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Development of indoor seismic damage simulator for evaluation of human injury

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Abstract. Many people suffered severe injuries from crashing into furniture or falling when attempting to evacuate during a large historical earthquake. To assess human injuries during an earthquake, it is essential to estimate both the behavior of furniture and a human response to shaking. This study proposes a method for evaluating injury during an earthquake that considers the behavior of humans and furniture by constructing seismic response analysis models in a physical simulator. First, shaking table tests with human subjects were conducted to observe the behavior of a human during strong motions. Next, a human body model considering walking and falling was developed based on a cart-type double inverted pendulum with a feedback control system. To set appropriate feedback gains of the control system, the displacement and velocity of the head of the human body model were compared with those of the human subject in the shaking table test. Entering the strong motion recorded during the 1995 Hyogo-ken Nanbu earthquake into the human body model, the manner in which people behave and fall when they are walking during shaking was investigated. A static loading test of a bookshelf was conducted to measure the static and dynamic friction coefficients to construct a seismic response analysis model of the furniture. Finally, the human body and furniture models were incorporated into the physical simulator. The floor responses calculated by seismic response analysis of an RC super high-rise building were input to the simulator to evaluate the risk of human injury in the building. The degree of injury was quantitatively evaluated using head injury criterion.

Introduction

People are injured by colliding with furniture, being cut by broken glass, or falling while trying to evacuate during an earthquake. Therefore, to assess the human injury and develop mitigation measures, it is necessary to evaluate the behavior of both humans and furniture simultaneously.

Previous studies addressed indoor damage during an earthquake. Yoshizawa et al. [1] investigated indoor damage in earthquakes based on shaking table tests. Previous studies dealt with human behavior during earthquakes. Cimellaro [2] investigated the behavior of a human maintaining a posture during shaking. However, these studies were not aimed to propose a method for the evaluation of human injury by considering the human response to earthquakes.

To estimate the human response during an earthquake, a seismic response analysis model of the human body is required because it is impossible to conduct realistic experiments in which people fall or are injured during an earthquake. Previous studies developed seismic response analysis models for the human body. Yamamoto [3] and Yoneda et al. [4] proposed seismic response

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models for the human body. The model is a single-mass system, and it is impossible to consider stepping to maintain the posture.

Hida et al. [5] developed a seismic response analysis model of the human body based on a cart-type double inverted pendulum, which evaluates injury caused by collision with a rigid plane using the HIC score. In addition, Hida et al. [6] developed a human body model, considering falling. However, the behavior of furniture during an earthquake was not considered.

This study proposes a methodology for the evaluation of the human injury, considering both human response and behavior of furniture using a physical simulator. First, a seismic response analysis model of the human body considering walking and falling due to an earthquake was developed. Next, an indoor model, including a human body model and a seismic response analysis model of furniture, was built on the physical simulator. This approach can be used to evaluate the injury status of people evacuating during an earthquake.

Outline of Shake Table Test

Figure 1 illustrates the setup of the shaking table test. The size of the shaking table was 5 m × 5 m. The vibration of the shaking table was in two horizontal directions. To ensure the safety of the subject, a handrail consisting of steel pipes and safety nets was added to the shaking table. Safety mats were installed under the handrail. To reproduce the indoor condition, a blackout curtain was installed at the end of the shaking table in front of the subject. Six video cameras (1920 × 1080, 60 fps) were installed around the test area to capture the behavior of the subject.

Figure 2 shows a human subject (male, 24 years old, 169 cm, 57 kg). The subject was equipped with a helmet and protectors to ensure safety. To measure the head movement during shaking markers were attached to the head. The displacement waveforms of the marker attached to the helmet and shaking table were obtained using a 3D motion capture system. The subject was instructed to walk 3.5 m at a steady rhythm during excitation.

The shake table test was performed using recorded strong motions. The records were observed at the operation floor of a reactor building of a nuclear power plant during the Niigata-ken Chuetsu-oki earthquake in 2007 in Japan.

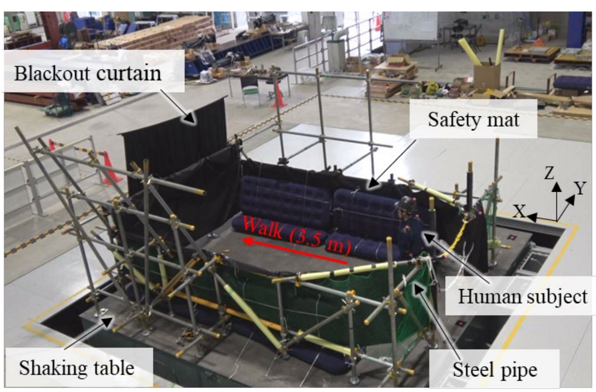

Figure 1 Bird eye view of Shaking Table Test

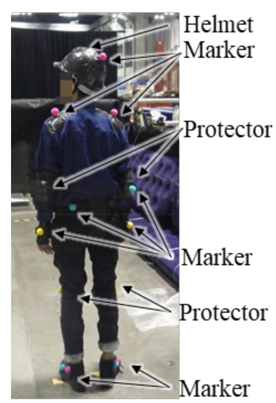

Figure 2 Human Subject

Seismic Response Analysis Model of Human Body

Figure 4 shows the nonlinear seismic response analysis model of the human body based on a cart-type double inverted pendulum with a feedback control system. The body was modeled using two pendulums. The upper pendulum corresponds to the upper body, whereas the lower pendulum corresponds to the lower body. The anteroposterior movement of the cart corresponds to the movement of the center of pressure due to foot stepping. The hip torque of a body can be considered the torque applied on a hinge between the upper and lower pendulums. The backbend of a body can be considered by a spring and damper attached between the lower and upper pendulum. The nonlinear equation of motion of the model is as follows [6]:

$$\begin{aligned} &d_1\{\ddot{\xi}(t)+\ddot{\xi}_0(t)\}+d_2\ddot{\theta}_1(t)\cos\theta_1(t)+d_3\ddot{\theta}_2(t)\cos\theta_2(t)+\mu_c\dot{\xi}(t) \\ &= d_2\{\dot{\theta}_1(t)\}^2\sin\theta_1(t)+d_3\{\dot{\theta}_2(t)\}^2\sin\theta_2(t)+f_c(t) \end{aligned} \tag{1}$$

$$\begin{aligned} &d_2\cos\theta_1(t)\{\ddot{\xi}(t)+\ddot{\xi}_0(t)\}+d_4\ddot{\theta}_1(t)+d_5\cos\{\theta_1(t)-\theta_2(t)\}\ddot{\theta}_2(t)-\tau_p(t)-\mu_p(t)\{\dot{\theta}_2(t)-\dot{\theta}_1(t)\} \\ &=d_7\sin\theta_1(t)-d_5\{\dot{\theta}_2(t)\}^2\sin\{\theta_1(t)-\theta_2(t)\}-\tau(t) \end{aligned} \tag{2}$$

$$\begin{aligned} &d_3\cos\theta_2(t)\{\ddot{\xi}(t)+\ddot{\xi}_0(t)\}+d_5\cos\{\theta_1(t)-\theta_2(t)\}\ddot{\theta}_1(\mathrm{t})+d_6\ddot{\theta}_2(t)+\tau_p(t)+\mu_p(t)\{\dot{\theta}_2(t)-\dot{\theta}_1(t)\} \\ &=d_8\sin\theta_2(t)+d_5\{\dot{\theta}_1(t)\}^2\sin\{\theta_1(t)-\theta_2(t)\}+\tau(t) \end{aligned} \tag{3}$$

where $\theta_1(t)$ and $\theta_2(t)$ are the angles with respect to the vertical line of the lower and upper pendulum at time t. $\xi(t)$ is the relative displacement between the cart and floor. $\xi_0(t)$ denotes the absolute displacement of the floor. $f_c(t)$ is the horizontal force applied to the cart. $\tau(t)$ denotes the torque applied to the hinge between the lower and upper pendulum. $\tau_p(t)$ is the torque of the spring used to confine the back bend. μ_c and μ_p are the viscosity coefficients of the cart and hinge attached between the lower and upper pendulums, respectively. Note that $d_1 \sim d_8$ and $\tau_p(t)$ in Equations (1)–(3) are expressed by the following equations [6]:

$$\begin{aligned} d_1 &= m_1+m_2+m_c & d_2 &= m_1 l_1 + m_2 l_2 \\ d_3 &= m_2 l_2 & d_4 &= J_1+m_1 l_2 + m_2 l_2 \\ d_5 &= m_2 l_2 L_1 & d_6 &= J_2+m_2 l_2^2 \\ d_7 &= (m_1 l_1+m_2 L_1)g & d_8 &= m_2 l_2 g \end{aligned} \tag{4}$$

$$\tau_p(t) = \begin{cases} 0 & (0 \le (\theta_2(t)-\theta_1(t)) \\ k_p\{\theta_2(t)-\theta_1(t)\} & (0 \ge (\theta_2(t)-\theta_1(t)) \end{cases} \tag{5}$$

where, m_1, m_2, and m_c are the masses of the lower pendulum, upper pendulum, and cart, respectively. l_1 and l_2 are the heights from the lower end to the center of mass of the lower and upper pendulums, respectively. L_1 and L_2 are the total lengths of the lower and upper pendulums, respectively. J_1 and J_2 are the rotational inertia of the lower and upper pendulums, respectively. $k_p(t)$ is the stiffness of the attached spring between the lower and upper pendulum.

The seismic response analysis model of a human body attempts to maintain its standing posture using a feedback control system. Feedback control is relevant to postural control in humans.

The block diagram of the model is shown in Figure 5.

$\mathbf{x}(t)$ is the state vector and $\mathbf{r}$(t) is the reference vector. These vectors are expressed by the following equations:

$$\mathbf{x}(t)=\{\xi(t)\ \ \theta_1(t)\ \ \theta_2(t)\ \ \dot{\xi}(t)\ \ \dot{\theta}_1(t)\ \ \dot{\theta}_2(t)\}^{\mathrm{T}}, \quad \mathbf{r}(t)=\{\xi_{\mathbf{r}}(t)\ 0\ \ 0\ \ 0\ \ 0\ \ 0\}^{\mathrm{T}} \tag{1}$$

where $\xi_{\mathbf{r}}(t)$ is the time-varying reference of the relative displacement between the cart and floor, and the human body model can be considered walking by changing that with time.

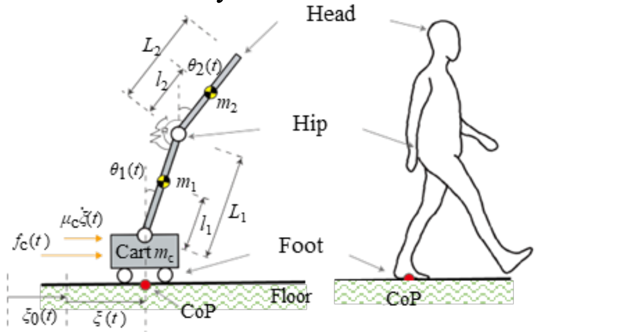

Figure 4 Seismic Analysis Model of Human Body

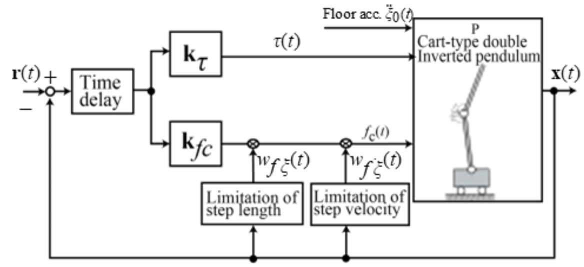

Figure 5 Block Diagram of Sesmic Analysis Model of Human Body

When a human is disturbed and tries to stabilize its standing posture, there is a time delay in generating the control force due to the time lag caused by neurotransmission, information processing in the brain, and force generation in the nerve-muscle-skeletal system. In this study, the time delay is considered the dead time (L) in the feedback system, and the difference between the state vector $\mathbf{x}(t)$ and reference vector $\mathbf{r}(t)$ is delayed for a specified time before input to the controller. The control torque $\tau(t)$ applied to the hip and the control force $f_c(t)$ applied to the cart are expressed by the following equations:

$$\tau(t) = \mathbf{k}_\tau\, e(t - L), \qquad f_c(t) = w_{f\xi}(t) w_{f\dot{\xi}}(t)\, \mathbf{k}_{fc}\, e(t - L) \tag{2}$$

where $e(t - L)$ is the difference between the state vector $\mathbf{x}(t)$ and the reference vector $\mathbf{r}(t)$, considering the dead time. $w_{f\xi}(t)$ and $w_{f\dot{\xi}}(t)$ are the coefficients that consider the falling of a human, as described later. $\mathbf{k}_\tau(t)$ and $\mathbf{k}_{f_c}(t)$ are the feedback gains, expressed by the following equations:

$$\mathbf{k}_\tau = \{k_{\tau\xi}\ \ k_{\tau\theta_1}\ \ k_{\tau\theta_2}\ \ k_{\tau\dot{\xi}}\ \ k_{\tau\dot{\theta}_1}\ \ k_{\tau\dot{\theta}_2}\}, \quad \mathbf{k}_{fc} = \{k_{f\xi}\ \ k_{f\theta_1}\ \ k_{f\theta_2}\ \ k_{f\dot{\xi}}\ \ k_{f\dot{\theta}_1}\ \ k_{f\dot{\theta}_2}\} \tag{3}$$

where $k_{\tau\xi}$, $k_{\tau\theta_1}$, $k_{\tau\theta_2}$, $k_{\tau\dot{\xi}}$, $k_{\tau\dot{\theta}_1}$ and $k_{\tau\dot{\theta}_2}$ are the feedback gains of τ, multiplied by the difference between the state vector $\mathbf{x}(t)$ and the reference vector $\mathbf{r}(t)$. State variables are the relative displacement between the cart and floor, angles of the lower and upper pendulum, relative velocity between the cart and floor, and angular velocity of the lower and upper pendulum. Similarly, $k_{f\xi}$, $k_{f\theta_1}$, $k_{f\theta_2}$, $k_{f\dot{\xi}}$, $k_{f\dot{\theta}_1}$ and $k_{f\dot{\theta}_2}$ are the feedback gains of f_c multiplied by the difference between the state vector $\mathbf{x}(t)$ and the reference vector $\mathbf{r}(t)$. In this study, MATLAB and Simulink [7] were used to perform the analysis.

To consider the fall of a person, the threshold for the relative displacement and velocity between the cart and the floor was set in the body model. It was based on the threshold for balance recovery in humans. Table 2 shows the thresholds of balance recovery in the forward and backward directions [8].

Table 2 Threshold of balance recovery of front-back direction [8]

Lean direction	Forward	Backward
Reaction Time (ms)	153±13	206±31
Step Time(ms)	238±7	193±28
Step Length(m)	1.032±0.082	0.724±0.047
Mean Step Velocity (m/s)	4.327±0.334	3.807±0.656

The threshold of the relative displacement between the cart and floor was 1 m forward and 0.7 m backward. The threshold of the relative velocity between the cart and floor was 4.3 m/s forward and 3.8 m/s backward. The control force applied to the cart becomes zero when the displacement or velocity of the cart exceeds a threshold. The limit coefficient of the control force applied to the cart is expressed as follows:

$$w_{f\xi}(t) = \begin{cases} 0 & (\xi(t)\text{-}\xi(t\text{-}0.2) < \text{-}0.7) \\ 1 & (\text{-}0.7 \le \xi(t)\text{-}\xi(t\text{-}0.2) \le 1) \\ 0 & (\xi(t)\text{-}\xi(t\text{-}0.2) > 1) \end{cases}, \quad w_{f\dot{\xi}}(t) = \begin{cases} 0 & (\dot{\xi}(t) \le \text{-}3.8) \\ 1 & (\text{-}3.8 \le \dot{\xi}(t) \le 4.3) \\ 0 & (\dot{\xi}(t) \ge 4.3) \end{cases} \tag{4}$$

Analytical Result of Seismic Response Analysis Model of Human Body

Table 3 lists the parameters of the seismic analysis model for the human body. The length and mass of the pendulum were set based on the height and weight of the subject in the shaking table test. ξ_{limit}, ξ^{+}_{limit}, $\dot{\xi}^{-}_{\text{limit}}$ and $\dot{\xi}^{+}_{\text{limit}}$ are limitation values of the relative displacement and velocity between the cart and floor. The dead time, L was set as 0.1 seconds.

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Table 3 Parameter of Seismic Analysis Model of Human Body

m_1	m_2	m_c	L_1	L_2	l_1	l_2	J_1	J_2
16.7 kg	38.6 kg	1.68 kg	0.82 m	0.785 m	0.453 m	0.301 m	5.55 kgm^2	3.5 kgm^2
μ_c	μ_p	k_p	ξ^-_{limit}	ξ^+_{limit}	$\dot{\xi}^-_{limit}$	$\dot{\xi}^+_{limit}$	g	Time delay
10000 Ns/m	20 Ns/rad	200 N/rad	0.7 m	1 m	4.3 m/s	3.8 m/s	9.8 m/s^2	0.1 s

In this study, a seismic response analysis of behavior in the forward/backward direction of a human was performed. Table 4 presents the feedback gains of the feedback control system. The feedback gains were determined such that the displacement and velocity of the head of the human body model corresponded to those of the human subject in the shaking table test.

Table 4 Feedback Gain

$k_{f\xi}$	$k_{f\theta 1}$	$k_{f\theta 2}$	$k_{f\dot{\xi}}$	$k_{f\dot{\theta} 1}$	$k_{f\dot{\theta} 2}$
−1800 N/m	−42300 N/rad	−11900 N/rad	−17000 Ns/m	−17300 Ns/rad	−2270 Ns/rad
$k_{\tau\xi}$	$k_{\tau\theta 1}$	$k_{\tau\theta 2}$	$k_{\tau\dot{\xi}}$	$k_{\tau\dot{\theta} 1}$	$k_{\tau\dot{\theta} 2}$
−9.49 N	−96.6 Nm/rad	113 Nm/rad	−26.3 Ns	−13 Nms/rad	−13.2 Nms/rad

Figure 6 shows the time-history waveforms of the absolute acceleration of the shaking table, as well as the experimental and analytical results of the relative displacement and velocity of the head with respect to the shaking table. The reference for the relative displacement between the cart and floor was set using a ramp function with a slope of 1.1 m/s. The amplitude and phase of the waveforms analyzed by the human body model were consistent with the experimental results.

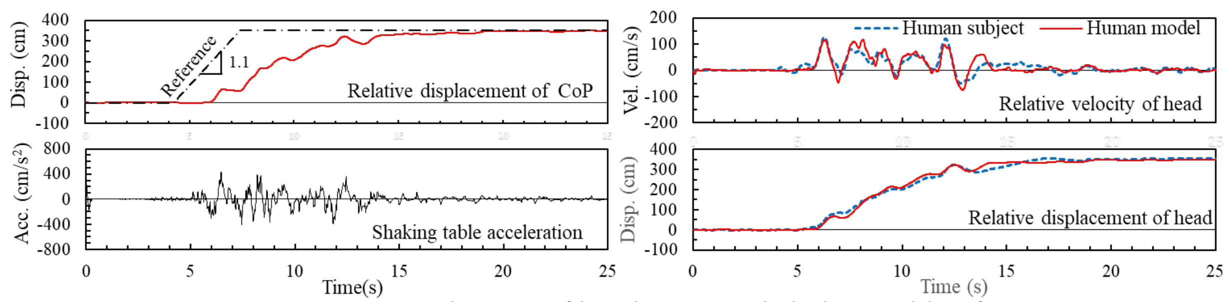

Figure 6 Time history of head, CoP and shaking table of Case3

Evaluation of Human Injury considering both Human and Furniture Behavior

In this section, a physical simulation is performed using Unity [9] to evaluate injury considering both human and furniture behavior. The human body and furniture models were incorporated into the physical simulator.

The furniture was modeled as a rigid body for the seismic response analysis. The static and dynamic friction coefficients of the furniture model were based on the results of the static loading test on a bookshelf. The static and dynamic friction coefficients were set as 0.171 and 0.120, respectively.

To generate the input motion, a seismic response analysis of an RC super high-rise building was performed. The analysis model used [10] was a 30-story multi-mass shear model.

The first natural period of the model was 1.8 s. The restoring force characteristics of the springs installed in each layer were a degrading trilinear model. The damping model was tangent stiffness-proportional damping, and the damping ratio was set to 0.03 for the first-order natural frequency. The strong motion record observed during the 1995 Hyogo-ken Nanbu earthquake was used as the input motion. Analysis was performed using SNAP Ver. 8 [11]. After the analysis of the building model, the acceleration waveforms of the 30th floor were input into the seismic response model of the human body and the physical simulator.

Figure 7 shows the situation of the room and the locations of the human model and furniture. This is a standard room for apartment buildings in Japan. The floor area is approximately 30 m^2. The distance from the window to the entrance was 6 m. The human body model was made to walk 6 m to simulate an evacuation.

Figure 8 shows the image sequence of the physical simulation before the human model falls. Figure 9 shows the image sequence of the human motion. The bookshelf collides with the model from one side at 9 s. The model collides head-on with the entrance door at 10.5 s. After 12 s, the human model falls backward, and the occiput collides with the floor. Injuries from collisions with furniture or doors occur before the model falls. These injuries cannot be evaluated when only human behavior was considered. Therefore, estimating the behavior of both furniture and humans simultaneously is essential for evaluating human injury during an earthquake.

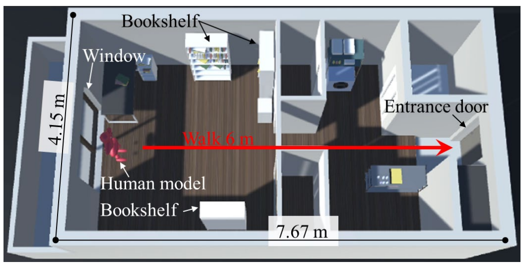

Figure 7 Situation of the room and relationship of location between human and furniture

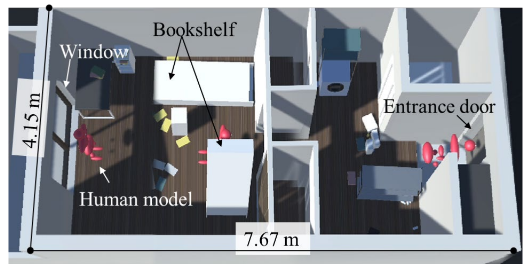

Figure 8 Image sequence of the physical simulation on 30th floor

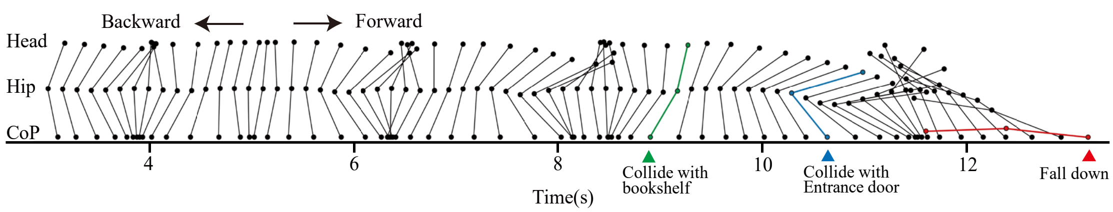

Figure 9 Image Sequence of Human Motion on the 30th floor

Figure 10 shows the relative velocity of the head with respect to the colliding object when the human body model collided with the furniture or door and fell. The HIC scores [12] corresponding to each injury were calculated based on head velocity as shown in the figure. The injuries are classified as minor when the head injury does not affect consciousness, moderate when the skull is fractured, critical when cerebral contusion occurs, and fatal when the person is dead.

The relative velocity of the head when the model collided with the entrance door exceeded the minor injury level and was larger than that when the model collided with the bookshelf. This suggests that the level of injury may be higher during frontal collisions than during side collisions.

The relative velocity of the head when the human body model fell exceeded the fatal injury level. These results suggest that falling backward is more dangerous than hitting an object on the head.

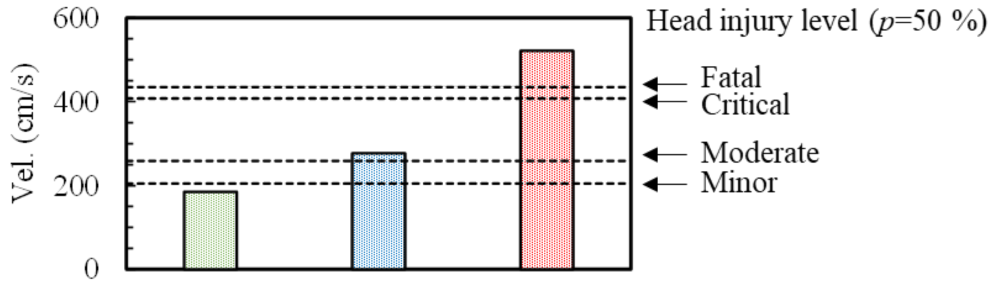

Figure 10 HIC and the relative velocity of head in each cause of injury

Using the human body and furniture models developed in this study, it is possible to quantitatively evaluate the possibility of injury during an earthquake. However, the seismic response model of the human body constructed in this study evaluated the behavior of only one subject in the shaking table test. Thus, the human body model could not evaluate the variation in behavior caused by individual differences. Furthermore, it is important to note that the HIC scores calculated in this study can lead to an overestimation of injury because the scores were evaluated under a assumptions that when the head collides with a rigid plane.

Conclusion

In this study, we developed a seismic response analysis model of the human body, considering walking and falling based on a shaking table test. To evaluate injury during an earthquake, considering the behavior of humans and furniture simultaneously, a seismic response analysis model of the human body and furniture was incorporated into a physical simulator. The probability of injury was evaluated using the HIC score. The findings are as follows:

1) The relative displacement and velocity between the human head and floor during walking can be evaluated accurately using the cart-type double inverted pendulum model.
2) The falling of a human can be simulated by setting a threshold for the relative displacement and velocity between the cart and the floor.
3) Using the seismic response analysis model of the human body and furniture developed in this study, it is possible to evaluate the possibility of injury during an earthquake.

Acknowledgments

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References

[1] Yoshizawa, M., Fukuyama, K., Inoue, T., Kaziwara, K., (2016): Study on Interior Damage of Office Building by Large-Scale Shaking Table Test, Journal of Structural and Construction Engineering (Transactions of AIJ), 81(730), 2013-2023. (in Japanese with English abstract). https://doi.org/10.3130/aijs.81.2013

[2] Cimellaro, G. P., Domaneschi, M., Boroschek, R., Cardoni, A., Kammouh, O., Galdo, D,Cares, D., Mahin, S., (2018): Monitoring Human Body Motions During Earthquakes, Eleventh U.S. National Conference on Earthquake Engineering

[3] Yamamoto, M. (2011): Human Body Dynamic under Horizontal Ground Motion Shaking-Table Test and Simplified Modeling under Standing Conditions, Journal of Structural and Construction Engineering (Transactions of AIJ), 76(667), 1631-1637. (in Japanese with English abstract). https://doi.org/10.3130/aijs.76.1631

[4] Yoneda, H., Yoshizawa, M., Suzuki, R., Yamamoto, M. (2022): Subject Experiments About Shaking Response of Human Body using Earthquake experience vehicle, the 17th World Conference on Earthquake Engineering (Transactions of 17WCEE)

[5] Hida, T., Karatsu H, Nagano, M., Itoi, T., Takada, T. (2022): Evaluation of Injury in Super High-Rise Building during Earthquake based on Nonlinear Seismic Response Analysis Model of Human Body, Journal of Structural and Construction Engineering (Transactions of AIJ), 85(776), 1263-1273. (in Japanese with English abstract). https://doi.org/10.3130/aijs.85.1263

[6] Hida, T., Muraji, T., Matsumoto, Y., Itoi, T., Takada, T. (2022): Falling Evaluation of Human During Earthquake Based on Seismic Response Analysis Model of Human Body Considering Longitudinal Asymmetry, Journal of JAEE, Proceeding of the 15th Annual of Japan Association for Earthquake Engineering C-1-4 (in Japanese)

[7] MATLAB - MathWorks - MATLAB & Simulink (accessed 2022. 7.26)

[8] Telonio, A., Cyr, M. A., Moglo, K. E., Smeesters, C. (2005): EFFCT OF PERTUBATION DIRECTION ON THRESHOLD OF BALANCE RECOVERY PRELIMINARY RESULTS, 29th Annual Meeting of American Society of Biomechanics, July 31-August 5, Cleveland Ohio

[9] Unity, https://unity.com/ （accessed 2022. 7. 26）

[10] Hinoura, Y., Nagano, M., Suzuki, K., Hida, T., Kitahori, T., Tanuma, T., Oda, S. (2018): Construction of Nonlinear Multi-Degree-of-Freedom System Models for Super High-Rise Residential Buildings and Estimation of Seismic Response during The 2016 Kumamoto Earthquake, Journal of Structural and Construction Engineering (Transactions of AIJ), 83(749), 963-973. (in Japanese with English abstract). https://doi.org/10.3130/aijs.83.963

[11] SNAP Ver.8, https://www.kozo.co.jp/index.php (accessed 2022. 8. 2)

[12] National Highway Traffic Safety Administration: Development of improved injury criteria for the assessment of advanced restraint systems-II, 1999.