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# 엉덩관절 위치감각과 균형능력의 상관관계

# Relationship between Hip Joint Position Sense and Balance Abilities

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*[Purpose] To investigate the correlation between joint position sense (JPS) during hip abduction and static/dynamic balance abilities. [Method] The study enrolled 22 healthy college undergraduates and a smartphone application known as Clinometer was used to measure JPS during hip abduction using the passive setting/active reproduction. Balance ability was measured at levels 12, 7, and 3 of the Biodex Balance System. The JPS error during hip abduction was correlated with balance ability in relation to sway level. [Results] Error in JPS during hip abduction was moderately correlated with all balance scores at all sway levels ($r \geq 0.38$, $p \leq 0.04$ for all), except for the anterior-posterior balance at levels 12 and 3 ($r \leq 0.24$, $p \geq 0.30$ for both). [Conclusion] A significant correlation existed between JPS during hip abduction and balance ability, regardless of sway level. Therefore, adequate sensory training of the hip joint is needed during balance training.*

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## NOMENCLATURE

JPS = Joint position sense
AP = Anterior-posterior
ML = Medial-lateral

## 1. Introduction

Calmly standing still with balance is one of the most common postures that humans use to interact with the surrounding environment.[1] To maintain a stable standing posture, the body receives information through visual, vestibular, and proprioceptive senses. Among these senses, proprioception enables normal motor control from the central nervous system by providing information about all joint movements that are involved in body movement, as well as protecting the joints from external injuries.[2] Joint proprioception is broadly divided into joint position sense (JPS) and motor sense.[3] JPS is strongly correlated with motor functions that are used to maintain balance.[4,5]

As a strategy to maintain balance, the inverted pendulum model, which stresses ankle movement, has been proposed. This was followed by the double inverted pendulum model, which focuses on both ankle and hip joint movements.[6] The ankle joint strategy is the most widely used strategy for activities of daily living. It has been widely accepted that with the ankle joint strategy, the body responds to even small sways, whereas the hip joint strategy is recruited to maintain balance by compensating for sway that is not adequately addressed with the ankle joint strategy.[7-9]

However, some recent studies have raised questions about these strategies according to the level of sway. In other words, these studies argue that the role of the hip joint may be equal or even greater than that of the ankle joint, even for small sways.[10,11] Considering that the hip joint is closer to the body's center of mass than is the ankle joint, the hip joint may play a more important role in the precise control of center of mass.[12] Furthermore, the hip joint is an important structure that affects the body's weight load distribution, and a functional impairment of the hip joint undermines one's balance ability.[13] Abduction of the hip joint is a particularly important movement for maintaining standing balance in relation to the ankle joint. Beckman and Buchanan (1995) suggested that an ankle injury is associated with the pattern of hip abductor mobilization[14], and Friel et al. (2006) reported that changes in hip joint movement increases the vulnerability of the ankle joint for injury.[15] Nguyen et al. (2011) stated that weakening of the hip abductor muscles has an adverse effect on leg alignment.[16] In light of these findings, we can infer that hip abduction plays an important role in maintaining balance and achieving a balanced standing posture.

Nevertheless, there is a lack of studies investigating the potential correlation between JPS during hip abduction and balance ability overall, as well as correlations in relation to the level of sway.

In this context, this study aimed to investigate the correlation between JPS during hip abduction and balance ability in relation to level of sway.

## 2. Methods

### 2.1 Participants

Sample size was computed using the G*power 3.1.5 software, with reference to Ha et al.'s (2013) study ($\alpha$ = 0.05, power = 0.90).[18] Calculated sample size was 21 (actual power = 0.90); therefore, we enrolled 22 participants (9 males, 13 females) in consideration of potential dropouts. Our study was approved by the Institutional Review Board of the U1 University (U1 University IRB 2017-5).

The specific inclusion criteria were as follows:

· Individuals with a visual or vestibular disorder without history of falling in daily life.

· Individuals without a musculoskeletal or neurologic disease or injury.

· Individuals who voluntarily consented to participate in this study.

The demographic characteristics of the participants are shown in Table 1.

Table 1 Participant demographic characteristics

| | n = 22 |
|---|---|
| Sex (M/F) | 9/13 |
| Age (y) | 21.56 1.90 |
| Height (cm) | 168.60 8.29 |
| Weight (kg) | 65.00 14.23 |

Data are presented in mean±standard deviation.

### 2.2 Equipment and Tools for Measurement

#### 2.2.1 Biodex Balance System

The Biodex Balance System (Biodex Medical Systems, Shirley, NY, USA) comprises a moving round foot plate, a monitor that visualizes the target, sensors that detect movement, and a computer for data analysis. There are 12 levels (12 = most stable to 1 = least stable) for testing using the foot plate; the lower the level, the greater the movement of the foot plate, which increases sway and makes it more difficult to maintain balance.

#### 2.2.2 Smartphone

A smartphone application called Clinometer (Manufacturer information) was used to measure the JPS of the hip joint. For this study, the application was installed on a Samsung Galaxy S7 smartphone (Samsung Electronics Co., Ltd., Suwon, South Korea). The smartphone was placed on the participants' legs (gastrocnemius muscle) and was secured using an armband and Velcro.

### 2.3 Measurements

#### 2.3.1 Dynamic Balance Ability

The participants were instructed to stand on the platform of the Biodex Balance System barefoot and to cross their arms while holding the opposite shoulder for the measurement.

The test was conducted while standing on both feet. All participants performed three levels (12, 7, 3) for three trials each. The mean values of the three trials were used. The Biodex Balance System generates scores for each parameter, and a lower score indicates better balance ability.

#### 2.3.2 Joint Position Sense for Hip Abduction

The passive setting/active reproduction test was performed to measure JPS during hip abduction. The participants wore an eye mask that covered both eyes in order to limit visual compensation. Participants held onto safety handles with both of their hands and were instructed to step on a sufficiently wide block with their non-dominant foot without allowing the dominant foot to touch the ground. This posture, a one-legged standing posture with the dominant leg hanging naturally, was set as the reference posture.

From this position, the examiner passively abducted the hip joint until the point at which the abducted. While returning the abducted leg to the reference posture, one position was randomly chosen (20 - 50 degree) and was maintained for three seconds (passive setting). The examiner instructed the participant to remember this position. Then, the examiner returned the participant to the reference position.

Then, the participant was told to reproduce the posture that they had been previously instructed to remember and to maintain that posture for three seconds (active reproduction). The absolute difference between the hip joint abduction angle during the passive setting and active reproduction was measured. This measurement was recorded three times, and a smaller JPS error indicated better JPS.

### 2.4 Analysis

Data were analyzed using Excel (Microsoft Office 365 ProPlus, v.1707; Microsoft, Redmond, WA, USA), with a statistical significance of 0.05. Correlation analysis was performed to examine the correlation between JPS during hip abduction and balance ability in relation to level of sway.

## 3. Results

Hip JPS error was moderately correlated to the total score and medial-lateral subscores of balance ability at all sway levels ($r > 0.30$, $p < 0.05$). Conversely, hip JPS error and the anterior-posterior (AP) balance score were moderately correlated at level 7, but not at levels 12 and 3 (Table 2).

Table 2 Correlation between joint position sense during hip abduction and balance ability in relation to sway level

| | Level | | Mean ± SD | r | p |
|---|---|---|---|---|---|
| Balance ability (unit: score) | 12 | Total | 1.30 ± 0.56 | 0.39 | 0.04* |
| | | AP | 0.91 ± 0.47 | 0.20 | 0.30 |
| | | ML | 0.73 ± 0.37 | 0.55 | 0.00** |
| | 7 | Total | 1.53 ± 0.59 | 0.47 | 0.01* |
| | | AP | 1.00 ± 0.42 | 0.39 | 0.04* |
| | | ML | 0.93 ± 0.40 | 0.48 | 0.01* |
| | 3 | Total | 2.29 ± 1.10 | 0.41 | 0.03* |
| | | AP | 1.65 ± .656 | 0.24 | 0.21 |
| | | ML | 1.35 ± .355 | 0.38 | 0.04* |
| JPS error degree | | | 3.26 ± 1.47 | | |

*p < 0.05, *p < 0.01. JPS: joint position sense, AP: anterior-posterior, ML: medial-lateral.
0.3 < r < 0.6: moderately correlation, r<0.6: strongly correlation[19]

## 4. Discussion

This study aimed to investigate the correlation between JPS during hip abduction and balance ability in relation to level of sway. A smartphone application was used to measure the JPS for hip abduction. Despite its importance, JPS is not widely measured in clinical practice, largely because existing equipment is too expensive and takes up too much space. On the other hand, smartphones are easily accessible and are not spatially restricted. Furthermore, JPS measurements using a smartphone have high reliability and high concurrent validity with an electrogoniometer.[20,21] Hence, we used a smartphone application to measure JPS of the hip joint in this study.

In a prior study, hip abduction was measured with a smartphone attached either to the thigh or the shin, and both methods had reliabilities exceeding 80%. It was difficult to attach the smartphone to the thigh with a regular armband in some participants, but attaching the smartphone to the shin was not difficult in most participants. Thus, in this study, we chose to attach the smartphone to the shin, as this was easier and yielded more reliable results.

Our results showed that JPS of the hip joint was significantly correlated with balance ability, which is supported by several previous studies. For example, Garland et al. (2009) suggested that a sensory deficiency affects balance ability,[22] and Park (2010) stated that weakening of hip proprioception has adverse effects on postural alignment.[23] Many balance training programs stress sensory training of only the ankle joint, with great neglect of the hip joint.[24] However, Roerdink et al. (2009) argued that ankle sense (proprioceptive sense) does not affect balance in stroke patients,[17] and Choi and Park (2011) suggested that individuals with better hip joint senses have better balance abilities.[25]

In this study, we used three levels (12, 7, 3) of sway. Level 12 most closely resembles static balance with hardly any sway, while in a pilot study, level 3 was found to be the most difficult level in which participants maintained balance without falling. Existing balance strategies state that the ankle joint is used for small sways while the hip joint is used for larger sways; however, the present study found that JPS during hip abduction was significantly correlated with balance ability at level 12 as well, suggesting that the hip joint also plays a key role in small sway. Pertaining to this result, Shim (2016) suggested that sensory-motor training of the hip abductor muscles is beneficial for improving balance ability,[24] supporting the findings of this study. In addition, Choi and Park (2011) found that sense of light contact to the hip joint affects both dynamic and static balance abilities,[25] which was also in line with our findings.

Wilson et al. (2006) stated that the functions of the hip joint and ankle joint are complementary in terms of preventing injuries and maintaining and continuing balance in daily living.[26] Therefore, we suggest that balance training programs should also include hip sensory training.

This study had limitations. For example, this study was only conducted in healthy adults within a specific geographical region. Further, we only analyzed correlations, which have no implications for causal relationships. We also did not examine JPS of other joints. Therefore, we hope that future studies address these limitations in an effort to propose effective balance training methods.

## 5. Conclusions

This study investigated the correlation between JPS during hip abduction and balance ability in 23 healthy undergraduate students. The following results were found:

(1) Error of JPS during hip abduction was moderately correlated with the total score and medial-lateral subscore of balance ability at all sway levels.

(2) Error of JPS of hip abduction and AP balance score was moderately correlated at level 7, but not at levels 12 and 3.

As shown here, JPS during hip abduction was significantly correlated with balance ability, regardless of sway level. Therefore, sensory training of the hip joint, in addition to the ankle joint, should be adequately performed during balance training.

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