

Identification of influential factors for seatbelt kinematics in a collision and analysis of their influence degree to the kinematics

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Abstract To study the effect of lap seatbelt engagement relative to the pelvis in a collision due to the orientation of the pelvis, we researched the individual differences of potential contributing factors, including human skeletal alignment, pelvic angle and pelvic shape. Additionally, we created human body models which represent those individual differences by modifying THUMS ver.4 and analysed seatbelt and occupant kinematics in a collision. The aims of this study are to research the individual differences of other potential factors, such as pelvic size and flesh thickness, and to analyse the effects on the lap belt kinematics. In particular, it is assumed that flesh thickness is associated with the position of the lap belt. Therefore, the initial position of belt was also measured and the correlation between body shape and lap belt position was analysed. THUMS was modified to the models which represent individual differences of above two factors: pelvic size and flesh thickness. The seatbelt kinematics on the ilium were studied by using these models, and the results indicated that both factors affect the belt sliding up over the ilium. Eventually, pelvic angle was found to have the greatest influence among the four factors: (a) pelvic angle, (b) pelvic shape, (c) pelvic size, (d) flesh thickness. It is therefore essential to control pelvic angle.

Keywords Abdominal injury, Individual difference, Pelvic size, Flesh thickness, Lap seatbelt.

I. INTRODUCTION

Although abdominal injury occurs less frequently than head and thoracic injuries, once it occurs it is likely to lead to serious injuries due to the wounds sustained by the internal organs and inner membrane. As the lap seatbelt sliding off the ilium is presumed to be one of the injury causes, the initial orientation of the pelvis relative to the lap seatbelt is important. Because pelvic orientation is associated with skeletal alignment in seated posture, this orientation in the real world includes individual differences depending on age, gender and body size. So far many studies for the relationship between pelvic orientation and a seatbelt have been reported. For example, Reed et al. indicated BMI is the most important effect for the initial lap belt position [1]. Gepner et al. performed an evaluation on the predictive capabilities of the obese human body models (HBMs) via comparison of model simulations to post-mortem human subject (PMHS) tests. It was found that improved models of abdominal flesh and subcutaneous adipose tissue, might be required to obtain biofidelic seatbelt-abdomen interactions and to predict submarining behaviour in crash simulations [2]. Joodaki et al. reported that the higher extremity injuries observed in obese occupants result from the consequence of limited effectiveness of the lap belt due to initial pelvis to belt distance [3]. Recently, lots of studies regarding new challenges for occupant restraint by the potential for non-traditional seated postures, including various degrees of recline, have been also reported [4-7].

In our efforts to reduce fatalities or serious injuries, we have been conducting studies with a special emphasis on abdominal injuries. We selected the following as factors influencing on pelvic orientation: (a) pelvic angle (the angle between anterior-superior iliac spine (ASIS) and pubic symphysis); (b) pelvic shape (the angle of ASIS); (c) pelvic size (the distance between ASIS and pubic symphysis); and (d) initial relative position between ASIS and lap seatbelt depending on flesh thickness. To analyse the influence of above two factors: (a) and (b) on pelvic orientation in seated posture, we collected X-ray images of asymptomatic subjects. These studies have been reported at previous IRCOBI conferences [8-10]. As a result, it was found that the greater the BMI, the more pelvic angle tilts forward. Additionally, our analyses revealed that both males and females have individual differences

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in pelvic shape, though this factor show less correlation with age, height and BMI. To evaluate the influence of individual differences in (a) and (b) on the seatbelt and occupant kinematics in a collision, the pelvis of THUMS ver.4 AM50 was modified as representative values of (a) and (b). By comparing the kinematics of those HBMs, our studies indicated that the more the pelvis tilted rearward or the flatter the shape of ASIS was, the larger the amount of lap belt sliding up over the ilium was. The outline of these studies is shown in Fig.1. The goal of this study is to investigate an influence of (c) and (d) on the phenomenon of lap belt sliding up and identify the most crucial factor from (a) to (d) for the control of pelvic orientation.

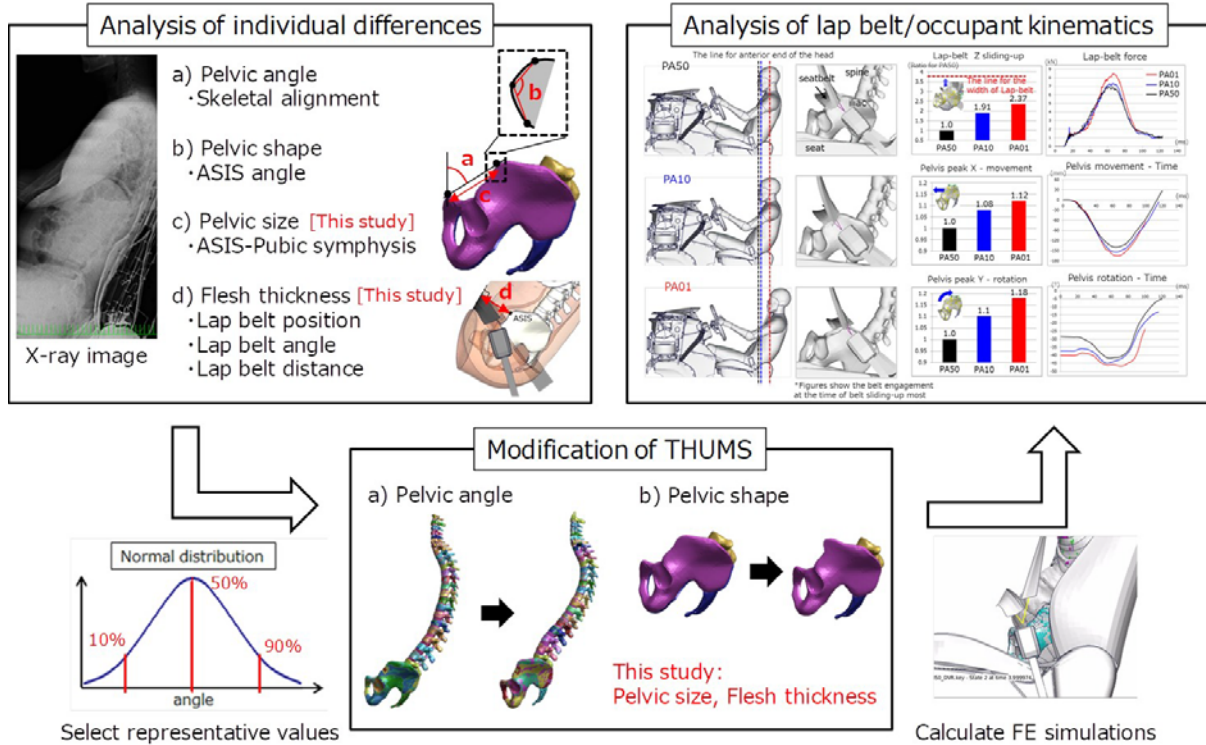


Fig. 1. The research outline of pelvic orientation. The study was conducted in the following order: (i) Analysis of individual differences in a) to d), (ii) Modification of THUMS ver.4 AM50, (iii) Analysis of lap belt and occupant kinematics using HBMs modified.

II. METHODS

Fabrication of an X-ray Facility and Posture Definition

The data of pelvic size from 111 subjects was obtained in the study last year [10]. In order to measure the initial position of lap seatbelt with an occupant in an automobile seat, the seatbelt system was added to the X-ray facility used for the analysis of human skeletal alignment [8-9]. To keep the normal posture seated in an automotive driver seat, the seat was set with its seatback inclined 24 degrees and seat pan inclined 21.5 degrees. Moreover, while being X-rayed the subjects were asked to sit back, with their foot on the pedal and footrest, both arms on the armrest, and the usual driving posture (Fig. 2). The role of an armrest was to prevent bones of upper extremities from overlapping with a vertebra and the pelvis at the time of an X-ray. In order to measure the position of lap belt, the belt buckle and lap anchor points were laid out as they are in Mazda 3 (MY2013-2016). With the seatbelt fastened, lead tape was put at the middle line of lap belt corresponding to subject's sagittal plane (middle position) and at the belt section directly in front of the ASIS (ASIS position) so that the location of lap belt could be visualised in the X-ray image. The lap belt buckle anchorage location for seatbelt fit condition was free at the range from 45 degrees to 75 degrees for horizontal. Subject orientation was adjusted with respect to the X-ray table to achieve a pure lateral view.



Fig. 2. The X-ray facility and situations of X-raying, a. the facility with an automotive driver seat, b. seated posture with the seatbelt.

Subjects

Asymptomatic subjects without any medical history in the vertebral body or pelvis, who gave informed consent after explanation of the overview of the study, were subjected to X-ray photography. They were divided into two groups: The first group (111 volunteers) was used for the measurement of pelvic angle, pelvic shape and pelvic size, i.e. pelvis measurement group. The second group (20 volunteers) was used for the measurement of flesh thickness and lap belt position among the standard ($25 \text{ kg/m}^2 > \text{BMI}$), overweight ($30 \text{ kg/m}^2 > \text{BMI} \geq 25 \text{ kg/m}^2$) and obese ($\text{BMI} \geq 30 \text{ kg/m}^2$) occupants, i.e. flesh measurement group. The pelvis measurement group consists of 56 males and 55 females, all aged over 20. The relationships between stature and age, or BMI and age were plotted (Fig. 3). The average values of age, stature and BMI for male were 43 YO, 1713 mm and 25 kg/m^2 . On the other hand, that for female were 47 YO, 1548 mm and 22 kg/m^2 . The flesh measurement group consists of 20 males, all aged over 20. In Fig. 4, the relationships between stature and age, or BMI and age of 20 subjects are plotted. Subjects were all aged 25–60 years, evenly distributed. Many of them were 1600 mm to 1750 mm tall. Obese subjects account for 30%.

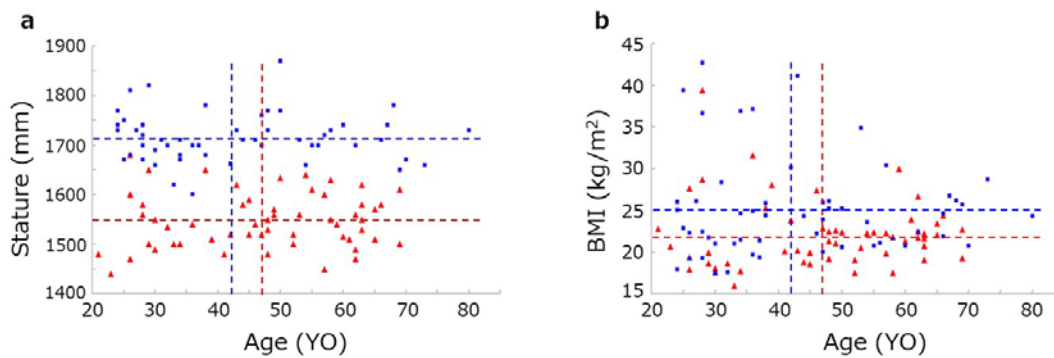


Fig. 3. The graphs of the correlation, a. stature vs. age, b. BMI vs. age. Blue squares mean males and red triangles are females. Dashed lines show the mean values.

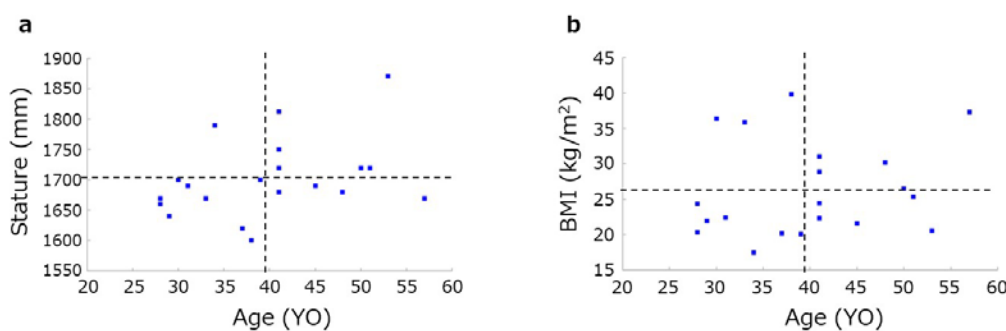


Fig. 4. The correlation between two factors, a. stature vs. age, b. BMI vs. age. Dashed lines show the mean values, a. 39.75 years old and 1702.6 mm, b. 39.75 years old and 26.35 kg/m^2 .

X-raying and Procedures in this study

X-ray images were taken using the SONIALVISION Safire17 SHIMADZU, a multifunctional universal R/F system at the Department of Radiological Technology, Yamaguchi University Hospital. For the measurement of initial position of lap seatbelt, subjects were X-rayed over a range from pelvis to lumbar spine in the anterior-posterior direction. All procedures in this study were determined by Yamaguchi University and Mazda Motor Corporation and received prior approval from the ethical committees of both Yamaguchi University Graduate of Medicine and Mazda Motor Corporation.

Image Acquisition and Data Analysis

In previous studies, the pelvic angle and the ASIS shape were measured (Fig. 5a, b) [9, 10]. The identification of the location of ASIS was performed by an orthopedic surgeon belonging to Yamaguchi university hospital. In this study, data were analysed as follows: for pelvic size, the distance between ASIS and pubic symphysis [11] was measured (Fig. 5c). The whole geometry of the pelvis could not be identified with the incomplete images of seated posture, therefore the standing X-ray images were used for this measurement alternatively. For the flesh thickness, a vertical line was drawn from ASIS to the middle position of lap belt and the distance of a vertical line was measured (Fig. 5d). For the initial position of lap belt, X and Z components of distance between ASIS and the upper/rearward edge of the middle or ASIS position of lap belt were measured (Fig. 5e) [12]. The middle and ASIS position of individual subjects were plotted in a coordinate system so that the belt path can be predicted based on the relative position between them. The lap belt angle relative to the horizontal plane, and distance between the middle and ASIS position were also measured (Fig. 5f). Samples of X-ray images was shown in Fig.6.

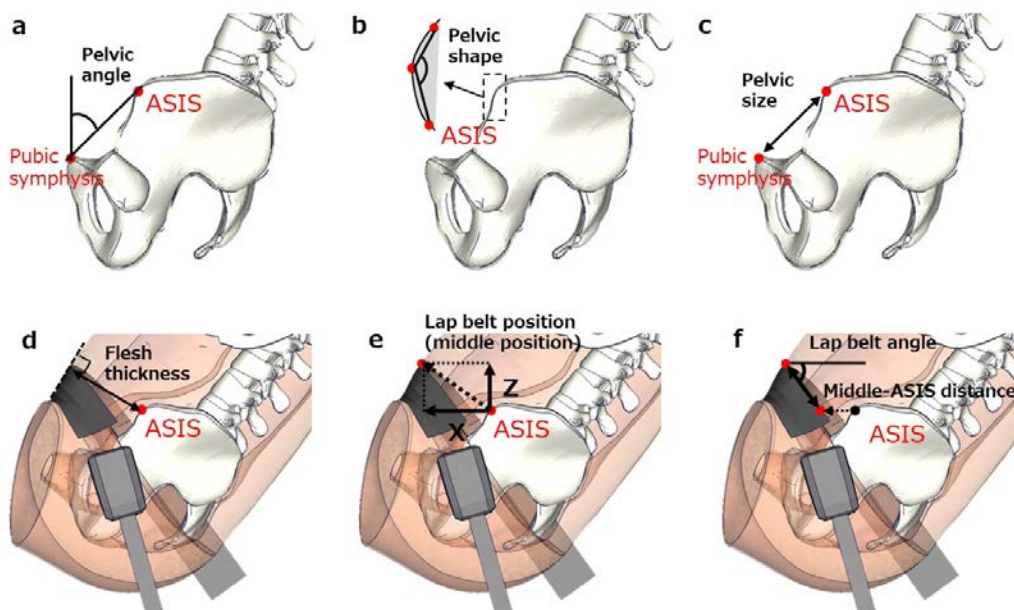


Fig. 5. Measurement of the pelvis and initial lap belt position. a. pelvic angle, b. pelvic shape, c. pelvic size, d. flesh thickness, e. middle position of lap belt.

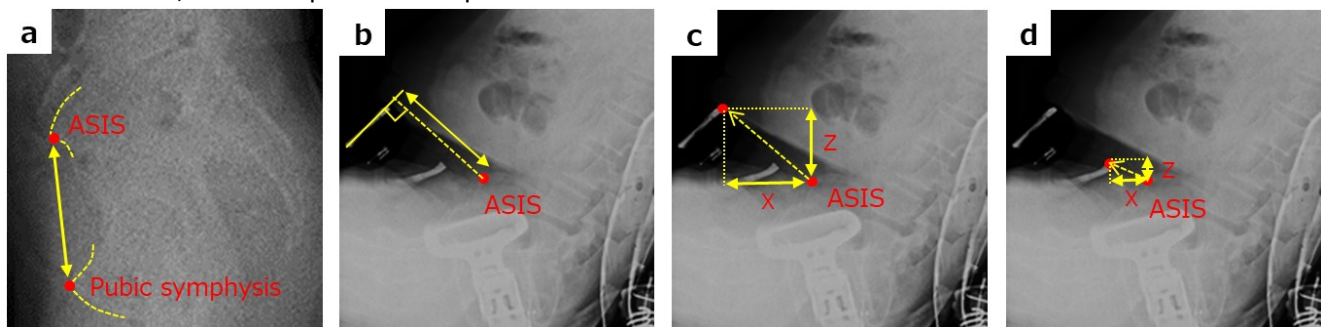


Fig. 6. X-ray images with each factor relative to the pelvis in this study, a. pelvic size (standing posture), b. flesh thickness, c. middle position of lap belt, d. ASIS position of lap belt.

Creation of FE-HBMs

The pelvic size and flesh thickness were the focus of this study to create different types of HBM that could be used to analyse the seatbelt kinematics. The measurement data of 90th percentile, 50th percentile and 10th percentile from each distribution were selected as representative values, and those data were reproduced in the models. In the creation of HBMs, subject’s data including both males and females were used in order to consider the influence of different pelvic size regardless of gender on the seatbelt and occupant kinematics in a collision. To modify the pelvis geometry of THUMS ver.4 AM50, the ORIENT functions in pre-processing software Oasys PRIMER™ (ARUP, UK) were used. The pelvis was scaled using the implemented interpolate method so as to keep the mesh quality. The surrounding tissues nearby the pelvic bone were also morphed as well while the outer surface of skin was maintained as default. Additionally, it is assumed that the other dimension except the distance between ASIS and pubic symphysis (e.g. the upper or back surface of the ilium) have a very small effect on the lap belt sliding up over the ilium. Therefore, the pelvis was scaled uniformly in this study. In the modification of flesh thickness, the pelvis geometry was maintained as that of the the default THUMS AM50, and only flesh thickness of abdomen was modified using the ORIENT functions in Oasys PRIMER™.

Condition of FE Simulation

In this study, simulations were conducted with the same condition of JNCAP 56 kph full frontal crash (Fig. 7a). Car models included in simulation were based on Mazda’s typical specification. The 6 DOF accelerations were applied to the car body about its CG in order to simulate the vehicle kinematics. The validation results of simulation model with the Hybrid III AM50 dummy were shown in Fig. 7b. The similar dummy kinematics and seatbelt forces in CAE simulation were confirmed by comparison to that in sled test. Besides, the validation of THUMS ver.4 were already confirmed [9]. Using HBMs with modified pelvic size or flesh thickness, their kinematics in frontal crashes was investigated. Those models were placed in the driver seat and constrained by a seatbelt with pre-tensioner and load-limiting retractor and without a dynamic locking tongue. Additionally, the occupant was constrained by a knee airbag deployed from the instrumental panel. HBMs were positioned with hands on the wheel and feet on the accelerator pedal and footrest. Positions and angles of pelvis, spine and head depend on the corresponding alignment. The seatbelt was fitted on the chest and pelvis, respectively. Seat cushion was squashed in order to consider the initial compression by the gravity. The simplified seating method implemented in Oasys PRIMER™ was used. However, the initial stress-strain distribution was not considered in this study.

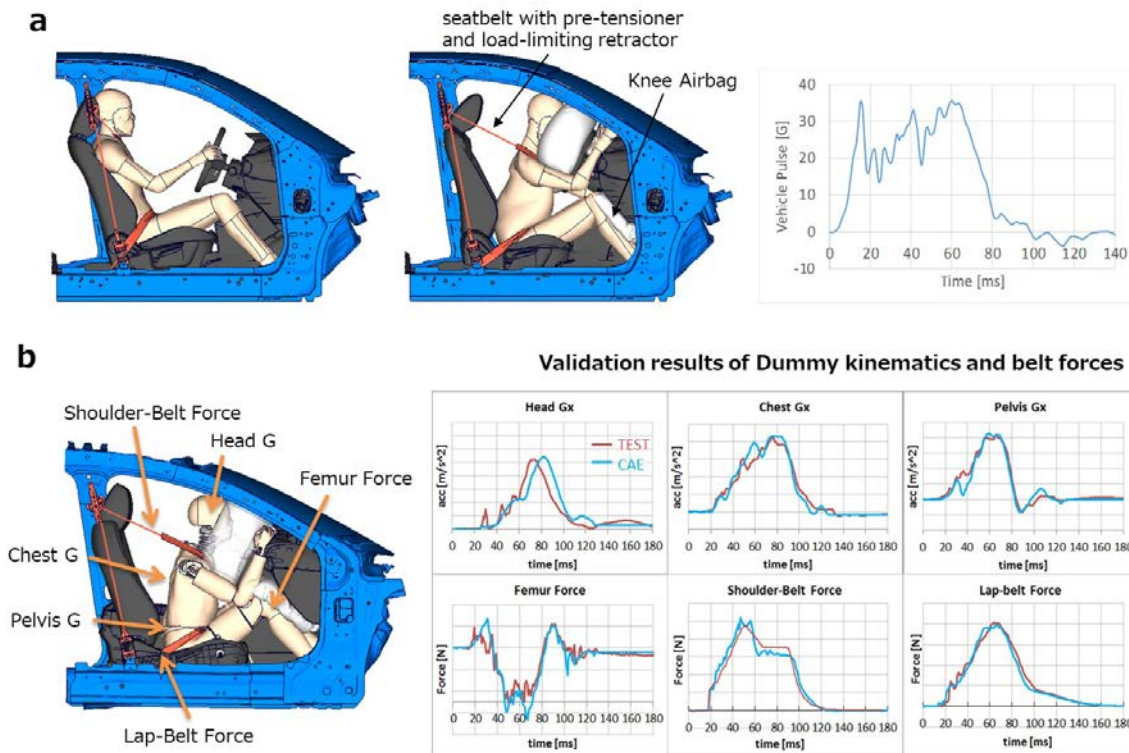


Fig. 7. a. The FE simulation model and vehicle pulse, b. the kinematics validation results of vehicle model.

Analysis of Seatbelt and Occupant Kinematics

Using the results of FE simulations, the seatbelt and occupant kinematics in full frontal crash were analysed. For the seatbelt, the amount of lap belt movement between the initial position relative to the ASIS and the position of sliding up over the ilium was calculated. For the pelvis, the maximum forward displacement of H-point on the x-axis and the peak forward rotation around the y-axis were measured. For the femur, the axial force on the middle of the femur shaft was calculated.

III. RESULTS

Pelvic Size

The data obtained from the pelvis measurement group indicated that the pelvic size has no correlation with age, stature, or BMI for each gender. (Fig. 8).

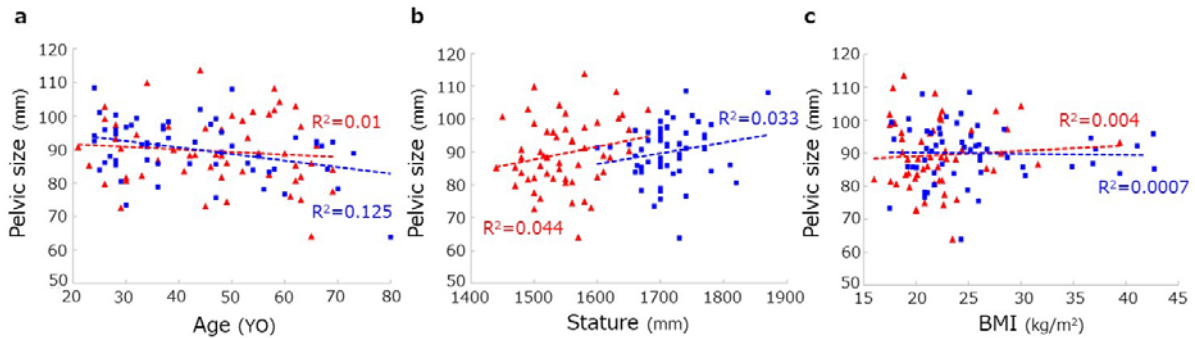


Fig. 8. The graphs of the correlation, a. pelvic size vs. age, b. pelvic size vs. stature, c. pelvic size vs. BMI.

Based on the analysis of the pelvic measurement group, the cumulative distribution was drawn (Fig. 9). To compare the influence of pelvic size on lap belt sliding up, 90th percentile, 50th percentile and 10th percentile were selected as representative values and the pelvis geometry of THUMS ver.4 AM50 was scaled to those values, respectively.

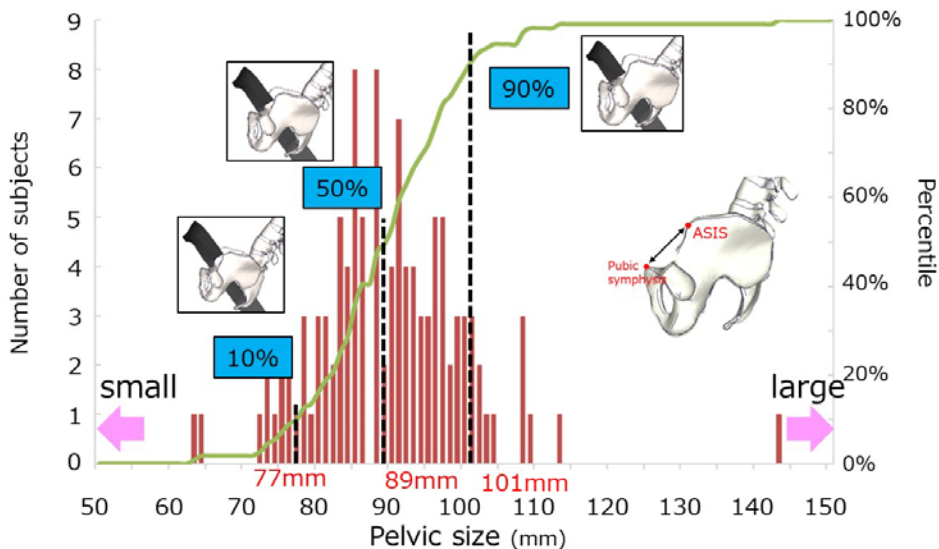


Fig. 9. Cumulative distribution of pelvic size and human models equivalent to each percentile selected.

From the simulation results of the three HBMs in a FE vehicle environment, it was found that the smaller the pelvic size was, the more the peak amount of lap belt sliding up increased (Fig. 10). Currently, the belt trajectory of 90th percentile relative to the ASIS was lower than that of 10th percentile. On the other hand, when the seatbelt engaged with the ilium, then the larger the pelvic size, the more the forward rotation of pelvis around the y-axis increased. The maximum forward displacement of H-point on the x-axis was almost the same. The peak femur loads of 10th percentile were the highest among three models.

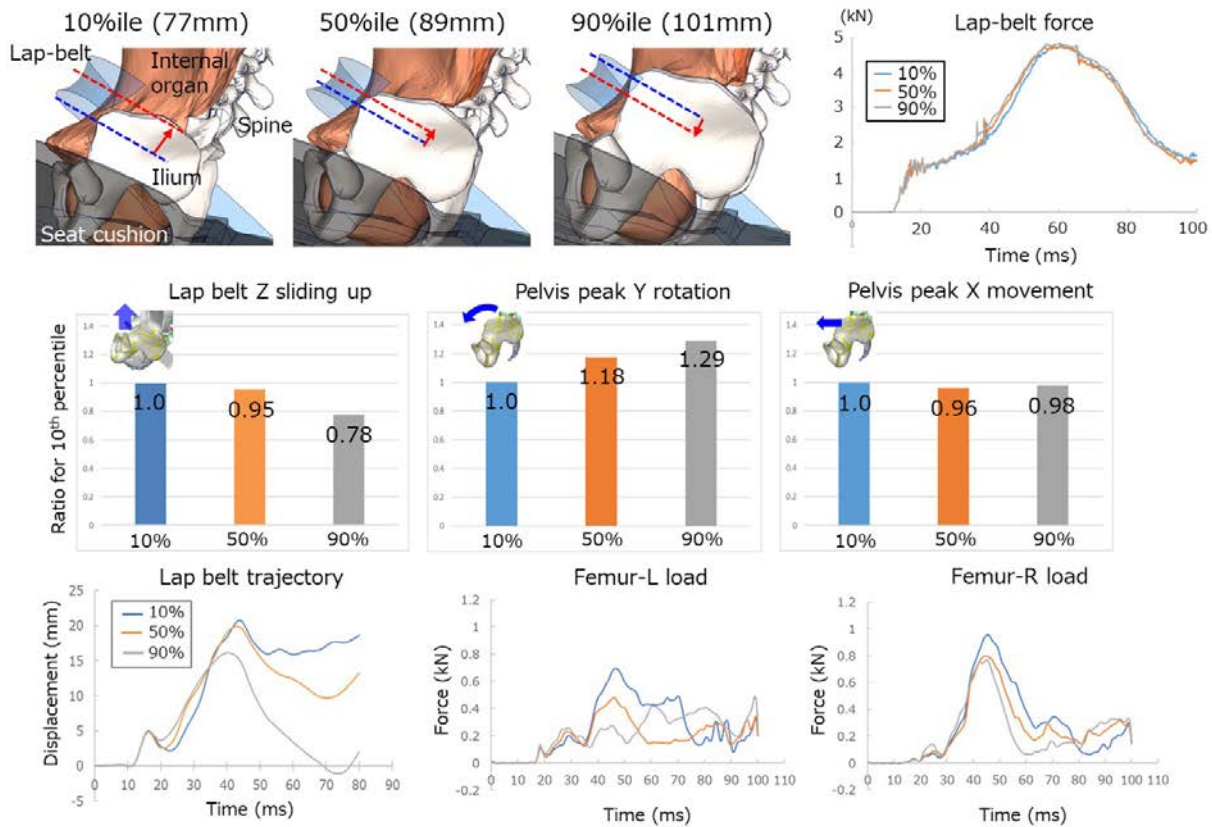


Fig. 10. The results of lap belt and pelvis kinematics using three models for pelvic size. The upper left figures of three models represent the maximum lap belt sliding up relative to the ASIS.

Initial position and angle of lap belt, distance between middle and ASIS position

For the flesh measurement group, each middle and ASIS position of lap belt was measured. The results were plotted in Fig. 11. Green squares are slender or standard subjects ($25 \text{ kg/m}^2 > \text{BMI}$), blue triangles are overweight subjects ($30 \text{ kg/m}^2 > \text{BMI} \geq 25 \text{ kg/m}^2$) and red circles are obese subjects ($\text{BMI} \geq 30 \text{ kg/m}^2$). Dotted lines show mean values. As for the middle position, the average of X component was -78.5 mm and that of Z component was 74.0 mm. The higher the BMI, the more the position moved away from the ASIS. However, the positions of overweight subjects were rarely different from those of standard. As for the ASIS position, the average of X component was -29.5 mm and that of Z component was 34.9 mm. There was no correlation between the ASIS position and BMI. The average predicted belt path of non-obese and obese type were provided in Fig. 12. The belt path of obese type was lower-angled and longer than that of non-obese. On the other hand, the belt was engaged above the ASIS in some cases regardless of the body size.

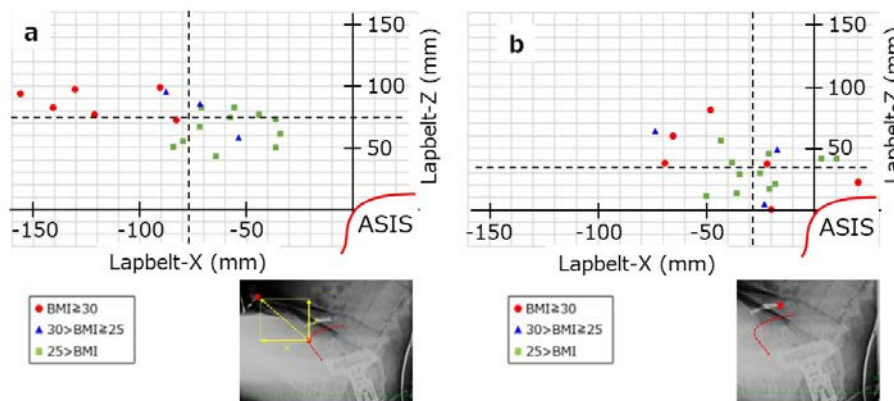


Fig. 11. The positions of lap belt for all subjects, a. middle position, b. ASIS position. Dashed lines are the mean values.

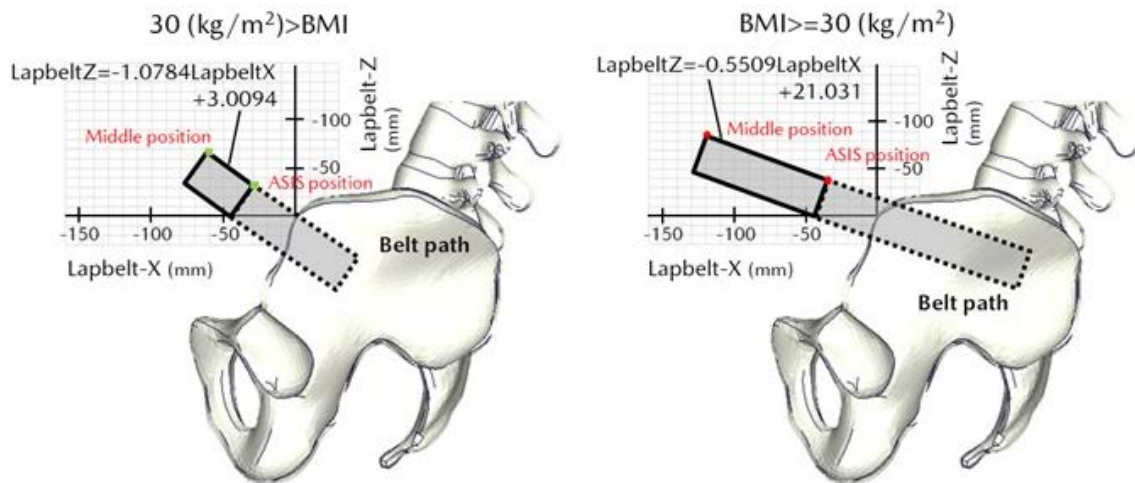


Fig. 12. The average predicted belt path of non-obese and obese subjects. The gray area surrounded by solid lines indicates a real average belt path and the area surrounded by dashed lines is a predicted path.

The regression analysis on the correlation between the seatbelt position and BMI was performed. The results indicated that

- 1) The flesh thickness was correlated with BMI (Fig. 13a).
- 2) The correlation between BMI or flesh thickness and X component of the middle position of lap belt was higher than that with Z component (Fig. 13b).
- 3) The middle-ASIS distance was correlated with BMI and flesh thickness (Fig. 13c). Although the R^2 values between the lap belt angle and these two factors (i.e. BMI and flesh thickness) were low, trends were seen in that the belt angle was small at the region of high BMI and thick flesh.
- 4) The middle-ASIS distance was correlated with both X component of the middle position and lap belt angle (Fig. 13d). On the other hand, trends were seen in that the belt angle was small in volunteers whose X component of the middle position was away from the ASIS, in other words obese subjects though the R^2 values between the lap belt angle and the middle position were low.

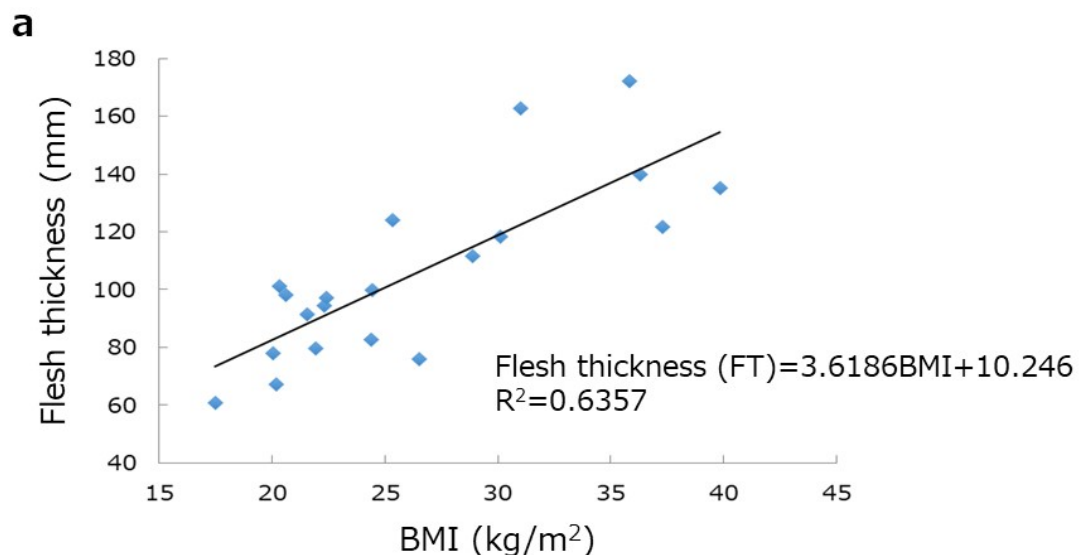


Fig. 13a. Correlation between BMI and flesh thickness.

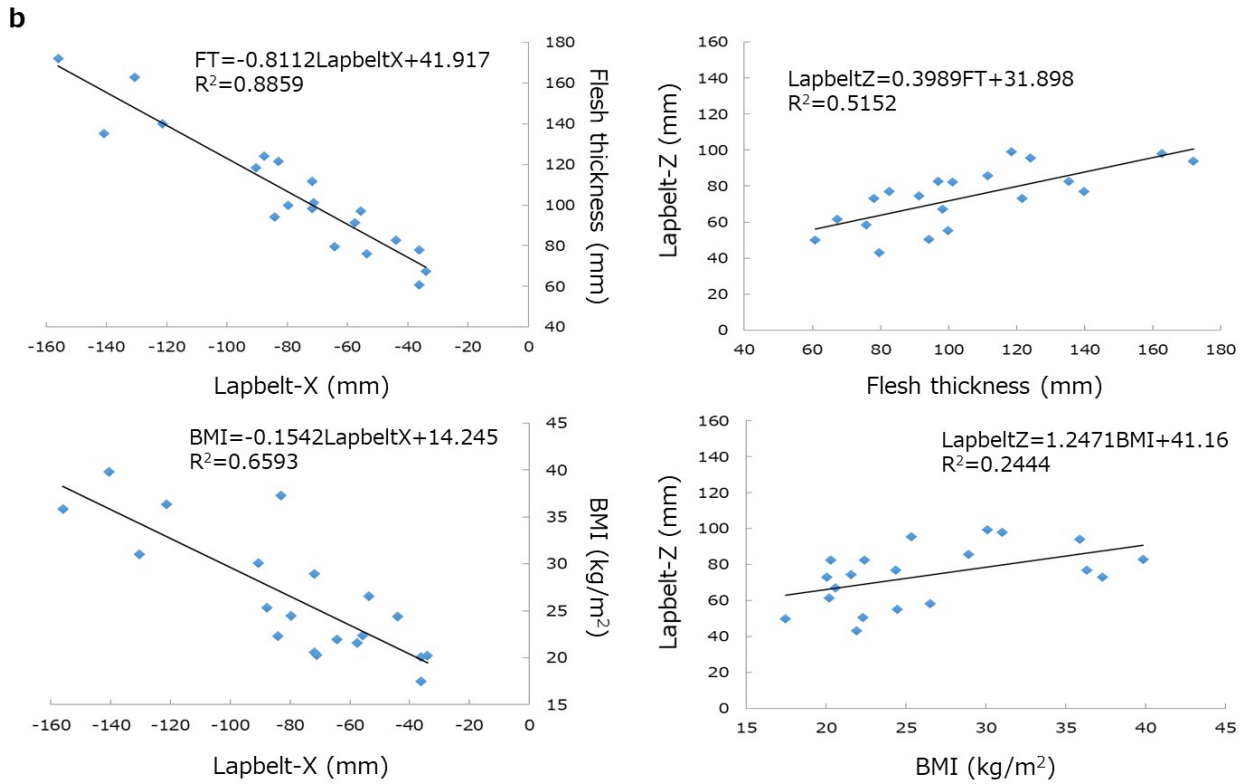


Fig. 13b. Correlation between the X component of middle position of lap belt and flesh thickness or BMI (Left), Z component of the middle position of lap belt and flesh thickness or BMI (Right).

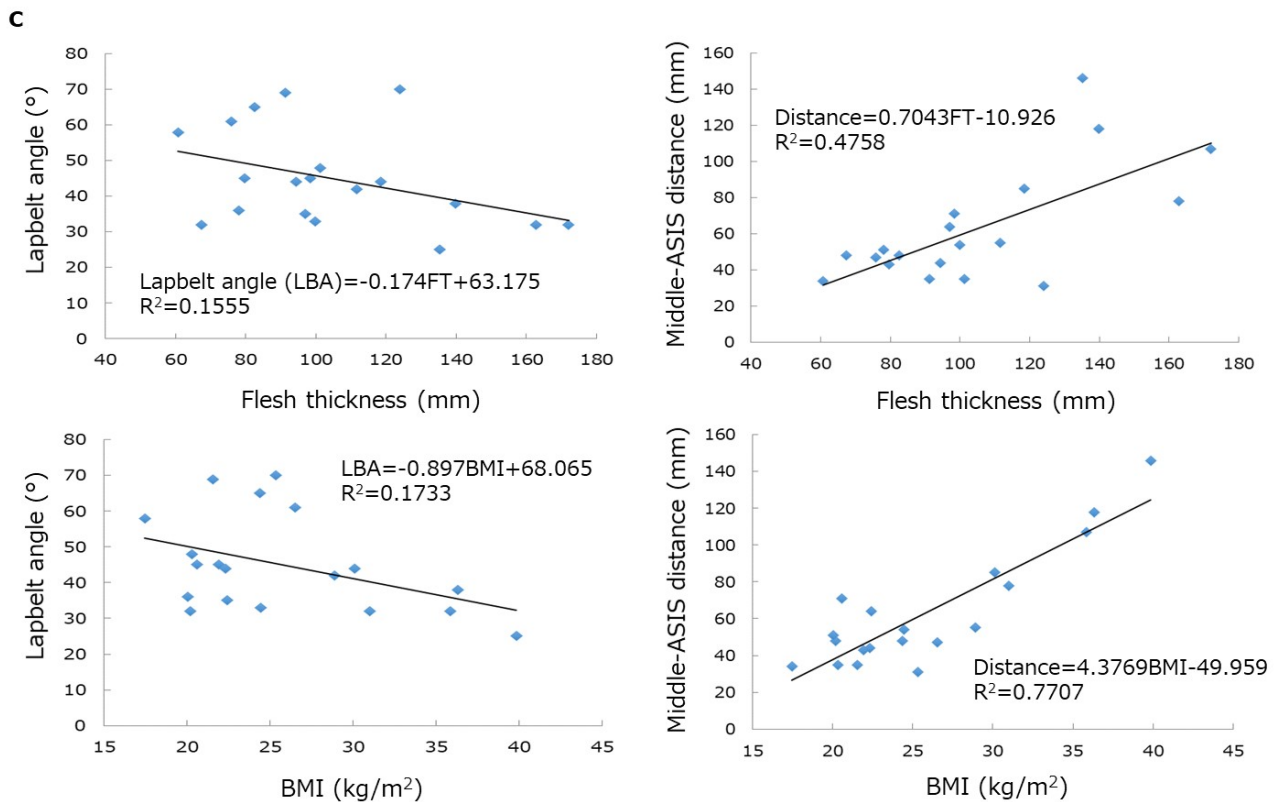


Fig. 13c. Correlation between the lap belt angle and flesh thickness or BMI (Left), the middle-ASIS distance and flesh thickness or BMI (Right).

d

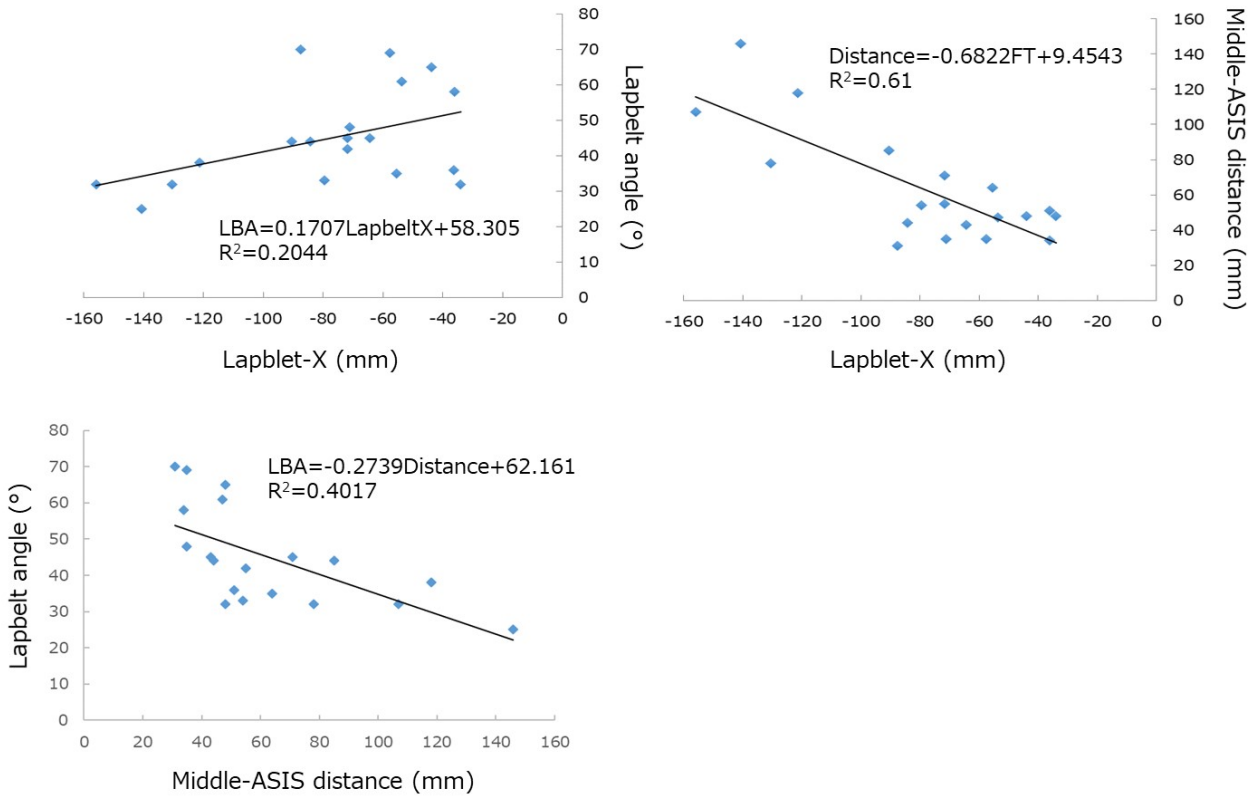


Fig. 13d. Fig. 13. Correlation between X component of the middle position of lap belt and belt angle (Up Left), X component of the middle position and middle-ASIS distance (Up Right), the middle-ASIS distance and belt angle (Low).

Flesh thickness

Based on the analysis of the flesh measurement group, the cumulative distribution was drawn (Fig. 14). To compare the influence of flesh thickness on lap belt sliding up, 90th percentile, 50th percentile and 10th percentile were selected as representative values and the abdominal flesh of THUMS ver.4 AM50 was modified to coincide with those shapes.

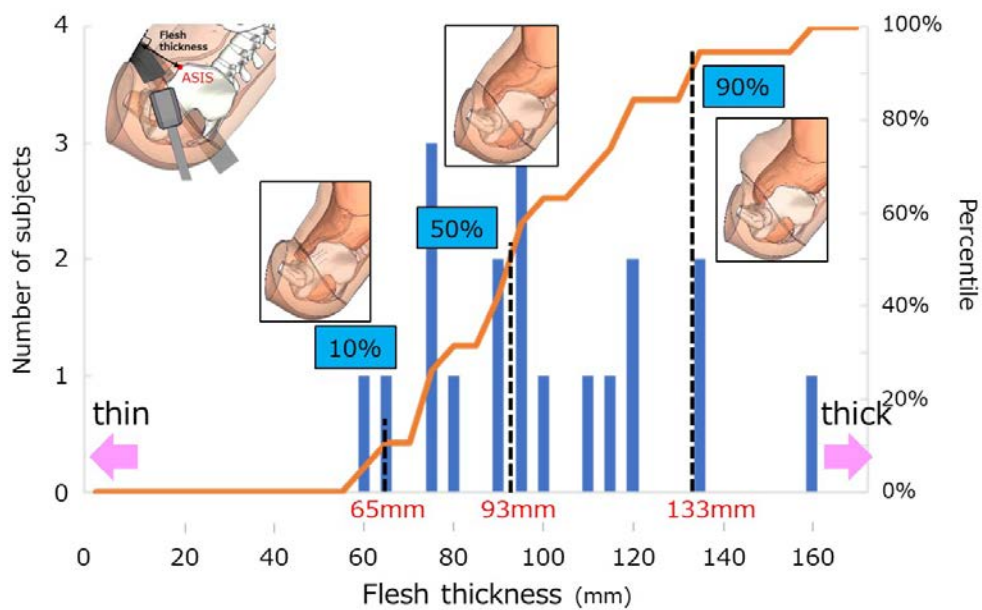


Fig. 14. Cumulative distribution of flesh thickness and human models equivalent to each percentile selected.

From the simulation results of the three HBMs in a FE vehicle environment, it was found that the maximum amount of lap belt sliding up in an obese model was greatly decreased (Fig. 15). Currently, the belt trajectory of 90th percentile was lowest among three models. In addition, the thicker the flesh of abdomen, the more the forward rotation of pelvis around the y-axis increased. The maximum forward displacement of H-point on the x-axis was almost the same. The difference in peak femur loads was less.

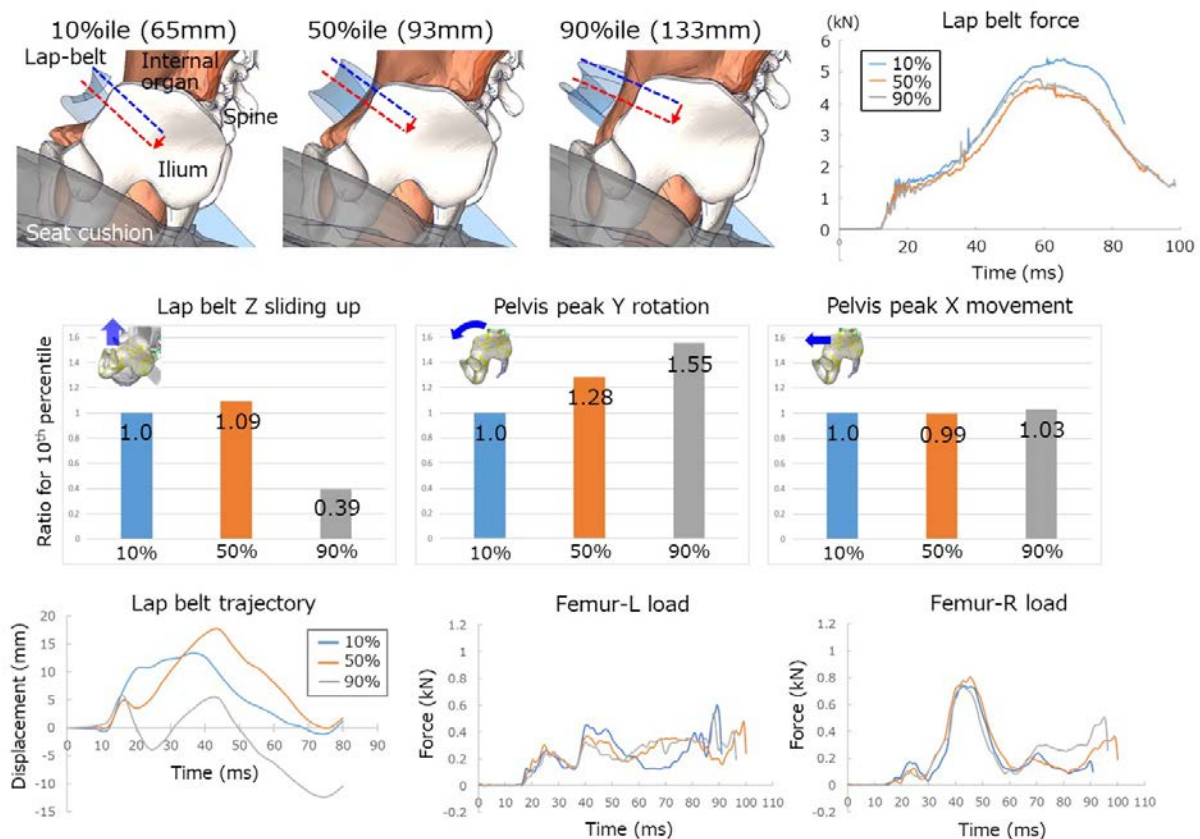


Fig. 15. The results of lap belt and pelvis kinematics using three models for flesh thickness. The upper left figures of three models represent the maximum amount of lap belt sliding up relative to the ASIS.

IV. DISCUSSION

The average lap seatbelt paths of obese group (BMI>=30) and non-obese group (BMI<30) from 20 subjects were analysed as shown in Fig. 12. In the obese group, the buckle was relatively located posteriorly and inferiorly against the pelvic bone. This difference is because that pelvis in the obese group is forced forward and upward by the flesh of buttocks and adipose tissue in the back, respectively. Furthermore, the length of seatbelt path was more and correspondingly the lap belt angle to the horizontal plane was less in the obese group. The reason of this difference can be summarized as following:

- A) As the abdominal flesh thickness increased, distance between the middle position of belt and ASIS position increased, especially in the x-axis (Fig. 14b).
- B) As the middle position of lap belt moving forward, the lap belt angle to the horizontal plane decreased. A large variation of the lap belt angle was found in case of the lap belt close to the ASIS (Fig. 14d).
- C) Generally, as the BMI increased, the lap belt angle decreases. There was a large variation of angle in non-obese group (Fig. 14c).

The large variation in the non-obese group is due to the individual difference of spine alignment and pelvic angle. Two types of alignment, S-shaped lumbar spine with forward tilted pelvis and lumbar kyphosis with backward tilted pelvis, could be found in non-obese group according to the previous research [9].

Four influential factors were assumed and three different HBMs representing 90th percentile, 50th percentile and 10th percentile of each factor were created referring to the sampling distribution obtained from x-ray images. Simulation results including the previous studies can be summarized as following:

- a) Large backward tilt of pelvis may lead to more the lap belt sliding up [9].
- b) Flat shape of pelvis may lead to more lap belt sliding up [9].

c) Small size of pelvis, i.e. short distance between ASIS and Pubic may lead to more lap belt sliding up (Current study).

d) More abdominal flesh thickness may mitigate the lap belt sliding up (Current study).

With regard to c), similar lap belt force in Fig.10 indicated that the seatbelt was not sliding off completely from the ilium in all three cases. However, in case of the small size of pelvis, the lap belt could slide up close to the top of ilium, resulting in more force on the superior iliac bone and backward tilt of pelvis. Consequently, the lower extremities moved forward, causing more femur compressive force.

With regard to d), the simulation results showed less lap belt sliding up in obese occupant. In addition, no apparent difference could be observed in either pelvis displacement or femur force. It was presumed that the lap belt was sliding down below the abdomen after the pre-tensioner fired, and constrained from sliding up by the interaction with the flesh of abdomen. As a result, the lap belt was retained on the ilium throughout the crash. Obviously the results could be strongly dependent on the specification of the obese models. Previous studies also have indicated that the shear property of the abdominal flesh could significantly affect the interaction of seatbelt and pelvis [2, 4, 6]. Further study on flesh property and more detail data of obese geometry is required to make a precise conclusion.

Comparing the contribution level of each factor, we found out that the pelvic angle, except for flesh thickness have the greatest influence on the lap belt sliding up over the ilium (Fig. 16).

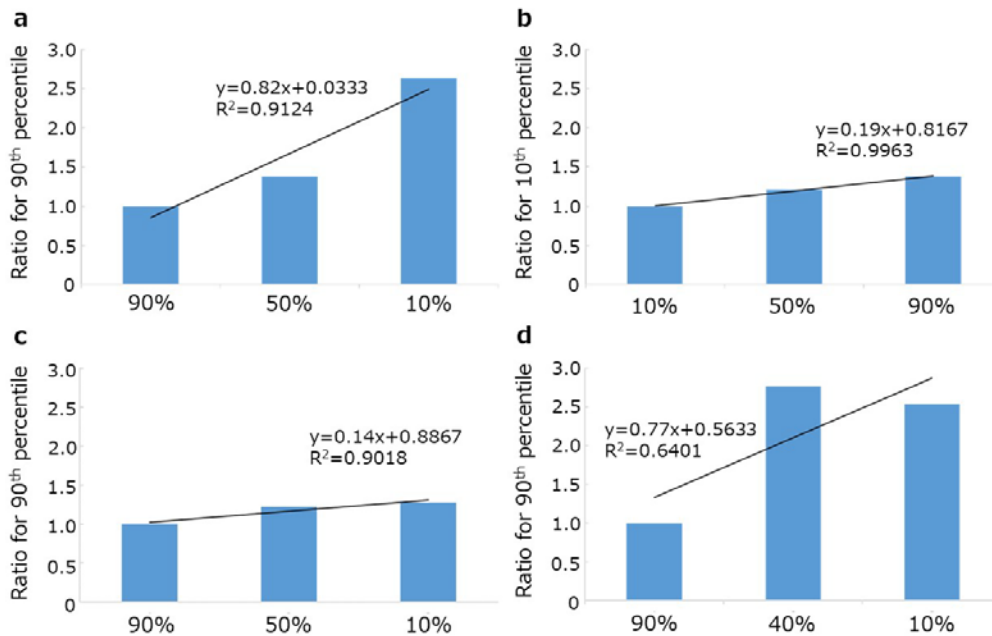


Fig. 16. The analysis of the contribution level for four influential factors, a. pelvic angle, b. pelvic shape, c. pelvic size, d. flesh thickness.

Limitations

Since this study deals only with Japanese occupants, the relevance of its findings to other ethnicities cannot be discussed. Furthermore, since X-ray photographs are taken with subjects seated in one type of automotive seat within a short time period, it is not known if the results are applicable to extended periods of driving. The automobile seat, including the belt buckle and lap anchor, was laid out in Mazda 3 (MY2013-2016). Also, the samplings for flesh thickness are not complete and further data analysis needs to be done. In addition, this study only focused on each factor, such as pelvic size or flesh thickness, separately. Therefore, the influence of each factor on the seatbelt and occupant kinematics in a collision was analysed, independently. In the future, analysis will need to be performed on the combination of four factors, i.e. pelvic angle, pelvic shape, pelvic size and flesh thickness. Finally, a study using the obese models with modified flesh properties will also be necessary.

V. CONCLUSIONS

In this study, the pelvic size of 111 volunteers was analysed via X-ray. HBMs representing three types of pelvic size – 90th percentile, 50th percentile and 10th percentile – were created by modifying THUMS ver.4 AM50. The calculation results indicated that the amount of lap seatbelt sliding up over the ilium might increase when the pelvic size was smaller. We also analysed the relationship between flesh thickness and related factors, i.e. the initial position of lap belt, belt angle and middle-ASIS distance of 20 subjects. The trends were seen in that these factors were correlated with BMI. The results indicated that the lap belt path of obese subjects was lower-angled and longer. On the other hand, the ASIS position of lap belt showed less correlation with BMI. HBMs representing three types of flesh thickness were created: 90th percentile (obese), 50th percentile (standard) and 10th percentile (slender). The simulation results indicated that the amount of lap belt sliding up in an obese model was the smallest amount among the three models. It is assumed that the obese occupants are more likely to have lower extremity injuries due to limited effectiveness of the lap belt and knee-knee bolster or instrumental panel interaction. However, these considerations could not be clarified in this study. In the future, the models with modified flesh properties also need to be studied because of a potential for a difference in seatbelt kinematics caused by the difference of flesh definition. The comparison of the influence on lap belt sliding up of three factors, excluding flesh thickness, suggested that it is important to control pelvic angle in order to mitigate the intrusion of lap belt into abdomen.

VI. ACKNOWLEDGEMENTS

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VIII. APPENDIX

TABLE A1
THE DATA OF PELVIC SIZE AND FLESH THICKNESS FOR ALL SUBJECTS

gender	height (cm)	BMI	age	ASIS-pubic (mm)
Female	144	20.7	23	85.3
Female	145	22.3	57	100.7
Female	147	19.4	26	79.8
Female	147	26.7	62	85.4
Female	148	19.2	48	88.3
Female	148	20.09	41	83.6
Female	148	22.8	21	90.8
Female	149	17.6	30	81.6
Female	149	22.5	62	103
Female	150	16.0	33	82.2
Female	150	17.5	52	98.7
Female	150	17.8	34	109.9
Female	150	20	29	72.7
Female	150	22.7	69	77.6
Female	151	22.1	65	85.9
Female	151	23.9	61	76
Female	151	28.1	39	90.05
Female	151.5	21.35	60	88.9
Female	152	18.6	45	96.3
Female	152	19.04	52	83.5
Female	152	22.9	47	88.5
Female	152	23.81	42	88.3
Female	153	21.3	48	96.1
Female	153	22.21	63	81.9
Female	153.5	18.67	32	94.5
Female	154	27.41	46	84.9
Female	154	30	59	104.3
Female	154	31.62	36	86.8
Female	155	17.5	58	101.8
Female	155	18.1	30	80.7
Female	155	21.64	63	97
Female	155	22.48	48	81.8
Female	156	20.5	53	93.6
Female	156	21.8	62	80.83
Female	156	22.6	49	74.5
Female	156	39.4	28	93.3
Female	157	21.1	49	86.1
Female	157	23.5	65	64.07
Female	158	18.83	44	113.7
Female	158	20.8	63	75
Female	158	24.4	66	91.2
Female	158	28.7	28	97.4
Female	159	20	45	73.1
Female	160	17.97	26	99.1
Female	160	19.9	57	82.5
Female	161	19.29	69	84
Female	161	22.4	55	89
Female	162	19.05	63	143.2
Female	162	20.2	43	88.4
Female	163	21.8	58	108.3
Female	163.4	22.4	50	100.2
Female	164	22.31	54	101.3
Female	165	18.7	29	90.4
Female	165	25.3	38	96.9
Female	168	27.64	26	102.9
Average	154.8	22	47	90
Standard deviation	5.458	4.063	13.69	12.417053

gender	height (cm)	BMI	age	ASIS-pubic (mm)
Male	160	37.11	36	91.3
Male	162	21	33	91.5
Male	165	25.7	69	92.2
Male	166	21.05	30	96.6
Male	166	23.59	54	83.9
Male	166	28.7	73	88.8
Male	166.3	30.2	42	85.8
Male	167	20.8	70	78.2
Male	167	21.51	34	90.7
Male	167	39.4	25	83.9
Male	167	42.7	28	85.3
Male	168	22.3	26	95.9
Male	168	24.4	38	93.4
Male	168	36.85	34	86.9
Male	169	17.51	30	73.4
Male	170	17.65	32	99.3
Male	170	19.37	37	97.1
Male	170	19.7	36	85.8
Male	170	20.07	47	85.6
Male	170	20.8	55	88
Male	170	21.11	56	78.1
Male	170	21.45	37	96.1
Male	170	22.49	62	93.5
Male	170	22.49	28	86.7
Male	170	24.9	36	78.8
Male	170	25.95	47	75.6
Male	170	36.68	28	94.6
Male	171	21.89	66	92.4
Male	171	22.23	46	97.6
Male	171	24.3	44	102
Male	171	24.62	34	91.9
Male	171	24.62	66	91.8
Male	171	28.4	31	97.3
Male	171	34.88	53	85.9
Male	172	19.3	28	100.4
Male	172	30.42	57	83.3
Male	173	21.7	58	84.1
Male	173	24.3	80	63.9
Male	173	26	24	92.5
Male	173	26.1	27	88
Male	173	26.1	48	89.2
Male	173	41.1	43	92.2
Male	174	20.81	60	76.6
Male	174	25.1	24	108.5
Male	174	26.75	67	91.1
Male	174	42.6	28	95.8
Male	175	22.9	25	101
Male	176	23.89	47	99.2
Male	177	17.9	24	94.2
Male	177	25.2	50	91
Male	177	25.22	48	95.2
Male	178	25.88	38	98.3
Male	178	26.2	68	84.15
Male	181	19.2	26	86
Male	182	21.74	29	80.5
Male	187	20.6	50	108
Average	171.3	25.45	43.07	89.983036
Standard deviation	4.67	6.287	15.15	8.3276823

gender	height (cm)	BMI	age	flesh thickness (mm)
Male	160	39.844	38	135.28
Male	162	20.195	37	67.33
Male	164	21.936	29	79.67
Male	166	20.322	28	101.2
Male	167	24.382	28	82.61
Male	167	35.856	33	172
Male	167	37.291	57	121.64
Male	168	24.447	41	99.9
Male	168	30.116	48	118.42
Male	169	21.568	45	91.3
Male	169	22.408	31	96.97
Male	170	20.069	39	78
Male	170	36.332	30	139.8
Male	172	22.309	41	94.28
Male	172	25.352	51	124.01
Male	172	26.535	50	75.89
Male	175	31.02	41	162.79
Male	179	17.478	34	60.79
Male	181.2	28.903	41	111.59
Male	187	20.59	53	98.3
Average	170.26	26.348	39.75	105.5885
Standard Deviation	6.2613	6.4908	8.5433	29.45909