neurological conditions involving the whole spine, the hip, the knee, and the ankle joints were checked by 3 independent orthopedic doctors, who have been certificated by the Japanese Society for Spinal Surgery and Related Research.

It was also determined whether participants had LBP through the interview and the physical examination. LBP was defined as a pain within the present week at the examination that was felt anywhere approximately from the L2–3 interspace through the gluteal area and lasted longer than 24 hours regardless of the pain degree.

Assessment of HR-QOL, GS-align, BMD, SMI, and BMES

For the evaluation of QOL, medical Outcome Study Short-Form36-Health Survey Version 2 for Japanese (SF-36v2) was used [8].

To evaluate GS-Align, the whole spine radiograms were taken in anteroposterior and lateral directions in a naturally standing position with the arms resting on the chest. The effective dose is estimated to 4.60mSv in our institute. As parametres of GS-Align, CL, TK, LL, SS, PI, PT, PI-LL, and SVA were measured by 3 radiographers certified by the Japan Association of Radiological Technologist, and the mean value of them was used for the evaluation.

BMI (body weight / body height squared, kg/m^2) was calculated. BMD of the hip in anteroposterior direction (g/cm^2) and SMI (arm muscle mass + leg muscle mass/body height squared, kg/m^2) were calculated using Dual Energy X-ray Absorptiometry (Hologic DISCOVERY A, Bedford, MA). The effective dose is estimated to 0.002mSv in our institute.

BMES was determined based on a method by Limburg et al [9]. A strain-gauge dynamotor (Biotec, Akita City, Japan) was attached to the frame, and the maximum extension force was measured at the T4 to T7 level in the supine position with the hips and knees extended, and the arms resting at the sides in bed. The BMES test was done under supervision of skilled physical therapists.

Statistical analysis

The significant difference between 2 measured items was analyzed by the Mann-Whitney *U* test for ordinal data, and by Fisher's test for nominal data. Associations between the parametres of GS-Align were determined by Kendall's rank correlation in case both were in normal distributions, otherwise by Spearman's rank correlation. Weak, moderate, and strong correlation are defined as r = 0.20 ~ <0.40, 0.40 ~ <0.60, and 0.60 ~ <0.80, respectively. Possible risk factors associated with LBP was evaluated by binomial logistic regression analysis. All analysis was performed by BellCurve for Excel (version III, Tokyo, Japan).

Results

Demographics

Out of the 302 participants, 20 and 7 participants were not included because of spinal scoliosis>10° and lumbar spondylolisthesis (more than 5 mm) on the whole spine radiograms, respectively. Two participants with a history of cervical laminoplasty and lumbar vertebral fracture were excluded. Five participants taking antipsychotics and/or NSAIDs were also excluded. Two participants without completed SF-36 v2 questionnaires were omitted. Two participants with incorrect documentation of BMD and SMI were not included. A participant who could not finish the BMES test was excluded. Finally, data of 263 participants was used in the final analysis (Fig. 1).

Participants' basic characteristics of each item have been summarized in Table 1. The percentage of female and male participants was

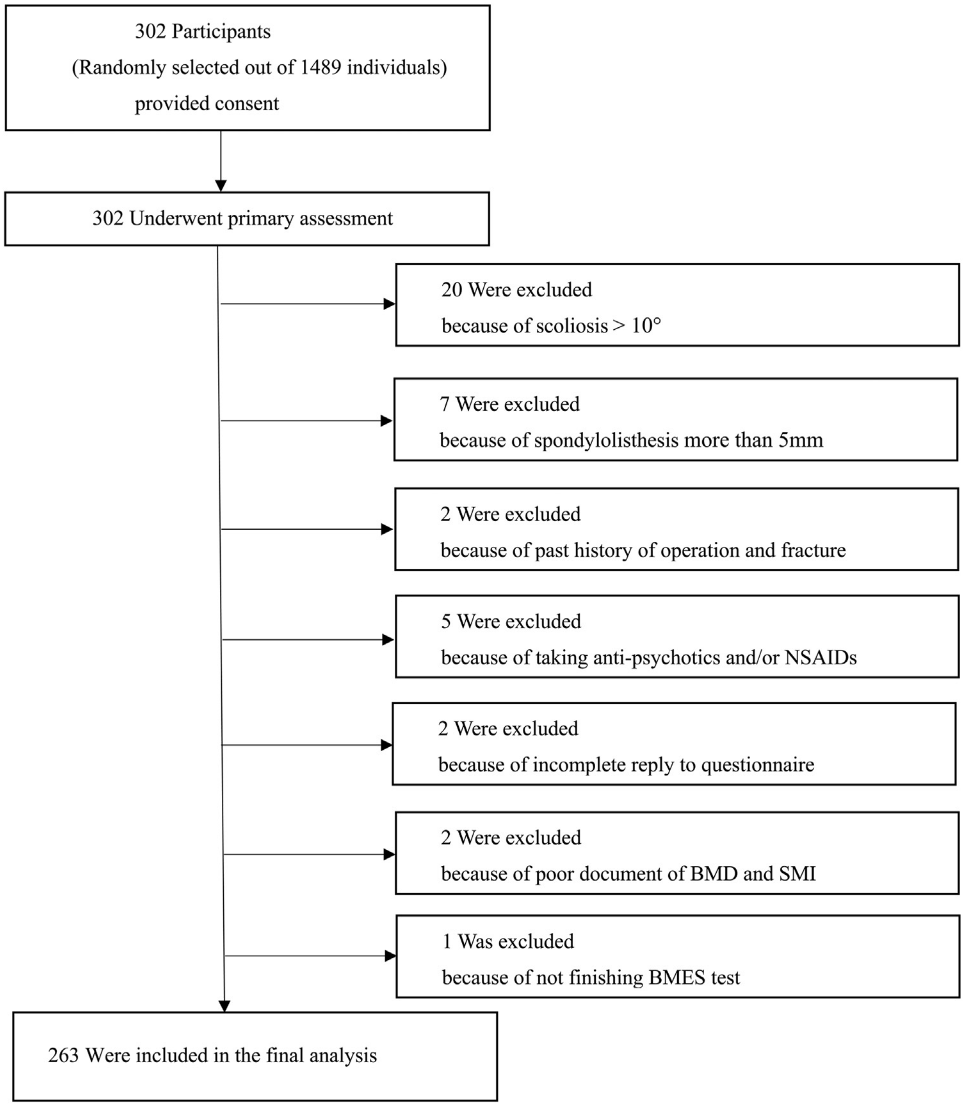

Fig. 1. Flow chart for the survey participants selection. BMD, bone mineral density; SMI, skeletal muscle mass index; BMES, back muscle extensor strength.

32% (84/263) and 68% (179/263). The mean age was 39 ± 13 years (mean ± standard deviation, range; 19–61).

Prevalence of 3 modifiers

In terms of prevalence of GS-MalAlign, 21% (54/263) of the participants were associated with 1 of 3 modifiers at least. Participants with PT≧20° was found in 12% (31/263), and the mean value was 25.0 ± 4.0° (range; 20.0–36.9). Participants with PI-LL≧10° was found in 11% (31/263), and the mean value was 15.3 ± 5.9° (range; 10.1–29.4). Participants with SVA≧40 mm was found in 6% (16/263), and the mean value 52.7 ± 12.2 mm (range; 40.0–87.0).

In the 54 participants with 3 modifiers, 5% (12/263) of participants were associated with both PT≧20° and PI-LL≧10°, 1 participant was associated with both PI-LL≧10° and SVA≧40 mm, and 2% (4/263) of participants were associated with all PT≧20°, PI-LL≧10° and SVA≧40 mm (Table 2).

Associations among spinal parameters, BMD, SMI, and BMES

Detailed data has been shown in Table 3. A positive correlation was strongly found between SMI and BMES (r = 0.62, p<.01). A negative correlation between SMI and LL (r = −0.24, p<.01), and a positive correlation between SMI and SVA (r = 0.28, p<.01) were subtly found.

Positive correlations were also found among the spinal parameters. A weak correlation was found between TK and LL (r = 0.30, p<.01). A strong and a moderate correlation were found between LL and SS, and between LL and PI (r = 0.77 and r = 0.54, p<.01), respectively. A moderate correlation was found between SS and PI (r = 0.52, p<.01). PT had moderate correlations with PI, PI-LL, and a weak correlation with SVA (r = 0.42, 0.54, and 0.21, p<.01), respectively. PI-LL positively had a weak and moderate correlation with PI and SVA (r = 0.23 and 0.48, p<.01), and it negatively had a weak and moderate correlation with TK and LL (r = −0.24 and −0.55, p<.01), respectively. SVA had a slight positive and negative correlation with CL and LL (r = 0.26 and r = −0.39, p<.01).

The influence of 3 modifiers on LBP and HR-QOL

Total prevalence of LBP was 23% (61/263) (Table 1). Prevalence of LBP was significantly higher in the participants with PI-LL≧10°than those with PI-LL<10° (43%; 12/28 vs. 21%; 49/235, p<.05), but no significant difference was found between the participants with PT≧20°and PT< 20°, and with SVA≧40 mm and SVA<40 mm (Table 4). By bino-

Table 1
Participants' Basic Characteristics

Items	Mean ± S.D.	Range
Female: male	32% (84/263): 68% (179/263)	
Age (y)*	39 ± 13	19–61
Weight (kg)*	65 ± 12	39–109
Height (cm)*	167 ± 9	144–187
BMI (kg/m^2) *	23 ± 4	16–36
BMD (g/cm^2) *	0.77 ± 0.13	0.54–1.26
SMI (kg/m^2)	7.5 ± 1.2	4.6–11.6
BMES(Newton)*	384 ± 156	95–978
CL (°)	7.6 ± 11.9	−21 to 42.2
TK (°) *	26.4 ± 8.1	0.8–43.9
LL (°)	49.9 ± 10.3	22.1–77.6
SS (°) *	35.6 ± 7.6	15.6–64.0
PI (°) *	48.5 ± 9.5	28.0–82.2
PI-LL (°) *	−1.4 ± 9.5	−38.0 to 29.4
PT (°) *	12.9 ± 6.8	−11.0 to 36.9
SVA (mm)	−2.2 ± 25.2	−61.0 to 87.0
LBP prevalence (%)	23(61/263)	
PCS*	52 ± 9	10–73
MCS	45 ± 10	10–71
RCS*	50 ± 10	4–71

BMI, body mass index; BMD, bone mineral density; SMI, skeletal muscle mass index; BMES, back muscle extensor strength; CL, cervical lordosis; TK, thoracic kyphosis; LL, lumbar lordosis; SS, sacral slope; PI, pelvic incidence; PI-LL, mismatch between pelvic incidence and lumbar lordosis; PT, pelvic tilt; SVA, C7 sagittal vertical axis; LBP, low back pain; PCS, physical component summary score; MCS, mental component summary score; RCS, role component summary score; S.D., standard deviation.

* Indicates a normal distribution.

Table 2
Demographic of Participants With 3 Modifiers (PT≧20°, PI-LL≧10°, and SVA≧40 mm)

	PT≧20°	PI-LL≧10°	SVA≧40 mm
Items			
Prevalence	12% (31/263)	11% (28/263)	6% (16/263)
Mean ± S.D.	25.0 ± 4.0	15.3 ± 5.9	52.7 ± 12.2
Range	20.0–36.9	10.1–29.4	40.0–87.0
with PT≧20°		12	0
with PI-LL≧10°	12		1
with SVA≧40 mm	0	1	
with PI-LL≧10° and SVA≧40 mm	4		
with PT≧20° and SVA≧40 mm		4	
with PT≧20° and PI-LL≧10°			4

PT, pelvic tilt; PI-LL, mismatch between pelvic incidence and lumbar. lordosis; SVA, C7 sagittal vertical axis; S.D., standard deviation.

mial logistic regression analysis in BMD, SMI, BMES, and 3 modifiers, PI-LL≧10° only had a significant association with LBP (OR: 3.0435, 95% CI, 1.1378–8.141, p<.05) (Table 5).

In PCS, MCS, and RCS of SF-36v2, no significant differences were found between the participants with PT≧20°and PT< 20°, PI-LL≧10°and PI-LL<10°, and SVA≧40 mm and SVA<40 mm. The 4 participants with all 3 modifiers had LBP and a significantly lower MCS than others (36 ± 7 vs. 45 ± 10, p<.05) (Table 4).

Discussion

The ADS classification system was established in 2012. Three modifiers (PT≧20°, PI-LL≧10°, and SVA≧40 mm) were defined as abnormal sagittal parameters in radiograms. The range of 3 modifiers was determined being based on pain and disability score in patients with symptomatic ADS [5]. But prevalence and significance of 3 modifiers in healthy, nonelderly populations without ADL disturbance has not been disclosed yet.

The current survey was introduced in a relatively young and healthy population with a mean age of 39 years. To my knowledge, the current result is the first and specific description about prevalence of 3 modifiers of GS-MalAlign (PT≧20°, PI-LL≧10°, and SVA≧40 mm). Considering the current results, clinicians should consider that some of individuals in healthy, nonelderly populations have abnormal values of PT, PI-LL, and SVA proposed by Scoliosis Research Society. As the number of participants was small (263 participants) in the current study, a further study in a larger number of healthy, nonelderly participants should be done to confirm the accurate prevalence of the 3 modifiers.

In elderly populations (≧65 years), low BMD, SMI, and weak BMES are independent risk factors for GS-MalAlign and poor HR-QOL. Decreased SMI is involved in progression of spinal deformity, especially in increased PT, and it results in worsening LBP [2,4,7,10]. Meanwhile, associations among the radiological parameters of GS-Align related to BMD, SMI, and BMES have been rarely analyzed in healthy, nonelderly populations.

In the current study, BMD (mean; 0.77 g/cm^2, range; 0.54–1.26), SMI (mean; 7.5 kg/m^2, range; 4.6–11.6), and BMES (mean; 384 ± 156 N, range; 95–978) were intimately correlated, but they had no moderate or strong correlations with the spinal parametres. Only weak correlation was found between SMI and LL (r = −0.24, p<.01) and SVA (r = 0.28, p<.01).

These results are quite contradictory to the previous reports in the elderly populations. Less flexibility and fixed deformity of the spine accelerate weakness of the back extensors, round back, and LBP [11]. Especially, thoracic spine ROM has been emphasized as predictors of PCS of SF36v2 [6]. Moreover, type II muscle fiber size, contractile velocity, fatigability, and force steadiness of the back extensors are very impor-

Table 3
Correlations Among Spinal Parameters, BMD, SMI, and BMES

	BMD	SMI	BMES	CL	TK	LL	SS	PT	PI	PI-LL
BMD										
SMI	0.46*									
BMES	*0.28**	0.62*								
CL	−0.16	0.03	−0.11							
TK	*−0.08*	−0.00	*−0.07*	0.16						
LL	−0.12	−0.24*	−0.15	−0.01	0.30*					
SS	*−0.02*	−0.15	*−0.02*	−0.03	*−0.04*	0.77*				
PT	0.02	0.08	*0.01*	−0.02	*0.02*	−0.10	*−0.07*			
PI	*−0.02*	−0.06	*−0.00*	−0.05	*−0.02*	0.54*	*0.52**	*0.42**		
PI-LL	*0.10*	0.19	*0.11*	−0.02	*−0.24**	−0.55*	*−0.12*	*0.54**	*0.23**	
SVA	0.10	0.28*	0.18	0.26*	0.08	−0.39*	-0.11	0.21*	0.06	0.48*

BMD, bone mineral density; SMI, skeletal muscle mass index; BMES, back muscle extensor strength; CL, cervical lordosis; TK, thoracic kyphosis; LL, lumbar lordosis; SS, sacral slope; PT, pelvic tilt; PI, pelvic incidence; PI-LL, mismatch between pelvic incidence and lumbar lordosis; SVA, C7 sagittal vertical axis.
Italic: Kendall's rank correlation coefficient. Nonitalic: Spearman's rank correlation coefficient.

* p<.01.

Table 4
Prevalence of LBP and SF-36v2 Score of the Participants

	PT≧20°	PT<20°	PI-LL≧10°	PI-LL<10°	SAV≧40 mm	SAV<40 mm	All 3 Modifiers	Not All 3 Modifiers
LBP (+)	29% (9/31)	22% (52/232)	**43%*(12/28)**	21% (49/235)	31% (5/16)	23% (56/247)	**100%†(4/4)**	22% (57/259)
LBP (-)	71% (22/31)	78% (180/232)	57% (16/28)	79% (186/235)	69% (11/16)	77% (191/247)	0% (0/4)	78% (202/259)
PCS	52 ± 7; 30–64	53 ± 9; 10–73	53 ± 8; 30–64	52 ± 9; 10–73	52 ± 7; 39–63	53 ± 9; 10–73	51 ± 6; 42–55	53 ± 9; 10–73
MCS	45 ± 11; 10–69	45 ± 10; 23–71	42 ± 11; 10–64	45 ± 10; 23–71	43 ± 10; 26–58	45 ± 10; 10–71	**36 ± 7*; 27–44**	45 ± 10; 10–72
RCS	49 ± 10; 25–63	50 ± 10; 4–71	50 ± 11; 25–66	50 ± 10; 4–71	49 ± 12; 25–63	50 ± 10; 4–71	42 ± 14; 34–63	50 ± 10; 4–71

LBP, low back pain; PT, pelvic tilt; PI-LL, mismatch between pelvic incidence and lumbar lordosis; SVA, C7 sagittal vertical axis; All 3 modifiers, participants with all of PT≧20°, PI-LL≧10° and SVA≧40 mm; Not All 3 modifiers, participants with not all of PT≧20°, PI-LL≧10° and SVA≧40 mm.
PCS, physical component summary score; MCS, mental component summary score; RCS, role component summary score.
* p<.05.
† p<.01. Statistically significant finding indicated in bold.

Table 5
ORs and 95% CIs for LBP in relation to BMD, SMI, BMES, and 3 Modifiers (PT≧20°, PI-LL≧10°, and SVA≧40 mm)

Variables	Coefficient (β)	SE	Odds Ratio	95% CI	Wald	p Value
BMES(Newton)	0.0003	0.0012	1.0003	0.9979–1.0026	0.045	.8319
SMI (kg/m^2)	0.1032	0.1635	1.1087	0.8047–1.5276	0.3981	.5281
BMD(g/m^2)	0.1441	1.2831	1.155	0.0934–4.2819	0.0126	.9106
SVA≧40 mm; 1 /<40 mm; 0	0.1833	0.589	1.2012	0.3787–3.8101	0.0969	.7556
PT≧20°; 1 / <20°; 0	0.2505	0.5288	0.7784	0.2761–2.1945	0.2243	.6357
PI-LL≧10°; 1 / <10°; 0	**1.113**	**0.502**	**3.0435**	**1.1378–8.141**	**4.9158**	**.0266**

Statistically significant finding indicated in bold (p<.05).
BMES, back muscle extensor strength; SMI, skeletal muscle index; BMD, bone mineral density.
PT, pelvic tilt; PI-LL, mismatch between pelvic incidence and lumbar lordosis; SVA, C7 sagittal vertical axis.

tant to maintain the energy expenditure in the core of spinal balance [1,12,13].

Thus, it is speculated that the nonelderly participants have better spinal flexibility, no fixed vertebral deformity due to osteoporosis, and better property of back extensors muscles in comparison to the aged population of the previous reports, and as a result, BMD, SMI and BMES were not definitively correlated with the radiological spinal parameters. The current findings could provide a new information about characteristics of GS-Align related to BMD, SMI, and BMES in healthy, nonelderly populations.

In healthy, nonelderly populations, significance of the 3 modifiers on LBP and HR-QOL remains unknown. PI-LL literally means an anatomical mismatch between the pelvis and the lumbar spine in the sagittal plane. In the current study, the mean value of PI-LL was −1.4 ° (range; −38.0 to 29.4). It was positively correlated with PI, SVA, PT, and negatively with LL and TK. Similar correlations in the 1,461 asymptomatic participants (446 men, 995 women), whose age was ranging 19 to 94 years., have already been reported [14]. The current results have also reconfirmed that PI-LL is a crucial indicator to represent individual, harmonious balance of the spine in a healthy, relatively young population (mean age; 39, range; 19–61).

Many studies demonstrated that an extreme discrepancy between PI and LL easily leads to LBP disturbing HR-QOL. The current result has shown that the participants with PI-LL≧10° have a significantly higher prevalence of LBP than PI-LL<10° (43% vs. 21%), and that PI-LL≧10° only has a significant association with LBP by the binomial logistic regression analysis in BMD, SMI, BMES, and 3 modifiers.

The cause of LBP is very complicated and multifactorial. It is impossible to explain it by a single independent risk factor, but it is demonstrated that PI-LL mismatch group had increased trunk imbalance more than the PI-LL match group based on the data using a stabiometry [15]. Thus, there is a possibility that even a small PI-LL mismatch (mean; 15.3°, range; 10.1–29.4) develops a trunk imbalance and back muscle fatigue, which would lead to a mild pain within a degree of no ADL disturbance. A further study consisting of a large number of healthy participants with PI-LL≧10 ° is necessary to confirm the assumption.

Regarding PT and SVA, increased PT and SVA were closely related to LBP and poor clinical outcomes as well. PT was positively correlated with SVA and negatively with HR-QOL's scores [3,5]. PT and SVA were also independent variables for LBP even after lumbar interbody fusion [16]. In contrast to the previous reports, our results have demonstrated that PT≧20° (mean; 25.0°, range; 20.0–36.9) and SVA≧40 mm (mean; 52.7 mm, range; 40.0–87.0) have no influence on LBP and HR-QOL. There is a report that incidence of SVA>50 mm was 10% (22/220) in an asymptomatic population with a mean age 59.0 years [17].

It is noticeable that all 4 participants with all of 3 modifiers have LBP, and could be hypothesized that both PT≧20° (i.e., unadjusted pelvic retroversion) and SVA≧40 mm (i.e., anterior shift of the center of gravity) synergically affect individual's harmonious balance with PI-LL≧10° and worsen back muscle overuse, fatigue, and deteriorate the mild pain. Moreover, the 4 participants with all of 3 modifiers also have a low MCS (mean; 36, range; 27–44). MCS is an easier and more valid predictor to detect subclinical, depressive conditions, and MCS with 35 or less, is a cutoff point of depressive symptoms in patients with spinal pain [18,19].

Both SVA≧40 mm and PT≧20° in addition to PI-LL≧10° might have worsening depressive moods secondarily caused by the mild pain, self-unsatisfied body image and/or posture [1–3]. Therefore, in clinical practice, clinicians should carefully observe patients who have all of 3 modifiers regarding the prognosis of LBP and related psychological symptoms.

It remains controversial whether ethnic differences in radiological parameters of GS-Align are present. A study demonstrated that mean value of PI was 55.8 ± 10.6 ° in 53 Japanese participants with the mean age of 63 years, and it was quite like Caucasians [20]. Meanwhile, some studies suggested that adults with Mongoloid heritage tended to have a smaller PI, LL, PK, and SVA than most Caucasians [21,22]. Other studies also mentioned that Africans had bigger values of PI, LL, and TK than Asians and Caucasians [23,24].

Our data has demonstrated that a healthy, nonelderly population with Mongoloid heritage have approximately 5 to 10° smaller values of PI, LL, TK, and SS than the data of Caucasians and Africans [23–27]. The mean value of SVA also demonstrated a close to 10 mm or smaller one than Caucasians [1,27]. If the ethnic difference of the spinal parameters is present, the validity of 3 modifiers (PT≧20°, PI-LL≧10°, and SVA≧40 mm) could not be completely applied to Mongoloid populations, especially when optimal surgical correction is targeted in patients with ASD. Vice versa, the influence of the 3 modifiers on LBP and HR-QOR, which have been disclosed in the current study, are not fully versatile in non-Mongoloid populations. Further studies are mandatory to unveil the interracial difference.

There are several limitations in the current survey. The weakest point is that the total number of participants was small (263 participants). In addition, the number of participants with each 3 modifiers (PT≧20°; 31, PI-LL≧10°; 28, and SVA≧40 mm; 16) were extremely small. Another study with a larger number of participants, with the values of the 3 modifiers but without ADL disturbance, should be performed to confirm that the influence on LBP and HR-QOR in healthy, nonelderly populations.

The second limitation is that the current study was a cross-sectional one. It could not be anticipated that the healthy participants with the 3 modifiers would be kept in the same condition when they become older [20]. In addition, the age of the total participants was relatively young (mean age; 39, range; 19–61), and the number of the participants around 55 to 60 years old was not enough to perform an accurate subgroup analysis in terms of age and gender. There might be an age and gender-related variation in prevalence of GS-MalAlign even in healthy, nonelderly populations [17].

Conclusions

In a healthy, nonelderly population consisted of 84 females and 179 males (mean age; 39, range; 19–61), a mono-centric, cross-sectional survey about GS-MalAlign has been done. Clinicians should consider that some of individuals are assocaitated with the 3 modifiers of GS-MalAlign proposed by Scoliosis Research Society. GS-MalAlign has no definitive associations with BMD, SMI, and BMES. But PI-LL≧10° may be one of the independent risk factors of LBP within a degree of no ADL disturbance. There is a possibility that coexistence of PI-LL≧10° plus PT≧20° and SVA≧40 mm lead to a poor mental HR-QOL.

Declaration of competing interest

The authors declare that there are no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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