Comparison of the anatomical severity between a natural fall and the fall from a wheeled platform imitated a two-wheeled, self-balancing, battery-powered electric vehicle

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Abstract: Although it is able to approximate the movement of each physical part of falling down human body by free-fall motion, there is no guarantee about relations the anatomical severity for each physical part and free-fall motion, and a comparison of the anatomical severity for each physical part between experimental conditions. We classified the ways of a fall of the dummy doll through the dimensionality reduction of the time series data of a natural fall and the fall from a wheeled platform imitated a two-wheeled, self-balancing, electric vehicle. As a result, it was suggested that the analysis based on the classification by the ways of the fall obtained high external validity for the anatomical severity, and the effect of the physical protection.

Keywords: natural fall, wheeled platform, anatomical severity, principal component analysis, dynamic time warping method

1. Introduction

The exogenous shock of the head when a doll imitated human body fell down varies according to the combination of fixed joints [1]. Therefore, the falling of the human body should be evaluated as a motion of a multi-jointed body. When we calculate a motion of the human body as a multi-jointed body, the degree of data becomes higher. Therefore it is necessary to reduce the degree of data to facilitate the analysis of the motion. The dimensionality reduction method of the data of the human body motion has been already used in the biological motion research [2, 3]. In this study, the organizing and integrating method of the verification of each dimensionally reduced time series data (dynamic time warping method) and the classification of the falling type (metric multidimensional scaling) would be presented, it would be more than the dimensionality reduction of the time series data of each physical part. And comparing the HIC (Head Injury Criteria) when the dummy doll fell down naturally and fell down from the wheeled platform imitated a two-wheeled, self-balancing, battery-powered electric vehicle, we would consider the effect of the tool for physical protection.

2. Analysis of the fall experiment with the dummy doll

2.1 Experimental procedure
1) The mass of the dummy doll was 45 kg, the height was 145cm.
2) The height of the platform was 11 cm from the floor.
3) The condition of the fall experiment is shown in Table 1.

### Table 1. Experimental conditions

<table>
<thead>
<tr>
<th>Test</th>
<th>Direction</th>
<th>Posture at the start</th>
<th>Angle of the trunk (degrees)</th>
<th>Protective equipment</th>
<th>HIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Backward</td>
<td>Upright</td>
<td>90.0</td>
<td>Collar</td>
<td>862</td>
</tr>
<tr>
<td>T2</td>
<td>Diagonally Backward</td>
<td>Upright (right leg flexure)</td>
<td>90.0</td>
<td>Collar</td>
<td>1198</td>
</tr>
<tr>
<td>T3</td>
<td>Backward</td>
<td>Upright (right leg flexure)</td>
<td>90.0</td>
<td>Bike helmet, Collar</td>
<td>10</td>
</tr>
<tr>
<td>T4</td>
<td>Backward</td>
<td>Upright (suspended)</td>
<td>90.0</td>
<td>Bike helmet</td>
<td>2502</td>
</tr>
<tr>
<td>T5</td>
<td>Backward</td>
<td>Upright (suspended)</td>
<td>90.0</td>
<td>Full-face helmet</td>
<td>1098</td>
</tr>
<tr>
<td>T6</td>
<td>Backward</td>
<td>Upright (suspended)</td>
<td>90.0</td>
<td>Safety hat</td>
<td>8726</td>
</tr>
<tr>
<td>T7</td>
<td>Backward</td>
<td>Upright (suspended)</td>
<td>90.0</td>
<td>Construction helmet</td>
<td>2515</td>
</tr>
<tr>
<td>T8</td>
<td>Backward</td>
<td>(suspended)</td>
<td>90.0</td>
<td>—</td>
<td>7374</td>
</tr>
<tr>
<td>T9</td>
<td>Backward</td>
<td>Standing on the platform</td>
<td>109.9</td>
<td>Bike helmet</td>
<td>436</td>
</tr>
<tr>
<td>T10</td>
<td>Backward</td>
<td>Standing on the platform</td>
<td>111.4</td>
<td>—</td>
<td>3595</td>
</tr>
<tr>
<td>T11</td>
<td>Backward</td>
<td>Upright</td>
<td>90.0</td>
<td>—</td>
<td>3989</td>
</tr>
</tbody>
</table>

*The angle of the trunk was estimated by the picture.

4) The HIC was used for an evaluation of the damage.

2.2 Analysis of the image

The images were acquired every experimental condition. Using the motion analysis software DIPP-Motion PRO (product made in Ditect Co., Ltd.), coordinate of each physical part was calculated. And then resultant acceleration of each physical part was calculated.

2.3 Evaluation of the data

![Figure 1. Classification of the fall by MDS](image)

Figure 1 shows the classification result of the falling type, it was based on metric multidimensional scaling through use of dynamic time warping distance. Because 6 falling types (T1, T2, T5, T6, T8, and T30) were classified in the same group, they did the manner of the statistically same falling. It was suggested that the neck color was impracticable to absorb the shock, and the safety of the safety hat was suspicious.

Because 3 falling types (T4, T15, and T16) were classified in the same group, they did the manner of the statistically same falling. The experimental condition of T4 was a falling from the floor. T15 and T16 were a falling from the platform. The HIC in T4 was higher than T15. In T4 and T15, the experimental condition about protective equipment was same, although the falling start height in T4 was lower than T15. It was supposed that this contradiction was because the indissociable factor in analysis got mixed. For example, the interval that some body part came in contact with the floor might have slightly differed.

T3 and T7 was classified alone each. It was unclear that the HIC was thought to be due to the performance of the protective equipment. Alternatively those might have been attributed to the falling type.

References


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