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# The Analysis of Related Variables on the Center of Gravity Deviation: Focus on the Musculoskeletal Pain

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## 국문요약

### 중력중심 이동과 관련 변인분석 -근골격계 통증을 중심으로-

**고태성**
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본 연구에서는 근골격계 통증이 자세유지와 균형능력에 핵심이 되는 중력중심 이동에 미치는 영향에 대해 알아봄으로서, 균형과 자세에 영향을 주는 다양한 요소들에 대한 새로운 접근을 시도해 보고자 한다. I-병원의 입원 및 외래 환자 중 신경계 손상이 없고 중력중심 이동에 직접적인 영향을 줄 수 있는 하지에 정형외과적 장애가 없으며, 전정계 손상이나 시력장애로 인한 균형에 문제가 없이 근골격계 질환으로 요통과 견통을 주소로 하는 71명의 환자(남자 38, 여자 33; 평균연령=44, 표준편차=13.8, 범위=19~79)와 신경계, 근골격계 및 평형감각에 문제가 없는 정상인 30명의 대조군(남자 16, 여자 14; 평균연령=39.2, 표준편차=13.7, 범위=21~72)을 대상으로 전산화된 힘판을 이용하여 중력중심 이동의 궤적을 표준편차값으로 측정하였다. 측정된 중력중심 이동값은 두 군간에 상이한 차이를 보이고 있음이 검증되었다($p<.01$). 또 측정된 여러 변수들의 중력중심 이동에 대한 영향력을 알아보기 위해 나이, 체중 및 신장과 중력중심 이동과의 상관분석 결과 중력중심 이동의 15.8%를 체중의 변화에 의한 것으로 설명할 수 있다는 결과를 얻었으며, 그 외의 변수들과의 연관성에 대해선 유의미한 차이가 없었다($p<.01$). 결과적으로 근골격계 통증은 올바른 자세유지와 균형유지를 위한 감각통합과 반응과정에 직접, 간접적으로 영향을 미치고 있다. 따라서 중력 중심 이동이 크면 클수록 중심을 잡기 위한 근육활동으로 추가적인 에너지가 사용되고, 편중된 중력중심 이동은 근골격계에 무리한 부담을 주어 통증을 증가시킬 수 있을 것이다. 또 통증으로 인한 중력중심 이동은 이를 보상하기 위해 신체 먼 곳에서의 이차적인 변형을 초래하여 각종 근골격계 증상의 원인이 될 수 있으므로 근골격계에 대한 적절한 치료는 통증을 감소시켜 자세의 이차적인 변형을 막고 자세유지 시 작용하는 근육의 에너지 효율을 높일 수 있을 것으로 사료된다.

**핵심단어:** 근골격계 장애; 중력중심 이동; 통증.

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## Introduction

### Necessity of the study

In remained standing, the center of gravity (COG) movement occur from back to front in the sagittal plane, and a little displacement occur in the coronal plane. When a person tries to balance him/ herself in the limits of stability, he/ she moves all directions creating a postural sway, and the middle of the postural sway becomes the COG (Nashner, 1989). As a basic of the balance, a person needs to keep the COG in the base of support (BOS). When the COG goes out of the BOS, the limits of the stability breaks, and as a result, the balance reaction kick out to prevent a fall. The most important function in human is to keep the body up straight. To do so, the vestibular system, the sensory system, and the visual system work together (Horak and Nashner, 1986; Shumway-Cook and Woollacott, 1995). The human balance is achieved by very complex process. First, the sensory system detects the body movements and sends that information to the central nervous system (CNS), the brain integrates the message, then sends the message back to the musculoskeletal system to react appropriately (Nashner, 1989). Since this complex process is necessary for the balance, a lot of factors can effect the balance such as age (Hasselkus and Shambes, 1975), height (Kilburn and Thornton, 1995), loss of proprioceptive sensibility (Fernie and Holliday, 1978), nervous system default (Newton, 1989), knee contracture (Potter et al, 1990), visual default (Dornana et al, 1978), foot position (Nichols et al, 1995), reaction time (Patla et al, 1989), leg length differences (Mahar et al, 1985), etc. Therefore, the necessity of the study arose on these many factors of the balance in a broad and diversed way.

The postural sway can be increased by the visual default, decreased vibration sensibility or the proprioception sensibility. It is because the postural sway is in very close relationship with the balance and mobility. Therefore, the postural sway can be used as a evaluation tool for the balance test (Hughes et al, 1996).

Many previous studies were done on the balance test of the normal and healthy people or on the evaluation and the rehabilitation of the patients with CNS lesion. Though, the studies considering the balance of the patients with the musculoskeletal system lesion were very few. If the paralysis is the chief complain of the CNS lesion, the pain is the chief complain of the musculoskeletal system lesion. In some studies, the effect of the pain were reported in relation to the asymmetry of the posture (Kappler, 1982; Magee, 1987; Norkin et al, 1992; Sluming and Norma, 1994), and to the weight distribution differences of the lower extremities, but not any study reported yet on the COG deviation or the COG deviation of the patients with a pain.

The fact of the practice is that the

**Table 1.** Characteristics of the subjects

| | Controls | | | Patients | | |
|---|---|---|---|---|---|---|
| | M(16) | F(14) | Mean(30) | M(38) | F(33) | Mean(71) |
| Age (yr) | 37.50* | 41.07 | 39.16 | 42.13 | 46.21 | 44.02 |
| | (11.90) | (15.90) | (13.78) | (13.15) | (14.57) | (13.88) |
| Height (cm) | 173.30 | 158.10 | 164.60 | 170.70 | 156.90 | 164.30 |
| | (4.28) | (4.78) | (7.60) | (7.87) | (6.30) | (9.95) |
| weight (kg) | 63.53 | 53.59 | 59.07 | 70.71 | 57.52 | 64.00 |
| | (8.13) | (7.19) | (9.00) | (14.24) | (7.57) | (13.07) |

*Mean (SD)

most of the patients complain the musculoskeletal pain and not too much of the CNS lesion problems. Therefore, the study of the COG which is a measure of the balance ability and the postural sway in relation to the pain, disturbing factor of the posture and the balance, seems to be in much of delay, and further systematic multiple studies are in needs.

### Purpose and hypothesis

This study observed the COG deviation, the core of the postural maintenance and the balance ability, of the patients with the musculoskeletal pain and tried to find the effect of the musculoskeletal pain on the COG deviation by using the computerized force plate. This study tried a new approach to the effect of many different factors of the balance and the posture.

The following hypothesis were set:

1) There will be no significant differences of the COG deviations between the patients group and the control group in the computerized force plate.

2) The age, height, and the weight do not have a significant meaning in the COG deviation.

## Methods

### Subjects

Inpatients and outpatients (n=71) were selected from I hospital who have a musculoskeletal low back pain and shoulder pain without any history of the central nervous system (CNS) lesions, COG affective orthopaedic problems of the lower extremities, or the vestibular and the visual default. For the control group, normal and healthy subjects (n=30) were selected without any history of these COG affective disorders. The general characteristics of the subjects are shown in Table 1.

### Instruments

This can be easily accessed commercially. The instrument is computerized force plate which has the hardware with 2 load cell, amplifier, offset controller, A/D (analog-digital) converter and the software, Mediance-I, Human Tech, Korea, which is the electrical posture-balance evaluation system having two module of the biofeedback and the evaluation. When the subjects step up to the frame which the load cells are attached, the weight of the subjects are measured and the graphs of the COG deviations are measured and displayed in the monitor. The result shows the calculated COG deviations which show how far off that is from the mean (remember it's in SD form).

**Procedures**

Before the trials, the consents were taken by every subjects, and the explanations of the measurement methods and the purposes of this study were given. To record the general characteristics of the subjects, the height were measured and recorded, and the age and the site of the pain were recorded. After a little break, the subjects were asked one at a time to stand on the frame with a light comfortable clothes without shoes and to relax without moving. While the subjects stand on the frame, the weight were measured. In the standing position on the frame, the feet were 4 inches apart as the study of Nashner (1989). To minimize the error, the feet print were made on the frame.

To minimize the visual feedback of the subjects, the monitor was turned away from the subjects on the frame. Then the switch was turned on to receive the data of the COG deviation in a graph. After taking one minute of break, the same procedure were taken through, and the mean result were printed. Same procedure for all of the subjects.

**Statistical analysis**

The data were analyzed by the SAS system.

1) The student t-test was done to find out the differences of the COG deviations of the patients group and the control group.

2) The correlation test (Pearson correlation coefficient : r) was done to find out the relations of the age, height, weight and the COG deviation.

When the p-value were less than .01, the hypothesis was renounced.

## Results

### The differences of the COG deviation on computerized force plate in the patient group and the control group

The student t-test was done to find out the differences of the COG deviations of the subjects group and the control group. The result is as the Table 2.

As a result, the COG deviation values of the patients group was 2.56, and that of the control group was .83, showing 1.73 difference. This difference was significant statistically ($p<.01$).

**The relations between the age, the height, the weight and the COG deviation**

To find out the relations of the variations which can affect the COG deviation values, the correlation test of the age, the height, and the weight with the COG value were done and presented in the correlation coefficient (r) and p-value for the significance. The result is shown in Table 3.

There were significant correlations between the weight and the COG deviation values ($p<.01$). This explains that 15.8% of the COG deviation values was created by the weight.

The other variations, otherwise, didn't show any significance ($p<.01$), and the coefficient wasn't even close to -1 or 1, meaning no correlations exist.

## Discussion

**The experiment equipment and the method**

Since it is one dimensional evaluation, measuring a simple postural sway in a fixed surface, it cannot be either a good quality or good quantity evaluation of the postural control (Horak, 1987). However, the measuring equipment used for this study only can analyze the movements which occur in the coronal plane, side to side trajectory of the COG in the standing position, making impossible to analyze the actual three dimensional COG deviation. There weren't many studies using the same equipment, making this study even harder to make the data quantitative statistically. To overcome these limitations, there should be a three dimensional analysis (anterior and posterior, side to side, up and down) of the COG deviations, and many other different groups of the patient, grouped by the disease/ diagnosis should be tested to make the data various.

This study was enforced even though there weren't too many studies of the COG deviations on the patients with musculoskeletal pain, just to prepare a basic datas for the further studies in the nearest

**Table 2.** Comparison of the COG deviation values

| Group | N | Mean | SE | t | p |
|---|---|---|---|---|---|
| Patients | 71 | 2.56 | .15 | 10.99 | .0001 |
| Controls | 30 | .83 | .02 | | |

**Table 3.** Correlations of the age, the height, and the weight with the COG deviation values

| Variables | | Age | Height | Weight |
|---|---|---|---|---|
| COG deviation | r | .09658 | .13227 | .39750 |
| | p | .42300 | .27190 | .00060 |

future.

Maki (1993) study stated that the arousal could affect the strategy, selection and the execution of the posture. That is why the settings of the equipments and the surroundings kept the same to make an objective status.

**Discussion on the result**

All the muscles, about 650 of them, take about 1/2 of the person's weight. These muscles uphold the body from the gravity, absorbs the mechanical impact of the repeated movements and the stimulus, acting as a protector of the body. When a muscle is over used or pertained in a stressed position, it tends to fatigue faster, and causes the muscle or the fascia to tight up in the bulk or the insertion area in the worst case (Goodgold, 1988). Since the body is sustained by the muscles and the bones, the changes of the muscles or the bones which bears most of the weight can cause the posture changes. Therefore, these musculoskeletal disorders, neurological disorders, and the visual or the vestibular disorders which can affect the equilibrium can be a disturbing factor of the balance, controlling weight bearings, and walking, further causing the rehabilitation to be difficult (Chang KU et al, 1994; Geurts et al, 1996). The balance is achieved by integrations of the nervous system and the musculoskeletal system. The related functions are the integrations of visual, hearing, vestibular, proprioception and sensory input in the CNS, visuo-spatial perception, tonicity of a muscle, muscle power, endurance, and the flexibility of a joint (Bae et al, 1992; Chandler et al, 1992). If the paralysis is the chief complain of the CNS lesion, the pain sis the chief complain of the musculoskeletal system lesion. Some where in this process, the pain comes in as a direct/ indirect factor of the COG deviation.

Standing position for the people is the most important posture for the movements of the transfers and works, and etc. (Licht, 1965; Rasch, 1978). To keep an upright posture, the COG should be distributed equally throughout the body, located in front and between the sacrum 1 and 2 level. (Smith et al, 1996). The good posture in upright position means a concept of the balance, symmetry, and minimal energy consumption. However, the standing position, actually, is a very unstable state which requires a constant control of the muscle contractions of the trunk and the lower extremities. As a result of these muscle activities, the postural sway occur in the coronal and the sagittal plane (Isakov et al, 1992) This postural sway caused by the continuous COG deviations and the displacement of a BOS is controlled by the input of the vision, vestibular system, proprioception, and sensory. All these make the postural sway not a stationary process (Carroll et al, 1993). The maintained standing position, therefore, is a dynamic process, and the little postural sway is just a physiological appearance.

The postural sway tends to increase as a person gets sick, gets injured, or ages (Isakov et al, 1992). The postural sway partially lie on the parallel relationships with the age, the fitness and the environmental factors (Era et al, 1985). Generally, the kids didn't show the differences of the sway either in the dark or the bright place; the adults, however, showed more sways in the dark (Ashmead et al, 1991). Though, the postural sway over the stability limits didn't show the differences between the age groups (Era et al, 1985). The weight and the balance index were very closely related to each other (Howard, 1995). The height got in a good relationship with the balance when the eyes were closed (Kilburn and Thornton, 1995). Every fact comes to a conclusion; the postural sway is a balance ability which can be affected by many variations.

Therefore, this study looked at the relationships between the pain and the balance and the COG deviation of the normal 30 people and 71 people with musculoskeletal pain, using the computerized force plate. As a result, there were a significant differences between the groups. Increased COG deviation cause increased repulsive power of the plate, then these increase cause the posture changes, and this posture changes cause the muscle energy consumption increase. To find out the relations of the variations which can affect the COG values, the correlations of the age, the height, and the weight with COG were tested, and showed that 15.8% of the COG value was created by the weight. The other variations showed no significance with COG values. The differences between the previous studies and this study appear because of the differences in the purpose, selecting the subjects different. There were 1 in control, 4 in patient's group of the left foot dominant people, excluded in calculating the result since the effect of them was believed to be minimal. Though, the study of the foot dominance should be added to the studies. In a broad way, the result can be summarized as the pain can be very affective to the COG deviation. As the COG deviation increase, the muscle energy consumption increase to keep the balance, and preponderated COG deviations end up loading too much on the musculoskeletal system to increase the pain. The COG deviation, a result of the pain, can cause a secondary deformity of the distal area, as a compensatory reaction, and this compensation actually can become a cause of the musculoskeletal symptom back in a cycle. Therefore, the appropriate treatment of the musculoskeletal problem should be given to decrease the pain, preventing the secondary deformities, and increasing the muscle energy efficiency of the posture remaining muscles.

## Limitations

The instruments used in this study was originally used for the measurements of the COG deviations in the coronal plane of the statically standing person only, so this will not be perfectly accurate of measuring the COG deviations of a person moving in three dimensional way.

There were difficulty in making the data quantitative statistically because there weren't enough studies using the same instruments.

When the 71 subjects, selected from one hospital, were broken down to the each group of the height and age, and etc., the number of the subjects in each group were too small; therefore, the result can not be applied generally to all of the musculoskeletal patients.

## Conclusion

This study was tried to find the effect of the musculoskeletal pain on the COG deviation which takes an important part in the posture and balance, using the computerized force plate.

For the subjects, 71 patients were selected who have a musculoskeletal low back pain and the shoulder pain without any history of the CNS lesions, COG affective orthopaedic problems of the lower extremities, or the vestibular and the visual default. For the control group normal and healthy 30 subjects were selected without any history of these COG affective disorders.

As a result, the measured values of the COG deviations showed a significant differences between the patients group and the control group. Further more, the correlations of the age, the height, and the weight with the COG deviation were tested to find out the effect of these variations on the COG. As a result of this correlations, 15.8% of the COG deviation was caused by the change of the weight, while the other variations didn't show any significant relations. The pain affected the sensory integrations for the good posture and balance and its reacting process directly or/ and indirectly.

Therefore, the appropriate treatment of the musculoskeletal system and the education of the posture correction can decrease the pain and prevent the secondary deformities, and increase the muscle energy efficiency. All the studies showing the COG deviation present well how the body are oriented. The further, definite study of the COG deviation and large data should be quantified to use it as basic datas to evaluate the body. Therefore, more mechanical and the physiological relationships of the pain with the COG deviations should be studied further more.

## References

Ashmead DH, McCarty ME. Postural sway of human infants while standing in light and dark. Child. 1991;62(6): 1276-1287.

Bae SS, Kim HS, Lee HO, et al. Kinesiology of the Human Body. Seoul, Hyun mun sa. 1992:182-190.

Carroll JP, Freedman W. Nonstationary

properties of postural sway. J Biomech. 1993;26(4-5):409-416.

Chandler JM, Duncan PW, Studenski SA. Balance performance on the postural stress test: Comparison of young adult, healthy elderly, and fallers. Phys Ther. 1992;70(7):410-415.

Chang KU. Seo GB, Lee SJ. Quantitative assessment of balance using balance index. J Kor Academy of Rehabil Med. 1994;18(3):561-569.

Dornan J, Fernie GR, Holliday PJ. Visual input: Its importance in the control of postural sway. Arch Phys Med Rehabil. 1978;59:586-591.

Era P, Heikkinen E. Postural sway during standing and unexpected disturbance of balance in random samples of men of different ages. J Geront. 1985;40(3):287-295.

Fernie GR, Holliday PJ. Postural sway in amputees and normal subjects. J Bone Joint Surg(Am). 1978;60:895-898.

Geurts CH, Ribbers GM, Knoop JA, et al. Identification of static and dynamic postural instability following traumatic brain injury. Arch Phys Med Rehabil. 1996;77:639-644.

Goodgold J. Rehabilitation medicine. St. Louis, Mosby, 1988:675-685,687.

Hasselkus BR, Shambes GM. Aging and postural sway in women. J Geront. 1975;30:661-667.

Horak FB, Nashner LM. Central programming of postural movements: A adaptation to altered support-surface configurations. Amer Physiol Society. 1986;55:1396-1381.

Horak FB. Clinical measurement of postural control in adults. Phys Ther. 1987;67(12):1881-1885.

Howard ME, Cawley PW, Losse GM, et al. Correlation of static and dynamic balance indecis to injury history, performance criteria and physical finding in 595 elite college football players. 8th Annual AOSSM Specialty Day. Orlando, Florida, 1995.

Hughes MA, Duncan PW, Rose DK, et al. The relationship of postural sway to sensorimotor function. Functional performance and disability in the elderly. Arch Phys Med Rehabil. 1996;77:567-572.

Isakov E, Mizrahi J, Ring H, et al. Standing sway and weight-bearing distribution in people with below-knee amputations. Arch Phys Med Rehabil. 1992;73:174-178.

Kappler RM. Postural balance and motion pattern. J Amer Osteopath Association. 1982;18:598-606.

Kilburn KH, Thornton JC. Prediction equations for balance measured as sway speed by head tracking with eyes open and closed. Occup & Environ Med. 1995;52(8):544-546.

Licht S. Therapeutic Exercise. Elizabeth Licht Pub., 1965:486-506.

Magee DJ. Orthopedic physical assessment. Philadelphia, W.B Saunders, 1987: 377-405.

Mahar RK, Kirby RL, MacLeod DA.

Stimulated leg-length discrepancy: Its effect on mean center of pressure position and postural sway. Arch Phys Med Rehabil. 1985;66:822-824.

Maki BE. Whitelaw RS. Influence of expectation and arousal on center-of-pressure responses to transient postural perturbations. J Vestib Reser. 1993;3(1):25-39.

Nashner LM. Sensory, neuromuscular, and biomechanical contributions to human balance. Proceeding of the APTA Forum. Balance, Nashville, Tennessee, 1989:5-7.

Newton RA. Recovery of balance abilities in individuals with traumatic brain injuries. Proceeding of the APTA Forum. Balance, Nashville, Tennessee, 1989:69-72.

Nichols DS, Glenn TM, Hutchinson KJ. Changes in the mean center of balance during balance testing in young adults. Phys Ther. 1995;75(8):699-706.

Norkin CC, Levangie PK, Joint Structure & Function: A Comprehensive Analysis. Philadelphia, F.A. Davis, 1992:131-134.

Patla AE, WinterDA, Frank JS, et al, Identification of age-related changes in the balace-control system. Proceeding of the APTA Forum. Balance, Nashville, Tennessee, 1989: 43-55.

Potter PJ, Kirby RL, Macleod DA. The effects of stimulated knee-flexion contracture on standing balance. Amer J Phys Med Rehabil. 1990;69:144-147.

Rasch PJ, Burke RK, Kinesiology and Applied Anatomy. Philadelphia, Lea & Febiger, 1978:361-387.

Shumway-Cook A, Woollacott MH. Motor Control. Theory and Practical Applica-tions. 1st ed. Baltimore, Williams & Wilkins, 1995:120-121.

Sluming VA, Norma DC. The role of imaging in the diagnosis of postural disorders related to low back pain. Sports Med. 1994;18:281-291

Smith LK, Weiss EL, Don LL. Brunnstrom`s Clinical Kinesiology Application. Philadelphia, F.A Davis, 1996:49-57.