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Original Article

Effect of unilateral exercise on spinal and pelvic deformities, and isokinetic trunk muscle strength

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Abstract. [Purpose] The purpose of this study was to collect basic data regarding the prevention of spinal and pelvic deformities by investigating the spinal shape and muscular function characteristics of imbalance reduction and functional improvement following asymmetric activities. [Subjects and Methods] The subjects were 14 archery athletes who mostly perform unilateral motion with spinal and pelvic pain, and 19 healthy subjects. All the participants were evaluated using spinal structure analysis and for 60°/sec isokinetic muscular strength of the trunk. [Results] Between the two groups, there were significant differences in the interaction effect of trunk inclination deformities, and flexor and extensor 60°/sec isokinetic muscular strength of the trunk. Also, the main effects of gender comparison showed significant differences in the trunk inclination deformities, pelvic rotation deformities, lordosis angles, and flexor and extensor 60 °/sec isokinetic muscular strengths of the trunk. [Conclusion] The basic data obtained in this study can be used to help develop a strategic exercise program for improving unilateral movement and malalignment of the spine and pelvis.

Key words: Spine and pelvis, Spinal structure, Isokinetic

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INTRODUCTION

The spine forms a closed kinematic chain through segmental coordination of the upper and lower extremities and the pelvic girdle, and affects the static and dynamic patterns of daily life activities and sports[1, 3)], while also having a direct influence on postural alignment through musculoskeletal connections[2)]. Moreover, the spine adopts a gentle curvature through cervical lordosis, thoracic kyphosis, and lumbar lordosis, which helps to maintain posture by absorbing and dispersing spinal impacts[32)]. However, if a normal form cannot be maintained due to internal and external forces, any force applied to the spine cannot be dispersed properly, causing lateral imbalance and accumulation of fatigue in the adjacent muscle which often results in chronic low back pain[4, 5)]. When the lumbar region and pelvis are unstable, chronic pain may arise due to repeated motion. Moreover, static and dynamic movements may decrease, causing morphological changes in the pelvic muscle segments[6)], which in turn could lead to instability that exacerbates spinal deformity and pain in the lumbosacral region[7, 36)].

Most human activities appear to be unilateral, and asymmetry is observed with dominant neuromuscular activities on the dominant side rather than on the non-dominant side[9)]. Lateral imbalance in the trunk often occurs in many athletes who engage in unilateral actions, and in whom the persistent, asymmetric force causes external deformity near the spine[10)]. Damage which is accompanied by twisting, is enhanced as trunk instability increases along with pressure on the spinal joints[11, 33)]. Such changes in the interactions between body segments cause instability in the standing posture and become the direct cause of low back pain[12)]. Moreover, from an energy efficiency point of view, the main lower extremity joints, including the pelvic

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girdle, are closely related to each other, and thus, an abnormal movement pattern in one joint can trigger compensatory action or an abnormal movement pattern in another joint[13, 14]. Consequently, there is increasing interest in spinal deformities, and evidence-based clinical methods are needed for the early diagnosis and prevention of musculoskeletal pain in athletes who perform large range of motion (ROM) movement. This study aimed to obtain basic data regarding the prevention of spinal and pelvic deformities by investigating the spinal shape and muscular function characteristics of imbalance reduction and functional improvement following asymmetric activities.

SUBJECTS AND METHODS

A total of 33 subjects participated in this study, including 14 archers (6 males, 8 females), who generally move unilaterally with 4 or more years of experience, who had spinal and pelvic pain, and 19 individuals in the control group (8 males, 11 females) (Table 1). The subjects had no musculoskeletal diseases or neurological problems. All the subjects understood the purpose of this study and provided their written informed consent prior to participation in the study in accordance with the ethical principles of the Declaration of Helsinki.

For the spinal structure analysis, as an alternative to radiological examination, a posterior trunk measuring system (Formetric 4D, Diers International GmbH, Germany) was used. Measurements were taken using the rasterstereography method that involves projecting a halogen light source on the trunk posterior[15]. The mean deviations for the accuracy of surface analysis and lateral spinal deviation are 0.15 mm and within 3°, respectively[16]. Highly reproducible and objective data could be obtained. For optimal measurement, the participants took off their top and lowered their bottom to the point where the posterior superior iliac spine could be seen and stood in an upright position approximately 2 m away from the camera. In accordance with the raster principle, the posterior trunk was reproduced 3-dimensionally. The spinous process positions from the center of the spine were established as the following 4 anatomical landmarks: the 7th cervical, sacrum point, and the left and right posterior superior iliac spine. Analysis were performed on groups divided according to the spine and pelvic deformity and spinal curves.

Humac Norm Testing & Rehabilitation (CSMi Medical & Solution, USA) was used for measuring the isokinetic muscular function of the trunk. A trunk adapter was connected to a dynamometer for the measurement. In order to prevent joint movement from applying external force to regions other than the lumbar region, a strap and belt were used to firmly hold the area, to enable the exertion of maximum muscle strength. The ROM of each joint was restricted by calibrating the ROM for each participant, to prevent injuries due to hyperextension or hyperflexion during the measurements. The angle of the lumbar region joint movement was set to the maximum ROM at which no pain was felt. A preliminary procedure was performed to reduce any unfamiliarity or uneasiness with the test equipment, and the maximal level of exercise was encouraged during the actual measurement. Data were recorded of 3 repeats at 60°/sec to eliminate any influence of fatigue on the measurements.

All data were analyzed using the statistical program SPSS 20.0 (SPSS Inc., USA) for Windows. Means and standard deviations were calculated for each variable and 2-way analysis of variance was used to analyze intergroup differences and interaction effects. Statistical significance was accepted for values of $p<0.05$.

RESULTS

The results for spinal trunk deformities in the unilateral exercise group and the control group are shown in Table 2. There was a significant difference in the interaction effect only for trunk inclination ($p=0.033$). Only trunk inclination showed a significant difference ($p=0.008$) among the main effects of group, while only trunk length ($p=0.033$) showed a significant difference among the main effects of gender.

The pelvic deformity analysis results are shown in Table 3. The interaction effects showed no significant difference for any of the variables ($p>0.05$). None of the variables showed a significant difference ($p>0.05$) among the main effects of group, while only pelvic rotation ($p=0.006$) showed a significant difference among the main effects of gender.

The analysis of variance results for the spinal curve are shown in Table 4. The interaction effect showed no significant difference in any of the variables ($p>0.05$). Significant differences were found only for the lordosis angle among the main effects of group ($p=0.019$) and gender ($p=0.002$).

The results for 60°/sec isokinetic trunk muscle function are shown in Table 5. Interaction effects showed significant differences in flexion ($p=0.010$) and extension ($p=0.001$) muscle strength. Among the main group effects, there was a significant difference in the extension muscle strength ($p=0.016$), while among the main gender effects, significant differences were found in the flexion ($p=0.000$) and extension ($p=0.000$) muscle strength.

DISCUSSION

Force that unilaterally twists the spine or exercise that is accompanied by rotational forces can lead to concentration of static strength in an improper position and repetition of sudden movements. This can cause spinal and pelvic deformities resulting in pain or deformities, such as abnormal posture[17]. Athletes experience developmental imbalance due to the disruption of physical balance following repetitive and long-term unilateral activities, and can also show diminished athletic

Table 1. General characteristics of the subjects

Groups	Gender	n	Age (yrs)	Height (cm)	Weight (kg)
UG	Male	6	16.2±0.4	173.7±3.2	78.0±9.9
	Female	8	16.4±0.9	164.3±5.4	62.0±9.1
CG	Male	8	23.6±2.2	175.0±4.6	70.1±7.4
	Female	11	22.3±2.2	167.2±8.1	52.9±6.3

Values are Mean±SD, UG: unilateral group, CG: control group

Table 2. Comparison of trunk deformity

Factor		UG	CG
Trunk length (mm)	Male	468.4±30.7	472.5±29.0†
	Female	463.0±27.3	434.4±24.1
Trunk inclination (deg)	Male	2.5±1.8	2.1±1.7**
	Female	3.8±2.3	0.5±1.5‡
Trunk imbalance (deg)	Male	−0.4±0.8	−0.0±1.3
	Female	−0.6±0.6	0.5±1.6

Values are Mean±SD, UG: unilateral group, CG: control group
** significant difference between groups (**$p<0.01$)
† significant difference between genders (†$p<0.05$)
‡ significant difference between groups and genders (‡$p<0.05$)

Table 3. Comparison of pelvic deformity

Factor		UG	CG
Pelvic obliquity (deg)	Male	0.3±6.6	0.2±2.4
	Female	1.3±1.8	1.7±2.9
Pelvic torsion (deg)	Male	1.5±4.2	0.1±2.1
	Female	1.9±3.3	−0.5±1.7
Pelvic rotation (deg)	Male	−3.4±3.0	−1.4±1.5†
	Female	−0.2±2.2	1.4±3.9

Values are Mean±SD, UG: unilateral group, CG: control group
† significant difference between genders (†$p<0.05$)

Table 4. Comparison of spinal curves

Factor		UG	CG
Kyphotis angle (deg)	Male	41.2±5.1	37.0±5.8
	Female	43.2±6.9	44.3±7.0
Lordotis angle (deg)	Male	29.2±4.1	30.2±8.9††
	Female	32.4±6.1	42.6±5.1

Values are Mean±SD, UG: unilateral group, CG: control group
†† significant difference between genders (††$p<0.05$)

Table 5. Comparison of isokinetic strength of trunk 60°/sec

Factor		UG	CG
Flexors (Nm)	Male	196.3±5.4	222.5±37.8†††
	Female	148.5±30.1	118.0±27.9‡
Extensors (Nm)	Male	158.8±15.3	240.9±50.0*†††
	Female	130.9±22.2	116.6±42.4‡‡

Values are Mean±SD, UG: unilateral group, CG: control group
* significant difference between groups (*$p<0.05$)
††† significant difference between genders (†††$p<0.001$)
‡ significant difference between groups and genders (‡$p<0.05$, ‡‡$p<0.01$)

performance due to asymmetric posture[18, 19, 35]. Abnormal posture structurally affects the joint tissues and increases pain factors, eliciting restrictions in dynamic movement and ROM[8, 20, 34]. For the collection of basic data regarding truncal muscle strength, and the trunk and pelvic structures related to these abnormal deformities, the study participants were divided into the unilateral group and the control group.

As the trunk is responsible for a wide ROM of the spinal joints, and because it possesses the center of gravity, stability must be maintained for functional movement[21, 22]. A study of 120 athletes by Lee et al.[23] showed that unilateral exercise resulted in trunk inclination of 2.0±1.9° in a unilateral group versus 1.4±1.6° in a bilateral group, while rotational angles of −3.7±9.8° and −0.1±3.6° were seen in the unilateral and bilateral groups, respectively. This indicated that the truncal alignment of the bilateral group was more stable, with differences of approximately 0.7° in forward inclination and −3.6° in left rotation between the 2 groups. The truncal alignment was more stable in the bilateral group in this study, as in the preceding study, with trunk inclination differences of 0.4° and 3.2° in men and women of the unilateral group (men: 2.5±1.8°, women: 3.8±2.3°) and control group (men: 2.1±1.7°, women: 0.5±1.5°), respectively.

The pelvis basically has a laterally symmetric structure, and because it influences postural control, efforts are required to resolve unilateral imbalance and asymmetry in order to maintain the center of gravity[7, 24]. Malalignment refers to a postural anomaly or imbalance in the spinal curvature, and because pelvic deformity causes changes in spinal alignment, pelvic movement is closely associated with postural change[25, 37]. Such asymmetry in the pelvis causes the entire body to change into a mechanically deformed structure and as a result, excessive tension in the bones causes tension in the soft tissues. As the musculoskeletal system adapts to the asymmetric structure, it should be given close attention over time[26]. The analysis of the pelvic obliquity, torsion, and the rotation angles of pelvic deformity in the unilateral group and the control group revealed there were no intergroup differences in any of the variables, although the unilateral group tended to show a larger change in angle than the control group.

When the thoracic kyphosis angle and lumbar lordosis angle of the unilateral and control groups were compared, no significant difference was found in the kyphosis angle, but the lordosis angle showed statistically significant main effects of group (p=0.019) and gender (p=0.002). These results were a similar to those reported by another study[27] that showed that the lumbar region is connected to the sacral region forming the lumbosacral region, which is directly involved in the formation of spinal curvature and pelvic alignment, and can have a direct impact on low back pain when there is asymmetry.

Repeating unilateral exercise over a long period of time can lead to a change in the pelvic position due to imbalances in the muscle length and strength, and asymmetric muscle strength, in particular, can be the cause of musculoskeletal injuries[28]. To confirm the findings of these previous studies, a comparison of the isokinetic muscular functions between the unilateral and control group was performed in this study. A significant difference was found in the interaction effects of the flexor and extensor muscles, showing that muscular factors do play a role in unilateral exercise. In particular, statistically significant main effects of group (p=0.016) and gender (p=0.000) were found for the extensor muscle strength of the unilateral group (males: 158.8±15.3 Nm, females: 130.9±22.2 Nm) and the control group (males: 240.9±50.0 Nm, females: 116.6±42.4 Nm).

The importance of core exercise with the goal of enhancing coordination between postural movement, muscle strength, and balance around the lumbar region has been being emphasized[29, 30]. The strengthening of the muscles near the lumbar region should help to regulate functional stability and improve muscle strength and function[29, 31]. Therefore, the basic data obtained in this study can be used to help develop a strategic exercise program for improving unilateral movement and malalignment of the spine and pelvis.

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