A STUDY OF THE WALKING FOR PREGNANT WOMEN

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Abstract: The physical changes that accompany pregnancy affect gait, making it difficult for pregnant women to maintain their balance. This study analyzed gait in pregnancy using three-dimensional motility analysis equipment in order to identify characteristic mechanisms for postural adjustments. We examined toe clearance (TC), a factor believed to affect tripping, and looked at the maximum TC during the swing phase in women wearing shoe heels of varying heights. 6 participants (20±8.8 years of age), all healthy Japanese women, were dressed in pregnancy experience jackets to simulate late pregnancy. All participants had lower TC when wearing the pregnancy simulation jackets, and the higher their heels the more restricted their TC. And when stepping, test subjects took conscious care in performing the task, and raised their legs accordingly. It was hinted that test subjects tried to secure a steady body by shortening the time needed to land the sole on the floor while keeping body sway width to a minimum, and, when stepping, moving only after confirming the tasks involved in stepping, etc.

1. INTRODUCTION

From midtrimester on, the swelling and protrusion of the abdomen and increased body weight accompanying pregnancy have been observed to result in such things as a change of cadence during walking and deviations in the center-of-gravity location(Y,Taketani.and S,Maehara.,2005), etc.; thus, a different walking style than that when not pregnant is presented. It could be said that this is a body state whereby "tripping" and/or "falling" may easily occur. In the present research, "tripping" is thought to be related to the distance between the shoe toe-tip portion and the floor surface (below, "TC" = "toe clearance"); we thus attempted an investigation with the focus on TC during walking time of pregnant women. Clarification of the walking mechanisms of pregnant women would, it is thought, contribute to a safer and more comfortable pregnancy period. This research was also performed with the idea that the results could be actively used as one foundation in providing health-insurance guidance for the daily lives of pregnant women.

2. PURPOSE

With presumption of the late pregnancy period, clarification will be made of differences in walking on a flat surface and when stepping, in the case where a pregnancy experience jacket is worn, and when this jacket is not worn. Especially, clarification will be made of differences in TC for different shoe heel heights.

3. RESEARCH METHOD

3.1. Test Subjects

In the period from July to August 2007, test subjects were 6 Japanese women, healthy and aged 20 and 21, all of whom granted their consent to cooperate in the present research.
3.2. Test Procedures

In the present research, test subjects were not actual pregnant women; instead, test subjects were asked to wear a pregnancy experience jacket, and while wearing footwear with three conditions of heels of different heights and shapes, test subjects performed ordinary walking using a flat surface and a step.

3.2.1. Setting of Photographing Environment

As in Fig. 1, 2 cameras each using a three-dimensional movement analysis apparatus (below, "Quick MAG", made by Ohyoh Keisoku Kenkyusho (OKK)) were set such that walking distance could be as long as possible. To enable maximum photography of the movement ranges of test subjects, the walking distance on the flat-surface walk path was set at a straight-line distance of 3,850[mm]. As for the step setting, on the basis of barrier-free standards as notified by the Japanese Ministry of Land, Infrastructure and Transport (MLIT., 2006), a step (250 (D) × 300 (W) × 150 (H)[mm]) was used. The step was set at the 3,000[mm] point, where it was hypothesized a walker would start the third cycle of her walking cycle.

![Figure1. Photographing Environment](image)

3.2.2. Calibration Setting

The calibration point was that which could serve as the standard for three-dimensional coordinate detection analysis sites. The spatial coordinate XYZ axis at this time was set such that the movement direction during walking would be the X-axis.

3.2.3. Adjustments when wearing the pregnancy experience jacket

For test subjects, a model (pregnancy experience jacket, made by Kyoto Kagaku Co., Ltd.) used for experience training was employed. This is an abdominal unit with resin lead weight inserts; the jacket weighs approximately 8.6 kg. This is assumed to be the weight borne by a pregnant woman in the late pregnancy stage.

When wearing the pregnancy experience jacket, due to its characteristics, a load is placed on a part of the body supporting the jacket. Based on prior research (Y.Hujita, and M.Uechi., 2006) and interviews with
women who have experienced pregnancy, we strove to reduce the burden to a minimum, and to come close to
the actual state of a pregnant woman in the late pregnancy phase.

The standard for the jacket wearing-period was set such that the maximum protrusion of the abdominal
portion of the pregnancy experience jacket was along a line extending from the navel of test subjects. Also, to
reduce to a minimum load on the neck, the pregnancy experience jacket was fixed at the waist portion by
wrapping the entire abdominal portion of the jacket in a sling used when carrying an infant. After putting on
the jacket, confirmation was made of the following points from test subjects, namely, that (1) there was no
burden on the neck, (2) that there was a load on the lower-back portion, and that there was a match between
the navel location and the maximum protrusion of the abdominal portion.

3.2.4. Application of Reflection Points

As for application of the reflection points required for measurements, reference was made of prior research
and documentation(Y.Hujita. and M.Uechi., 2006), and these points were applied to a total of four points: at
the vertex, the navel, and at the toe-tip portions of the right, and left footwear (Fig. 2).

3.2.5. Selection of Footwear

Prior to testing, a survey was performed of 2 physicians 5 midwives, and 3 public health nurses from public
health centers or hospitals having an obstetrics clinic to determine trends of footwear worn by pregnant
women who visit the facilities for pregnancy examinations. The survey method was to obtain responses upon
showing examples of shoes having different heel heights and shapes. As the result of the survey, two pairs of
shoes were selected for use in the test: pumps having a heel height of around 7 cm, and shoes with a heel of 0
cm, such that the sole is flat. In Japan, when a woman submits a notice of pregnancy, she is issued a
"Mother-Child Handbook" (boshi-techo); in the "health guidance" section as printed in the handbook,
suggestion is made to wear "shoes with stable heels of approximately 3 cm height." This height was thus also
selected as a size for comparison, and selection for use in this test was made upon reference to a textbook used
in the schooling of public health nurses who are engaged with pregnant women.

3.2.6. Measurement method

Prior to measurement, to enable test subjects to become accustomed to the footwear and the pregnancy
experience jacket, walking was performed for around 1 minute with each item type, and whether or not the
subject had become accustomed was confirmed orally. As for walking speed, free speed was allowed, and
walking sequences were set randomly for different footwear used by test subjects. Subjects were instructed to "walk as you do normally," and the subjects chose the timing for when they would begin walking.

Used for measurements and analysis was the three-dimensional movement analysis apparatus (Quick MAG).

Used for the analysis was the portion from the fourth step on, which is said to be the point where the walking state when walking on a flat surface becomes stationary; measurements were made 3 times for each test subject. Thereafter, taken was the mean value of the max values when detection of the reflection points was favorable.

Taken as the TC for flat-surface walking was the distance from the floor to the toe-tip, and for the step, the distance from the floor until reaching the step. Measurements were also made for left and right foot, whichever foot was the first to reach the step. With regard to left-right differences, a survey was made of left-right differences on the basis of prior research. As for center-of-gravity location, when wearing the pregnancy experience jacket, this was the line extending from the navel of test subjects, while the navel marker was used when not wearing the jacket.

Also, after completion of the testing, test subjects were interviewed mainly concerning their states at times of walking. As for the response method, the "free response" method was adopted, and multiple responses were also allowed.

3.2.7. Ethical Considerations

The purpose of the research, the guarantee of anonymity, consent to the testing, and the possibility of leaving the research at any time during the testing were sufficiently explained, verbally and in writing, to persons cooperating in the research, to which they gave their agreement; and testing was performed only after obtaining the consent of persons cooperating in the research.

4. RESULTS

4.1. Overview of Persons Cooperating in the Testing

An overview of the persons cooperating in the testing is as shown in Table 1. After testing, there were no persons among the tested persons who experienced secondary physical pain such as lower back pain, etc., resulting from wearing the pregnancy experience jacket and/or from the wearing of unaccustomed footwear.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>mean±SD</th>
</tr>
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<tbody>
<tr>
<td>Number</td>
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</tr>
<tr>
<td>Age (years)</td>
<td>20±8.8</td>
</tr>
<tr>
<td>Standing height (cm)</td>
<td>158.3±1.6</td>
</tr>
<tr>
<td>Size of shoes to usually wear (cm)</td>
<td>23.7±8.4</td>
</tr>
</tbody>
</table>

4.2. Differences in gait due to different heel heights

TC values within the free swing phase due to differences of heel height when wearing and when not wearing the pregnancy experience jacket were each lower when wearing the jacket; the higher the heel, the lower each
TC value. When stepping, compared with when walking on the flat surface, each TC value became higher (Fig. 6). As for center of gravity locations, these were each roughly constant. Gait velocity when walking on the flat surface was roughly constant. As for stepping, when climbing onto the step, the time was measured from the single-leg support phase to the double (both-leg) support phase when both legs are on the step surface. The times were longer when wearing the pregnancy experience jacket. Also, when wearing and not wearing the pregnancy experience jacket, while times were roughly constant for heel heights of 0 cm and 3 cm, times were longer for 7 cm heels.

![Figure 3: Toe Clearance values within the free swing phase due to differences of heel height when wearing and when not wearing the pregnancy experience jacket.](image)

![Figure 4: A Change of Center-of-Gravity within the free swing phase due to differences of heel height when wearing and when not wearing the pregnancy experience jacket.](image)
After test subjects performed walking when wearing the pregnancy experience jacket, interviews were conducted concerning their states at times of walking, etc. The "free response" method was adopted, and the following were results, including multiple responses, from the interviews: "My visual field was limited when my abdomen was protruding," and "The higher the heel, the more difficult it became to raise up my lower leg (thigh)." Subjects continued with the statements: "I don't think it was easy to walk with a 3-inch wide heel," and "I had the feeling that my walking step length became shorter," and "There was a feeling of increased burden on my back and lower back." There was a complaint made such that "I felt uneasy due to the change in my field of vision"; this response included two changes in visual field, namely, the limitation on the visual field caused by the abdominal protrusion of the pregnancy experience jacket, and the changes in visual field resulting from heel height.

Table 2. Results of interviews after this experimentation

<table>
<thead>
<tr>
<th>The items of interviews</th>
<th>number</th>
</tr>
</thead>
<tbody>
<tr>
<td>• My visual was limited when my abdomen was protruding</td>
<td>6</td>
</tr>
<tr>
<td>• The higher the heel, the more difficult it became to raise up my lower leg</td>
<td>6</td>
</tr>
<tr>
<td>• I don't think it was easy to walk with a 3-inch wide heel</td>
<td>6</td>
</tr>
<tr>
<td>• I felt uneasy due to the change in my field of vision</td>
<td>6</td>
</tr>
<tr>
<td>• I had the feeling that my walking step length became shorter</td>
<td>3</td>
</tr>
<tr>
<td>• There was a feeling increased burden on my back and lower back</td>
<td>2</td>
</tr>
</tbody>
</table>

*We include some repetition answers.

5. DISCUSSION

When a person is walking, their center-of-gravity deviates up and down, and left and right, with the aim of keeping movement energy to a minimum and maintaining stability. Normally, in order to walk forward, in the swing phase, it is necessary to secure a sufficient TC (M.,Kaneko. and T,Fukunaga., 2006)—this is an
indispensable motion. While it is necessary to raise one's legs to accomplish the walking forward movement, in the case of a pregnant woman, in the swing phase when the foot is separated from the ground, her center-of-gravity location is deviating forward, and it is imagined that it is difficult to maintain body stability when securing TC.

From the present research, it was hinted that when wearing the pregnancy experience jacket, the TC, or distance to the floor, is made to be extremely small, and, by keeping whole-body swaying as small as possible, to enable stability both when walking and when stepping. It was learned that especially when stepping, the foot is raised cautiously. This was backed up by the interview results. As for this phenomenon, while when walking on a flat surface, the higher the heel height, the more the stepping style becomes such that one "tests" the step down (the "arrival") onto the surface with the sole of the foot, it was suggested that when one confirms an obstacle such as a step, movement becomes a conscious and active engagement. In ordinary daily life, the Japanese Ministry of Land, Infrastructure and Transport (MLIT., 2006) has set 16 cm as a standard stairs height. When one seeks to avoid a height around that of a stairs, it is difficult—and especially for a pregnant woman—to secure TC, and even greater caution is aroused in a pregnant woman who is wearing high-heeled shoes.

From both the test and interview results, from the responses obtained such that, the higher the heel, "I had the sense that my step length became narrower," "I felt that raising my lower leg became more difficult," "my field of vision become narrower due to the abdominal protrusion," and "I felt uneasiness due to my limited field of vision," it is imagined that, in the swing phase when one's leg is separated from the ground, a self-protection reaction occurs such that one wants that leg to reach as quickly as possible to the ground to avoid falling over. It was hinted that the protective reaction that works unconsciously in humans mutually cooperates in the walking motion to help secure a stable gait.

From the present results, one can say that with the "3 cm width heel" recommended by public health nurses involved in the pregnancy cycle, a pregnant woman would show a walking style that becomes closer to "shuffling one's feet" compared with the gait evinced when walking with 0 cm heels, where the sole is flat. And from the interviews, one can say that, with the 3 cm heel, one is not always definitely able to maintain stability while walking, and thus the 3 cm heel is inappropriate. There is still room, however, for further study regarding the "ideal" walking condition, where in the provision of public health guidance, consideration is given to the mutual relationship between the external appearance (fashion aspect) of shoes, such as heel height, and a woman's internal environment, including the mechanisms of walking movements, etc.

6. CONCLUSIONS

When wearing the pregnancy experience jacket, TCs were lower than when not wearing the jacket, and TCs became lower the higher the heel height. And when stepping, test subjects took conscious care in performing the task, and raised their legs accordingly. It was hinted that test subjects tried to secure a steady body by shortening the time needed to land the sole on the floor while keeping body sway width to a minimum, and, when stepping, moving only after confirming the tasks involved in stepping, etc.

7. REFERENCE