The Effect of Pelvic Inclination on Gait Elements and Weight Bearing of Healthy Adults

The purpose of this study was to investigate the influence of the static pelvic inclination and declination in the static standing position on weight bearing rate and gait elements. Fourteen healthy adults in their twenties were participated. Two groups of healthy adults were allocated in this study: above and below the average of pelvic tilt. The correlation between the pelvic inclination, weight bearing rate and gait elements were measured. There was a statistical correlation between the pelvic tilt and step. Also, there was a statistical difference when we compared anterior declination with swing period and posterior declination with step. There was an asymmetric correlation between pelvic tilt and step. However, there was no statistical difference between the groups above and below the average of pelvic tilt. This result indicates that dipper pelvic inclination doesn’t affect the asymmetry of step.

Key words: Gait: Pelvic Inclination: Weight Bearing: Gait Asymmetry Ratio

INTRODUCTION

Gait refers to the walking shape or attitude of complex motion pattern composed of changes in the neuromuscular system, biodynamical and functional movements generated over a long period after birth(1). The gait of the human body is a complicated process that generates well-balanced dynamic motions in several joints of the lower limbs to achieve gradual conversion on center of pressure(2). Gait refers to the act of moving the human body from one point to another by alternatively taking rhythmic movements, swing phase and stance phase of both lower limbs(3). Furthermore, an appropriate joint movement range and stability that permits alternative movement are required the head, neck, and body maintains normal alignment(4, 5).

Gait is an alternative movement that presents advanced coordination by moving the human body in stages while maintaining required speed in a regular direction(6). The lower limbs present an interconnection with the head, body and arms in walking and basically presents a weight loading structure. The limbs maintain stability and balance and moves the body forward to provide basic exercise required for movement(7).

There are many factors that are reported to affect the gait of normal people, such as gender, age, balance of standing position, and strength of lower limbs(8). The diversity of humans enables humans to present individual gait methods. In other words, no two people walk alike. This is externalized by the motor mechanics and kinematic factors of walking(9). Upright gait is affected by various factors and many people walk slightly different from what is perceived as ‘normal gait’(10). This is because individual walks affect one another and the body expresses the surrounding environments and self-purpose through walking(11).

Gait cycle is divided into stance phase, the period in which the foot is on the surface, and swing phase, the period in which the foot is lifted from the ground to move forward. A normal gait must be composed of 60% stance phase and 40% swing phase(12). Stance phase is composed of heel strike, foot flat, mid-stance, push-off, toe off. Swing phase can be divided into acceleration, midswing, deceleration(13). As the factor for establishing standing posture, the pelvis...
performs movement for connecting the spine with the lower limbs, facilitates inclining or rotating movement for moving left or right as the supporting point(14). Pelvis helps maintain or support weight, and continuously adjusts the balance according to human-centered movement(15). The motion pattern of the pelvis is achieved by the harmony of the hip joint and lumbosacral joint to accompany declination of pelvis according to anterior/posterior pelvic tilt(16). The ideal pelvic arrangement refers to the condition in which anterior superior iliac spine(ASIS) is parallel to posterior superior iliac spine(PSIS), and ASIS is perpendicular to the pubic symphysis. The anterior/posterior pelvic tilt is reported to be classified according to the frontal/rear inclination of ilium(17).

Excessive frontal inclination of the pelvis shortens tensor fasciae latae and iliotibial tract, restricts general external rotation of coxa, weakens gluteus medius and piriform muscle, straightens certain posterior part, and causes imbalance of coxa muscle due to compensation of the lower limbs including excessive internal rotation of the thigh bone, genu varum and internal rotation of femur, torsion of external tibia, pes valgus and hallux abduction during the first half of the stance period along with increased stress of the center part of the knees(18). Furthermore, excessive posterior and lateral inclination of the pelvis triggers a slouching position and excessive body movement during walking to increase stress on the waist and affect weight bearing and normal gait(19, 20).

Thus, weight bearing rate and walking factors are analyzed according to static pelvic inclination to investigate the correlation with walking according to the asymmetry of pelvic inclination. Also, walking is revised through pelvis correction exercise and stretching to improve asymmetrical or abnormal pelvic inclination.

This study used a plantar pressure and GAITRite system equipment to investigate the effect of pelvis angle in static standing position on left/right weight bearing rate and walking factors, was 23.79, average weight was 61.89kg, and average height was 169.09cm. The average lengths of the lower left and right limbs were measured as 88.26cm, 88.79cm, respectively. Plantar pressure and GAITRite system equipment installed in Ulsan College were used to conduct this study from December 2010 to February 2011.

**Measuring Instrument**

Sticker(Latech Korea, Korea), 150cm tape (Shanghai, China) and 30cm square measure (Songwo Industry, Korea) were used as tools for measuring pelvic inclination. The stickers were used to accurately mark the location points of ASIS and PSIS and the tape measure was used to measure the length of ASIS and PSIS. The square measure was used to achieve perpendicular arrangement from the wall to the sticker point to increase accuracy of the pelvic inclination measurement. Furthermore, 30cm ruler was attached on 30cm square in a similar form with Vernier calipers and the English alphabet F shape was formed to measure distance between frontal/rear ASIS, distance between PSIS, and distance between PSIS in left/ right ASIS(Fig. 1).

Foot scan(Novel Gmbh, Germany) that can be easily carried around and measure results was used for the measurement instrument of plantar pressure distribution(Fig. 2). Foot scan was used to measure the pressure of the plantar surface to calculate pressure distribution and left/right weight bearing rate,  

**METHODS**

**Subjects**

This study selected a total of 14 normal adults, 7 men and 7 women, without history of neurological/orthopedic diseases, such as surgery or injury that can affect walking. The average age of the subjects...
Measurement of gait ability

GAITRite system was used to measure the gait of the research subject. GAITRite system is a device verified with high credibility and validity for analyzing temporal/spatial gait characteristics(21, 22).

To measure gait cycle, the subject was instructed to walk naturally on bare foot in standing posture. Temporal variables(gait time and swing time, single support time, double support time) were measured with spatial variables( step length, stride length). To increase credibility, each measurement was measured 3 times by the same person to record the mean value.

Measurement of plantar pressure

To measure plantar pressure, the subject maintained static balance in standing posture for 20 seconds and average plantar pressure record value was calculated during the 5 seconds (11-15 seconds) in which the subject could maintain stable static balance. Both feet were measured by using this method to compare left/right weight values and calculate the difference between left/right weight bearing rates(Fig. 4).

Gait asymmetry ratio

To express gait characteristics, the difference in temporal/spatial gait variables measured in the main foot and opposite foot was presented as asymmetry rate. The calculation method is as follows. Asymmetry rate signifies larger degree of asymmetry with higher value and smaller degree of symmetry with lower value(23).

This study converted all values included in the gait cycle to asymmetry rate for statistical application.

\[
\text{asymmetry ratio} = 1 - \frac{\text{gait variable of main foot}}{\text{gait variable of opposite foot}}
\]
Measurement of pelvic tilt angle

Triangular calculation method proposed by Sanders & Stavarakas was used to measure pelvic inclination angle related with horizontal plane(24). Tape measure was used to measure the height from the floor to ASIS and PSIS, while F ruler was used to measure the distance between ASIS and PSIS, Slight pressure was exerted to measure the distance when using the F ruler in consideration of error generated between the osteophyte and skin.

Measured values were recorded in the assessment inspection form written after the researcher conducted the preliminary experiment and were calculated by the triangular calculated method

\[
\sin \theta = \frac{A-B}{C} \quad (\theta = \text{degree of tilt})
\]

Fig. 5, Shematic diagram of pelvic tilt measuring, A–B : side opposite, C : hypotenuse

Data Analysis

Technical statistics were applied to research the mean and standard deviation of general characteristics and body structure of research subjects. Static and dynamic gait cycle and weight bearing rate were analyzed by using technical statistics.

Non–parametric test was applied as the subjects were small in number. Pearson’s correlation test was conducted to investigate the correlation between body structure, gait cycle and weight bearing rate. Mann– Whitney U test was conducted to research the differences in the gait factors and mean value of weight bearing rate of the above-average group and below-average group according to pelvic angle. For data analysis, SPSS was used to conduct statistical treatment, and \( \alpha = .05 \) was used to verify statistical significance.

RESULTS

General Characteristics of Subjects

This study selected a total of 14 normal adults, 7 men(50%) and 7 women(50%), without history of neurological/orthopedic diseases, such as surgery or injury that can affect walking. The average age of the subjects was 23.79±1.72, average height was 169.09±6.90cm, and average weight was 61.89±9.82kg. The average lengths of the lower left and right limbs were measured as 88.26±.04cm, 88.79±.07cm(Table 1).

<table>
<thead>
<tr>
<th>Table 1, General characteristics of subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>M±SD</td>
</tr>
<tr>
<td>Age(years)</td>
</tr>
<tr>
<td>Height(cm)</td>
</tr>
<tr>
<td>Weight(Kg)</td>
</tr>
<tr>
<td>Leg length(cm)</td>
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</table>

Pelvic Inclination and Declination of Subjects

The pelvic inclination and declination of experiment subjects are as presented in Table 2 and 3. The mean value of anterior pelvic declination(ASIS) was .32°, with 2 subjects(14.29%) from the above-average group and 12 subjects(85.71%) from the below-average group. The mean value of the posterior pelvic declina-
tion(PSIS) was .94°, with 4 subjects(28.58%) from the above-average group and 10 subjects(71.42%) from the below-average group. The mean value of left pelvic inclination was 7.34°, with 5 subjects(36.72%) from the above-average group and 9 subjects(63.28%) from the below-average group. The mean value of right pelvic inclination was 7.29°, with 8 subjects(57.15%) from the above-average group and 6 subjects(42.85%) from the below-average group(Table 2).
Table 2. Pelvic declination of subjects

<table>
<thead>
<tr>
<th>Pelvic declination angle</th>
<th>Above-average</th>
<th>Below-average</th>
<th>M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASIS</td>
<td>2(14.29%)</td>
<td>12(85.71%)</td>
<td>.32±.72</td>
</tr>
<tr>
<td>PSIS</td>
<td>4(28.58%)</td>
<td>10(71.42%)</td>
<td>.94±2.01</td>
</tr>
</tbody>
</table>

Table 3. Pelvic inclination of subjects

<table>
<thead>
<tr>
<th>Pelvic inclination angle</th>
<th>Above-average</th>
<th>Below-average</th>
<th>M ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>5(36.72%)</td>
<td>9(64.28%)</td>
<td>7.34±3.87</td>
</tr>
<tr>
<td>Right</td>
<td>8(57.15%)</td>
<td>6(42.85%)</td>
<td>7.29±3.52</td>
</tr>
</tbody>
</table>

Correlation of Pelvic Inclination/Declination, Gait Cycle and Weight Bearing Rate

According to research on the correlation of the pelvis inclination/declination, gait cycle and weight bearing rate, significant correlation was presented in right and left pelvic inclination only for stride among the presented variables.

Table 4. Correlation between pelvic inclination and step

<table>
<thead>
<tr>
<th>Pelvic inclination</th>
<th>Left tilt</th>
<th>Right tilt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step</td>
<td>.590*</td>
<td>.604*</td>
</tr>
</tbody>
</table>

*P<.05

Comparison of Gait Factor and Asymmetry Ratio between Two Groups according to Pelvic Inclination

The following results were gained from the comparison of the difference between gait factors of the above-average group and below-average group according to pelvic inclination and declination. Statistically significant difference was presented in the comparison of the swing period between the above-average group and below-average group according to anterior declination(p<.05)(Table 5).

Furthermore, statistically significant difference was presented during the comparison of step length between the above-average group and below-average group according to posterior declination (p<.05)(Table 6).

Table 5. Comparison of swing period on between two groups according to anterior pelvic declination

<table>
<thead>
<tr>
<th>Anterior pelvic declination</th>
<th>Above-average</th>
<th>Below-average</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swing period</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>.004±.004</td>
<td>.08±.08</td>
<td>-2.008</td>
<td>.045*</td>
</tr>
</tbody>
</table>

*p<.05

Table 6. Comparison of stride on between two groups according to posterior pelvic declination

<table>
<thead>
<tr>
<th>Posterior pelvic declination</th>
<th>Above-average</th>
<th>Below-average</th>
<th>Z</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride</td>
<td>.006±.004</td>
<td>.03±.04</td>
<td>-2.121</td>
<td>.034*</td>
</tr>
</tbody>
</table>

*p<.05

DISCUSSION

Gait performs a very important role in the daily lives of humans, and serves as the basis for humans to lead independent lives(25). Furthermore, as the most natural, habitual and automated motion among human movements, gait can be simultaneously performed with other acts, such as communicating with others or moving objects(26).

As the area attaching the body with lower limb muscles, the pelvis supports the abdomen and maintains weight in seated posture while intervening with weight bearing from the spine to the lower limbs in standing posture(27). Moreover, the pelvis maintains an upright posture to stabilize the body and perform smooth movements of the upper limbs(28). In this regard, the pelvis is an important factor that affects the entire posture of humans(1).

This study conducted an experiment on normal adults without neurological/orthopedic disorders to investigate the effect of pelvis inclination and declination on weight bearing rate and gait factors. 14 men and women of the 20s attending U college were selected as the subjects of the experiment.

Kendall et al. argued that anterior superior iliac spin was horizontal to the posterior superior iliac spine while the anterior superior iliac spine was vertical to the pubic symphysis according to the anatomical location of the pelvis(17). Kapandji stated...
that the location of the posterior superior iliac spine was higher than the anterior superior iliac spine(14). Furthermore, Kelsey et al. stated that anterior pelvic tilt is commonly presented in office workers (students) and drivers that work most of the time sitting down(29). Anterior pelvic tilt was also commonly observed in this study. This is stipulated to be due to the fact that all 14 research subjects were students who sit down and study for a long time.

According to the research of Yoon et al., left/right declination of the pelvis was analyzed in 26 normal people(30). Results presented that left declination (15 subjects, 57.7%) was slightly more common in anterior part (ASIS) when compared with right declination (11 subjects, 42.3%), whereas right declination (14 subjects, 53.8%) was slightly more common in posterior part (PSIS).

This study presented more cases of left declination (9 subjects, 64.28%), than right declination in the anterior part, and more cases of right declination (11 subjects, 78.57%) than left declination in the posterior part.

Generally, anterior pelvic tilt lifts the ilium and increases lordosis of lumbar spine, externally rotates the coxa and internally rotates the tibia, inversion the foot to externally rotates the talus, and finally moves the pressure distribution of the foot to the posterolateral direction. Conversely, posterior tilting of the pelvic lowers the ilium and increases kyphosis of lumbar spine, internally rotates the coxa and externally rotates the tibia, eversion the foot to internally rotates the talus, and finally moves the pressure distribution of the foot to the posteromedial direction(15).

Although the role of the pelvis has yet been clarified with regard to median plane balance, the pelvis is observed to rotate centered on the coxa to increase and decrease anterior tilting of the huckleBone(31).

Although gait analysis was initially used to evaluate the suitability of reconstruction surgery, post-surgery, and prosthetic leg, it is now being used to analyze all defective factors of gait(32).

This study conducted the experiment on adults without neurological/orthopedic problems. However, it is stipulated that asymmetrical pelvic inclination can be presented in static condition due to acquired factors, such as usual habit or posture. Thus, the effect on gait factors and weight bearing rate must be investigated.

The limitation of this study is that it is difficult to generalize the results due to the small number of subjects. The gait speed was different for each experiment subject during measurement of gait cycle. Also, anthropometrical problem of subjects was not considered during use of F ruler and differences are presented in the normal angle of pelvis between men and women.

Lastly, as this study conducted research by dividing the pelvic inclination and declination according to the pelvic angle measured in static posture, future research must investigate the effect on weight bearing rate and gait factors according to the pelvic angle measured in dynamic posture during walking.

**CONCLUSION**

This study researched the effect on weight bearing rate and gait factors according to the pelvic inclination and declination of normal adults in their 20s. The results are as follows. Significant correlation with stride was presented in both right, left inclination of the pelvis. Correlation was shown in a normal positive relationship. Also, statistically significant difference in swing period was presented between the above average group and below-average group in forward declination. Greater asymmetry was presented in the below average group. Statistically significant difference in step length was also presented between the above average group and below-average group in backward declination. Greater asymmetry was presented in the below average group.

Although asymmetry of stride is increased according to the left/right pelvic inclination, significant difference was not presented between the above average group and below average group. Thus, it is stipulated that asymmetry of stride is not increased with greater pelvis inclination.

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