

THE EFFECT OF MUSCULOSKELETAL DISORDERS ON BODY REGIONS AND PAIN LEVELS IN ELDERLY PEOPLE ON DYNAMIC BALANCE ABILITY

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ABSTRACT

Background and objective

Musculoskeletal disorders (MSDs) are caused by factors such as aging, smoking, high body mass index (BMI), muscle loss, repetition of specific movements, and physical activity of intense muscle demands. MSDs cause pain, decrease the range of motion of joints, reduce proprioception sensory function, and reduce posture maintenance. This study aims to present basic data on prescription of exercise for musculoskeletal movements in elderly people by evaluating the dynamic balance ability according to the presence of MSDs and the body regions affected by MSDs, and verifying the effects of MSD pain on the dynamic balance ability.

Material and methods

This study examined and identified differences according to the presence MSDs (Disorders, $n = 51$, age = 67.35 ± 2.62 years; Control, $n = 15$, age = 66.33 ± 3.10 years) and MSDs of body regions (shoulder, $n = 14$, age = 66.14 ± 1.95 years; lower back, $n = 17$, age = 67.82 ± 1.77 years; and knee, $n = 20$, age = 67.80 ± 2.36 years) in 66 elderly males. The causal relationship between MSD pain and dynamic balance ability was analyzed. The dynamic balance ability was measured using S3-Check (Multi-Functional Training, MFT S3; GmbH, Germany) where the subject takes off his shoes and positions on a 530-mm diameter round platform that moves in the axial direction (left-right or front-back) in the measuring range of $+20^\circ$ to -20° tilt angle.

Results

The postural stability level was lower in the MSD group than in the group without MSD (left-right, $P < 0.001$; front-back, $P < 0.001$). The group with MSDs in the knee and the lower back showed lower results in the left-right and front-back stability index than the group without MSDs. Also, the knee and lower back MSD group showed lower scores in the front-back stability index than the shoulder MSD group. The level of sensory-motor function was lower in the MSD group than in the group without MSD (left-right, $P < 0.001$; front-back, $P < 0.01$). The MSD pain showed significantly positive standardized coefficients in the order of sensorimotor index (front-back, $\beta = 0.404$, $P < 0.01$; left-right, $\beta = 0.397$, $P < 0.01$) and stability index (front-back, $\beta = 0.382$, $P < 0.01$; left-right, $\beta = 0.311$, $P < 0.01$). As the degree of MSD pain increased, the postural stability level and sensory-motor function decreased.

Conclusions

We verified that the MSDs of body regions (knee and lower back) and pain level in the elderly are important factors in the decrease of dynamic balance ability.

Keywords: *dynamic balance ability; elderly; fall; musculoskeletal disorders; pain level; risk*

INTRODUCTION

Musculoskeletal disorders (MSDs), also called cumulative trauma disorders, are defined as disorders that impair human body structures such as muscles, tendons, nerves, and intervertebral disc.¹ MSDs are caused by the accumulation of minor traumas because of repeated use of specific body parts that trigger biomechanical stress, rather than a one-time trauma.² MSDs are also caused by factors such as aging, smoking, high body mass index (BMI), muscle loss, repetition of specific movements, and physical activity of intense muscle demands.^{1,3-5} MSDs cause pain, decrease the range of motion of joints, reduce proprioception sensory function, and reduce posture maintenance.⁶ MSDs in elderly people are known to reduce muscle strength and gait ability and increase the frequency of falls.^{6,7} Elderly people have a higher incidence of MSDs, such as fractures, osteoporosis, osteoarthritis, and rheumatism.⁸ MSDs cause chronic pain and limited physical activity in 22.1–26.3% of elderly people.⁹ Thus, chronic pain and physical activity restrictions decrease the quality of life in elderly people because of secondary symptoms such as reduced daily life ability, reduced balance ability, sleep disorders, and depression.¹⁰⁻¹²

The incidence of MSDs in adults occurs in the order of lower back, neck, knees, hands, shoulders, and feet, while elderly people are mostly diagnosed with lower back (49.7%), knee (26.7%), hand (26%), and shoulder (20.8%) MSDs, and elderly men are known to have a higher prevalence than elderly women.⁹

Elderly people are usually classified as having a biological age of 65 years or more which leads to an increase in the prevalence of chronic senile diseases and a decrease in physical functions.¹³ Elderly people experience decrease in their physical functions depending on the aging process, with 0.34% reduction in the central nervous system (CNS), 0.36% in the musculoskeletal system, 0.40% in the circulatory system, 0.63% in the endocrine system, 0.84% in the respiratory system, and 1.19% in the autonomic nervous system.¹⁴ Muscle power and gait ability decrease as skeletal muscle mass decrease by ~1–2% annually.⁶ Also, ability to balance decreases due to reduction of vision, vestibular sense, reaction time, and proprioception functions. Reductions in balance ability, muscle strength, and gait functions are known to cause falls in elderly people,^{15,16} wherein, in particular, the reduction in balance ability is known as the primary cause of falls. Reduced balance ability

is caused by decreased visual feedback, sensory-motor functioning, skeletal muscle mass, and muscle strength.^{17,18} About 33% of elderly people experience falls, with 10% of it being severe injuries such as hip fractures, other fractures, subdural hematoma, and head injuries that require emergency treatment and hospitalization. Physical activity restricted during the treatment period causes rapid frailty (or deterioration), which increases the death rate in elderly people.^{14,18,19} Also, elderly women are known to have a higher frequency of falls because of risk factors such as lower muscle strength and higher BMI than elderly men.^{14,19} Therefore, this study aims to present basic data on exercise prescriptions for elderly people having MSDs by verifying their effects on disordered body regions and dynamic balance ability. This study further verifies the effects of MSD pain on dynamic balance ability in elderly people.

METHODS

Subjects

The subjects in this study comprised 66 elderly males aged over 65 years. These include 51 elderly

with moderate to severe chronic pains who had a medical diagnosis and conservative treatment related to MSDs of the shoulder, lower back, and knee joints within the past three months (14 shoulder disorders, 17 lower back disorders, and 20 knee disorders) and 15 healthy elderly without MSDs. The elderly people with MSDs have not undergone medical diagnosis related to total joint replacement of the knee and hip joints, acute MSDs of less than 7 days of injury, MSDs of two or more joints, obesity, dementia, visual impairment, hearing and vestibular organ disorders, and CNS disorders. Voluntary participants diagnosed with MSDs, such as degenerative arthritis, spinal stenosis, calcific tendinitis, and adhesive capsulitis, were sampled and selected wirelessly as subjects. After completing the training regarding the purpose, contents, methods, and precautions of the study, the participants who voluntarily completed the experiment contract and general characteristic questionnaire were selected as the final study subjects (Table 1). This study was approved by the Institutional Review Board and carried out in accordance with the Declaration of Helsinki (DUIRB-201808-01).

TABLE 1 The Characteristics of Study Subjects.

	MSD patients (n = 51)			Control (n = 15)	F	P	Post hoc
	Shoulder (n = 14)	Lower back (n = 17)	Knee (n = 20)				
Age (years)	67.35 ± 2.62			66.33 ± 3.10	1.848	0.148	—
	66.14 ± 1.95	67.82 ± 1.77	67.80 ± 2.36				
Height (cm)	156.86 ± 3.33			155.80 ± 4.42	0.373	0.373	—
	156.71 ± 3.58	156.71 ± 2.76	157.1 ± 3.74				
Weight (kg)	57.09 ± 6.87			55.73 ± 6.80	0.704	0.704	—
	58.14 ± 7.02	55.35 ± 7.26	57.85 ± 6.49				
BMI (kg·m ²)	23.20 ± 2.71			22.94 ± 2.69	0.574	0.574	—
	23.68 ± 2.67	22.54 ± 2.86	23.45 ± 2.65				
VAS (cm)	6.92 ± 1.84			0.53 ± 0.51	57.310	0.000*	Kn, LB, Sh > Con*
	7.14 ± 1.65	6.65 ± 1.76	7.00 ± 2.07				

Values are mean ± SD.

BMI, body mass index; VAS, visual analogue scale; Sh, shoulder; LB, lower back; Kn, knee; Con, Control.

*P < 0.001.

MEASUREMENT

Procedures

The subjects of the study recorded musculoskeletal and underlying disorders through the preparation of a preliminary questionnaire and measured the pain awareness level for each MSD of body regions. The pain awareness level was subjectively measured using a Visual Analogue Scale (VAS).²⁰ The level of pain in the shoulder, lower back, and knee joints caused by MSDs was measured and evaluated in centimeters through a VAS-only questionnaire (10 cm straight type) with a proven test validity of $r = 0.97$.²¹ Later, a dynamic balance ability test was conducted after measuring participant's height and weight through an automatic height and weight device (BSM330, Inbody, South Korea).

Dynamic balance ability

The measurements were conducted after pre-training to reduce possible errors caused by differences in the test experience. The dynamic balance ability was measured using S3-Check (Multi-Functional Training, MFT S3; GmbH, Germany) where the subject takes off his shoes and positions on a 530-mm diameter round platform that moves in the axial direction (left-right or front-back) in the measuring range of $+20^\circ$ to -20° tilt angle. The measurement was taken while balance was maintained by the subject on both feet for 30 seconds. The measuring posture was performed with elbows bent at 90° , and arms crossed together to limit the upper body's compensation. Three measurements were taken with 1-minute break, and the highest measurement was used in this study. The left-right stability and sensory-motor control ability were first measured through the left-right axis test. The platform was then rotated 90° to measure front-back stability and sensory-motor control ability through the front-back axis test. A comprehensive assessment was performed with the evaluation of postural stability level through "stability index left-right" and "stability index front-back," and the evaluation

of sensory-motor function level was done through "sensorimotor index left-right" and "sensorimotor index front-back."^{15,22} The postural stability level is an evaluation factor that processes the sensory nerves' information to stabilize body's posture and balance by controlling skeletal muscle contractions. The sensory-motor function level is a factor that evaluates the function of transmitting the balance sensory stimulus information obtained through proprioception sensor to the CNS.^{15,22-24} The postural stability level and sensory-motor function level are used to evaluate dynamic balance ability.^{15,22,23} Infraclass correlation coefficient (ICC) evaluation factors are listed in the order of stability index left-right (ICC = 0.959), sensorimotor index left-right (ICC = 0.938), stability index front-back (ICC = 0.937), and sensorimotor index front-back (ICC = 0.919) and showed a high level of reliability.^{15,23} The validity of the test is different for individual subjects but shows an above-the-moderate level. All measured values for each factor were quantified on a 9-point scale, where 1 being the highest and 9 being the lowest level.^{15,22,23} The evaluation method indicates that the higher the number, the lower the dynamic balance ability.²⁵

STATISTICAL ANALYSIS

The data of this study was analyzed using the SPSS 20.0 software for Windows (SPSS Inc., Chicago, IL, USA). The average (Mean value) and standard deviation (SD) of dependent variables measured through technical statistics were calculated. The independent t-test was used to analyze differences in postural stability and sensory-motor function levels, which were variables of dynamic balance ability evaluation according to the presence or absence of MSDs in elderly people. One-way ANOVA was used to analyze differences in MSDs of body regions, and the Scheffe test was conducted for *post-hoc* analysis of variance. Correlation analysis between pain and dynamic balance ability measurement variables was conducted to determine

MSD pain’s effect on the dynamic balance ability in elderly people. Simple regression analysis between pain and dynamic balance ability measurement variables was conducted secondarily to evaluate the effect of pain on dynamic balance ability. The statistical significance level was set at $P < 0.05$ for all analyses.

RESULTS

Comparison of postural stability level

Differences in postural stability level according to the presence or absence of MSDs

The postural stability levels in elderly people of both groups, that is with and without MSDs, showed significant differences in the stability index left-right ($P < 0.001$) and the stability index front-back ($P < 0.001$) (Table 2).

Differences in postural stability level according to the MSDs of body regions

The postural stability levels in elderly people between different MSDs of body regions showed significant differences in the stability index left-right ($P < 0.001$) and the stability index front-back

($P < 0.001$). In the stability index left-right, the control group showed significant differences from the knee group and the lower back group ($P < 0.001$). The shoulder group also showed significant differences from the knee group ($P < 0.001$) and the lower back group ($P < 0.01$). In the stability index front-back, the control group showed significant differences from the knee group ($P < 0.001$) and the lower back group ($P < 0.05$) (Table 2).

Comparison of Sensory-motor Function Level

Differences in sensory-motor function level according to the presence or absence of MSDs

The sensory-motor function level showed significant differences in the sensorimotor index left-right ($P < 0.001$) and the sensorimotor index front-back ($P < 0.01$) in elderly people with and without MSDs (Table 3).

Differences in sensory-motor function level according to the MSDs of body regions

The sensory-motor function level according to the MSDs of body regions in elderly people showed significant differences in the sensorimotor index left-right ($P < 0.001$) and the sensorimotor index

TABLE 2 Differences in Postural Stability Level According to the Presence or Absence of MSDs and the MSD Body Regions.

Variable	MSD patients (n = 51)			Control (n = 15)	t or F	P	Post hoc
	Shoulder (n = 14)	Lower back (n = 17)	Knee (n = 20)				
Stability index Left-right (point)	6.05 ± 1.03			4.97 ± 0.84	3.710	0.000***	-
	5.03 ± 0.60	6.32 ± 0.99	6.54 ± 0.80		16.543	0.000***	Kn, LB > Con,*** Kn, LB > Sh**
Stability index Front-back (point)	5.94 ± 1.08			4.71 ± 0.92	4.013	0.000***	-
	5.39 ± 1.00	5.89 ± 1.15	6.38 ± 0.92		8.524	0.000***	Kn > Con*** LB > Con*

Values are mean ± SD.

Sh, shoulder; LB, lower back; Kn, knee; Con, control.

t: value between the overall MSD group and control group comparison; F: Value between shoulder MSD, lower back MSD, knee MSD, and control comparisons

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

TABLE 3 Differences in Sensory-Motor Function Level According to the Presence or Absence of MSDs and the MSD Body Regions.

Variable	MSD patients (n = 51)			Control (n = 15)	t or F	P	Post hoc
	Shoulder (n = 14)	Lower back (n = 17)	Knee (n = 20)				
Sensorimotor index Left-right (point)	5.40 ± 0.98			4.22 ± 0.69	4.315	0.000***	—
	5.34 ± 0.84	5.04 ± 0.98	5.74 ± 0.99		8.419	0.000***	Kn > Con,*** Sh > Con*
Sensorimotor index Front-back (point)	4.74 ± 1.09			3.64 ± 0.90	3.559	0.001**	—
	4.67 ± 0.79	4.62 ± 1.21	4.89 ± 1.19		4.353	0.008**	Kn > Con*

Values are mean ± SD.

Sh, shoulder; LB, lower back; Kn, knee; Con, control.

t: value between the overall MSD group and control group comparison; F: Value between shoulder MSD, lower back MSD, knee MSD, and control comparisons

*P < 0.05, **P < 0.01, ***P < 0.001.

front-back (P < 0.001). In the sensorimotor index left-right, the control group showed significant differences from the knee group (P < 0.001) and the shoulder group (P < 0.05). The control group also showed a significant difference from the knee group (P < 0.05) in the sensorimotor index front-back (Table 3).

Effects of MSD pain on dynamic balance ability

Correlation analysis between MSD pain and dynamic balance ability variables

The MSD pain in elderly people showed a positive correlation in stability index left-right (P < 0.01, r = 0.344), stability index front-back (P < 0.01, r = 0.382), sensorimotor index left-right (P < 0.01, r = 0.397), and sensorimotor index front-back (P < 0.01, r = 0.404) (Figure 1). (The high measurements of the stability index and the sensorimotor index by S3-Check indicate a low level of dynamic balance ability. In other words, an increase in pain indicates a decrease in the level of dynamic balance ability.)

Regression analysis between MSD pain and dynamic balance ability variables

The standardized coefficients of MSD pain in elderly people affecting the dynamic balance ability evaluation factor showed a significant positive

influence in the order of sensorimotor index front-back (β = 0.404, P < 0.01), sensorimotor index left-right (β = 0.397, P < 0.01), stability index front-back (β = 0.382, P < 0.01), and stability index left-right (β = 0.344, P < 0.01; Table 4). (The high measurements of the stability index and the sensorimotor index by S3-Check indicate a low level of dynamic balancing ability. In other words, an increase in pain indicates a decrease in the level of dynamic balance ability in the order of sensorimotor index front-back, sensorimotor index left-right, stability index front-back, and stability index left-right.)

DISCUSSION

This study verified the effects of MSDs and MSD body regions on the dynamic balance ability of elderly people. The results showed that postural stability level and sensory-motor function level were significantly lower in the group with MSDs than in the control group without MSDs. In particular, elderly people with knee disorders and lower back disorders had lower postural stability levels than elderly people with shoulder disorders and without MSDs. Also, elderly people with knee disorders and shoulder disorders had lower sensory-motor function level than elderly people without

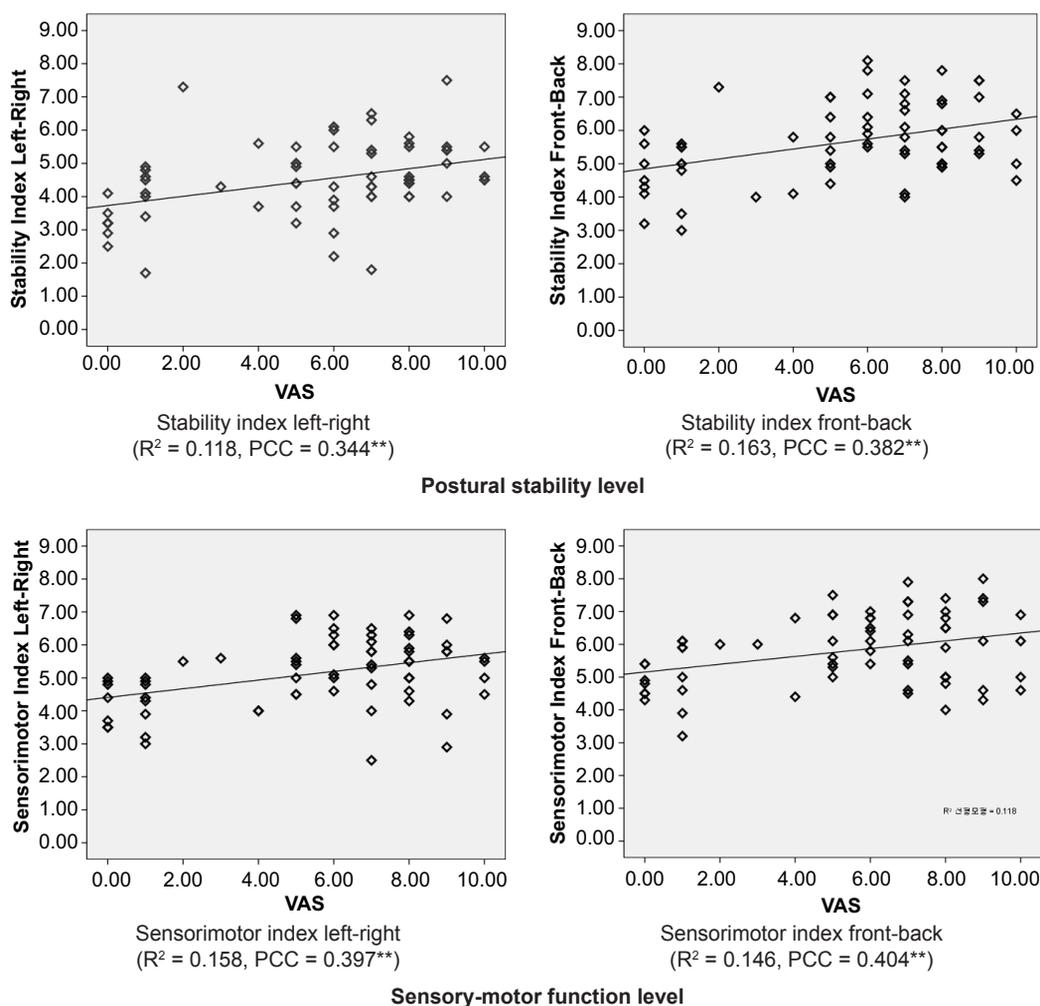


FIGURE 1 Effects of musculoskeletal disorder pain on dynamic balanced ability. PCC: Pearson correlation coefficient (=Pearson r); **P < 0.01.

MSDs. Additionally, the increase in pain caused by MSDs reduces the level of dynamic balance ability, particularly causing a higher functional decrease in the order of front-back sensory-motor function, left-right sensory-motor function, front-back postural stability, and left-right postural stability.

Elderly people with knee disorders and lower back disorders had lower left-right postural stability than elderly people with shoulder disorders and without MSDs. They also showed lower front-back postural stability than elderly people without

MSDs, indicating a decrease in the overall postural stability level. Also, elderly people with knee disorders showed a 1.54 points higher stability index left-right than the normal elderly range (4.6 to 5.1 points), and a 1.28 points higher stability index front-back than the normal elderly range (4.2 to 5.1 points). Additionally, elderly people with lower back disorders showed a 1.21 points higher stability index left-right and a 0.79 points higher stability index front-back than the normal elderly range.^{15,22} As such, knee disorder or lower back disorder in

TABLE 4 Regression Analysis between MSD Pain and Dynamic Balanced Ability Variables.

Dependent variable	Independent variable	Unstandardized coefficients		Standardized coefficients	t	P
		B	SE	β		
Stability index left-right	Constant	5.155	0.256		20.160	0.000
	VAS	0.119	0.041	0.311	2.932	0.005*
	R ² = .118, adjusted R ² = 0.105, F = 8.597, P = 0.005					
Stability index front-back	Constant	3.732	0.264		14.134	0.000
	VAS	0.139	0.042	0.382	3.311	0.002*
	R ² = .146, adjusted R ² = 0.133, F = 10.963, P = 0.002					
Sensorimotor index left-right	Constant	4.409	0.240		18.381	0.000
	VAS	0.132	0.038	0.397	3.459	0.001*
	R ² = 0.158, adjusted R ² = 0.144, F = 11.966, P = 0.001					
Sensorimotor index front-back	Constant	4.847	0.266		18.211	0.000
	VAS	0.149	0.042	0.404	3.530	0.001*
	R ² = 0.163, adjusted R ² = 0.150, F = 12.462, P = 0.001					

*P < 0.01.

elderly people reduces postural stability level compared to those with shoulder disorder and without MSDs. The activation of muscles around the legs and hips responds rapidly to the process sensory information input from sensory organs such as proprioception, visual, auditory, and vestibular organs. Neuromuscular properties that maintain the stability of body posture^{24,26,27} are associated with pain, muscle strength reduction, joint range limitation, and intrinsic receptive sensory function decrease caused by knee or lower back disorders, thus limiting muscle activity and reducing the postural stability level.^{17,24,28}

Elderly people with knee disorders showed lower left-right sensory-motor function and lower front-back sensory-motor function than elderly people without MSDs, thus showing an overall decrease in sensory-motor function level. Elderly people with shoulder disorders showed lower front-back sensory-motor function than elderly people without MSDs, indicating an overall decrease in sensory-motor function level. Also, elderly people with knee

disorders showed a 1.54 points higher sensorimotor index left-right than the normal elderly range (3.5 to 4.2 points) and a 0.49 point higher sensorimotor index front-back than the normal elderly range (3.8 to 4.4 points), indicating a lower sensory-motor function level than the aged standard. Elderly people with shoulder disorders showed a 1.14 points higher sensorimotor index left-right than the normal elderly range, indicating a lower left-right sensory-motor function level.^{15,22,23} As such, knee disorders and lower back disorders in elderly people reduce the sensory-motor function level compared to those without MSDs. Common knee disorders in the elderly are mostly degenerative disorders such as osteoarthritis, meniscal rupture, and patellar tendinitis. These MSDs limit the function of sensory receptors, such as the articular mechanoreceptors, muscle spindles, golgi tendon organs, baroreceptors, and peripheral nerve sensory, that accept sensory-motor information around the knee joint, leading to a decrease in sensory-motor function.^{6,11,24,28,29} Shoulder disorders in elderly people cause pain

to limit the movement of arms and decrease the sensory-motor function.²³ The pain stimulus input through the nociceptor and the balance stimulus input through the proprioception show the neuro-physiology mechanism that is inputted and processed in the same way as the CNS. Therefore, a decrease in sensory-motor function occurs due to the limitation of average balance sensory information input by inducing confusion in balance stimulus input caused by shoulder pain stimulus.^{30–32} The results of this study and the findings of Baierle et al.²³ suggest that shoulder disorder causes a significant reduction in left-right sensory-motor functions, rather than the front-back sensory-motor functions.

On the other hand, there was no significant difference between elderly people with shoulder disorders in the postural stability level and lower back disorder in the sensory-motor function level compared to those without MSDs. These results contradict previous studies that show that middle-age shoulder disorder reduces the level of posture stability,²³ indicating that the posture stability level is reduced by aging and shoulder disorder is decreased at a slightly similar level.^{23,26,27} The results of elderly people with shoulder disorders showed higher postural stability than elderly people with knee or lower back disorders, suggesting that elderly people's shoulder disorders may not affect their postural stability level.

Pain caused by MSDs in elderly people showed a strong correlation with the decrease of dynamic balance ability in the order of front-back sensory-motor function, left-right postural stability, front-back postural stability, and left-right postural stability. It also showed a causal relationship between pain and reduction of dynamic balance ability. In particular, the pain reduces the sensory-motor function and front-back dynamic balance ability. This results in a reduction of dynamic balance ability because of limited information on balance sensory stimulation, decreased muscle contraction, and confusion in the CNS pathways caused by pain.^{19,28,29,31} Increase in pain reduces the level of dynamic balance ability.

As such, MSDs in elderly people cause a decrease in postural stability and sensory-motor function and reduce dynamic balance ability, thereby increasing the risk of falls.^{7,18,19} In particular, knee disorders induce a decrease in postural stability and sensory-motor functions, negatively affecting the dynamic balance ability and consequently leading to an increased risk of falls.^{8,16–18,29} However, elderly people with shoulder disorders do not differ from those without MSDs in posture stability that maintains balance and body posture, which controls skeletal muscle contraction by processing sensory nerve information. Also, elderly people with lower back disorders did not show differences from elderly people without MSDs in the sensory-motor function that quickly delivers balance sensory stimulation information to the CNS. Additionally, MSD pain in elderly people reduces dynamic balance ability, and in particular limits their sensory-motor function and front-back dynamic balance ability.

In light of the above results, a proprioception stimulation exercise to improve sensory-motor function and a muscle-strengthening exercise for efficient skeletal muscle contraction control should be performed in combination when designing an exercise prescription program for the elderly people with knee disorders. Also, elderly people with lower back disorders need to exercise muscle strength to control skeletal muscle contractions, while elderly people with shoulder disorders need to exercise proprioception stimulation to improve their sensory functions. Post-MSD pain control treatment will improve the dynamic balance ability reduction caused by pain through proprioception stimulation exercise to improve sensory-motor function and dynamic balance exercise for front-back movement.

This study had limitations that controlled external factors for usual exercise habits and small sample sizes. In the future, it will be necessary to study the development of exercise prescription programs through evaluation of the dynamic balance ability of the elderly, which is considered by many sample sizes and habits before exercise.

CONCLUSIONS

The MSDs in elderly people reduce their ability to balance dynamically, especially knee disorders decrease this ability more than lower back and shoulder disorders.

Musculoskeletal pain reduces dynamic balance ability, especially causing restriction on sensory-motor function and front-back movement dynamic balance.

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