Asia-Pacific Conference on Fracture and Strength 2024

E151P Performance evaluation of pedestrian helmets by multibody dynamics analysis
-Influence of walking posture and collision behavior on head injury risk-

UNIVERSITY OF YAMANASHI

ISSEI WATANABE*, YASUMI ITO*, RYUICHI YAMADA*, TETSUYA NEMOTO*
YOSHIYUKI KAGIYAMA*, TAKASHI NONAKA*, MASAYOSHI TSUCHIYA*
FUGO NISHIMURA*, MITSUHIRO SUGITA** and YUZURU TASHIRO***
* University of Yamanashi ** OGK KABUTO Co., Ltd *** Shizuoka Children's Hospital
E-mail : uy.issei.watanabe@gmail.com, yasumii@yamanashi.ac.jp

Introduction

- In Japan, we have many traffic accidents involving children on the school-commuting roads[1].
- Some local governments require the students to wear helmets designed for bicycle rider[2] due to no standard product of helmets for pedestrians.
- The effectiveness of wearing such helmets is not proven.
- It is necessary to develop a safety standard for pedestrian helmets.

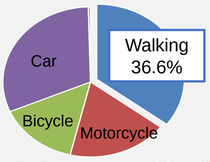

Fig. 1 Percentage of fatalities in traffic accidents by condition[1]

Fig. 2 Children wearing helmets to school[2]

1) Institute for Traffic Accident Research and Deta Analysis, Traffic Statistics 2022 Edition, (2024), pp.85-92
2) Ushiku City, Ibaraki Prefecture, Free distribution and use of helmets for elementary school students, (2022)

Aim of this study

Analyze the following two issues and propose safety standards based on them.

- Issue 1 -

The correlation between pedestrians' walking posture and head injuries

In pedestrian-vehicle collisions, it is necessary to consider the whole body behavior of pedestrians and secondary collisions. However, it is currently unclear how pedestrian posture influences the occurrence of head injury.

- Issue 2 -

The correlation between protective effect of helmet and injuries without skull fractures

The protective effect of helmets has been evaluated by HIC, which has been correlated with skull fractures. The correlation between the protective effect of helmets and head injuries without skull fractures such as subdural hematoma has not been resolved.

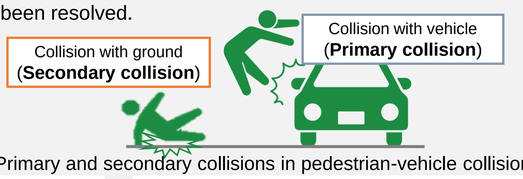

Fig. 3 Primary and secondary collisions in pedestrian-vehicle collisions

Method

We conduct parameter studies of multiple walking postures and with/without helmets by Pedestrian-vehicle collision simulations to estimate the effect of each parameter on the external force to the pedestrian's head.

【Analysis Method】

Multi-body dynamics analysis Software「MADYMO」

【Features of Multi-body dynamics analysis and MADYMO】

- Analysis time is shorter than FEM.→ Suitable for parameter studies.
- In addition to values, we can obtain video data as analysis results.

→ Evaluation based on the whole-body behavior is possible.

- MADYMO is used for human body damage evaluation in a wide range of fields such as automobile crashworthiness evaluation, etc.

【Analysis parameter 】

Table 1 Analysis parameters for MADYMO

Parameter	Number	Detail
1. Walking posture	6	Pos. 1~Pos. 6 shown in Fig. 4
2. Vehicle velocity[km/h]	5	10, 15, 20 25, 30
3. Helmet	2	with or without
Total	60 (=6×5×2)	

1. We varied the walking posture at the time of collision with the vehicle. Six walking postures were set up (Fig. 4).
2. We varied the Vehicle velocity from 10 km/h to 30 km/h in 5 km/h increments.
3. We compare the results of analyses in models with and without helmets (Fig. 5).

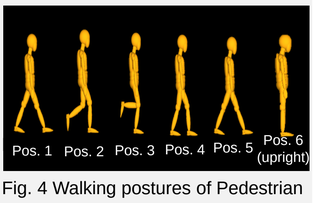

Fig. 4 Walking postures of Pedestrian

- Deceleration: 0.7G (brake)
- Vehicle : Only sedan type common in Japan

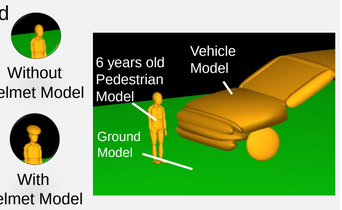

Fig. 5 Overview of collision simulation

Results & Discussion

The correlation between pedestrians' walking posture and head injuries

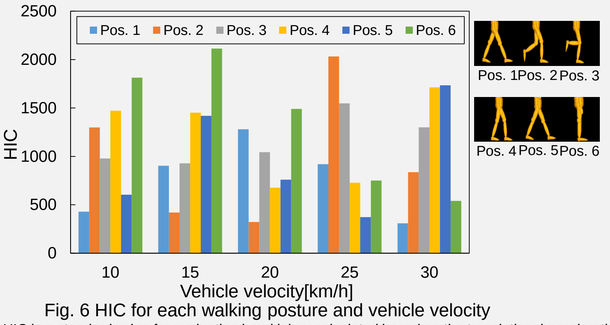

Fig. 6 HIC for each walking posture and vehicle velocity

HIC is a standard value for evaluating head injury calculated based on the translational acceleration of the head. When HIC values exceed 700, skull fractures occur at a high rate[3].

- The risk of injury suffered from traffic accidents depends on not only the speed of the vehicle but also the walking posture.
- After a vehicle speed of 25 km/h or higher, the collision behavior changes (Fig. 7) and the number of impacted areas increases before the secondary collision.
- For vehicle speeds below 30 km/h, the translational acceleration applied during the secondary collision was higher than that during the primary collision.

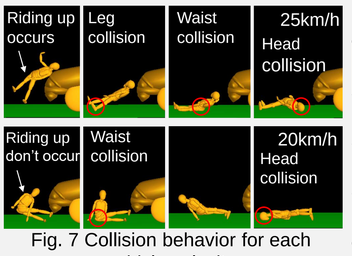

Fig. 7 Collision behavior for each vehicle velocity

Table 2 Maximum acceleration applied to the head in Pos.6

Velocity [km/h]	Primary [m/s²]	Secondary [m/s²]
10	414	2003
20	716	2212
30	788	1406

3) Eppinger, R., Sun, E., Bandak, F., Haffner, M., Khaewpong, N., Maltese, Matt., Kuppa, S., Nguyen, T., Takhounts, E., Tannous, R., Zhang, A. and Saul R., Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems-II, (1999), pp.ES-1-4

The correlation between protective effect of helmet and injuries without skull fractures

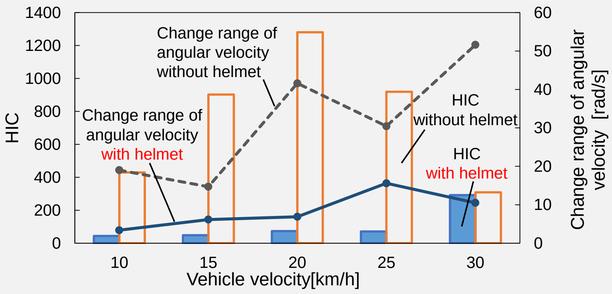

Fig. 8 HIC and change range of angular velocity with and without helmet in Pos.1

Change range of angular velocity is an indicator of the width of the change in direction that occurs at the moment of head impact, and is calculated as the difference between the maximum and minimum values of the angular velocity of the head. When the value of change range of angular velocity is 40 rad/s or more, a subdural hematoma is considered to be caused[4].

- The results of this study indicate that pedestrians wearing helmets during vehicle collisions reduce not only the HIC but also the change range of angular velocity.
- The helmet suppresses the head bounce after the secondary collision.

➢ We have concluded that the suppression of bounce may be one of the reasons why the change range of angular velocity was smaller than without the helmet.

4) Aiba, K., Omiya, M., Iteya, M., Kamiya, T. and Tomatsu, T., Comparison of evaluation indices for the occurrence of acute subdural hematoma during occipital impact in judo and the effect of head protection devices, Transactions of the JSME, Vol. 78, No. 796 (2012)

Conclusion

1. The risk of head injury to pedestrians is influenced by the walking posture of the pedestrian, but the situation at the time of the secondary collision has a greater effect. Depending on the secondary collision, the pedestrian's head seems to be seriously injured even at low vehicle velocity.
2. At a vehicle velocity of 30 km/h or less, the translational acceleration of the head is higher in a secondary collision than in a primary collision. Therefore, we have concluded that it is necessary to develop safety standards for pedestrian helmets based on the assumption of accidents at vehicle velocity of 30 km/h or less and head injuries due to secondary collision.
3. Pedestrians wearing helmets during vehicle collisions reduce not only the HIC but also the change range of angular velocity. Therefore, pedestrians wearing helmets can reduce the risk of head injury without skull fracture.

This study was funded by OGK Co., Ltd and OGK KABUTO Co., Ltd.