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Original Article

Seatbelt paths of the pregnant women sitting in the rear seat of a motor vehicle

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ABSTRACT

Purpose: Seatbelt use during pregnancy is important to improve maternal and fetal survival after motor vehicle collisions. However, because the rear seatbelt of a motor vehicle tends to make contact with the neck, even if it is adequately used, some pregnant women sitting in the rear seat opt not to fasten the belt. The purpose of this study is to explore seatbelt–neck contact for pregnant women sitting in the rear seat of a motor vehicle.

Methods: We carried out an anthropometric study. Japanese women who were ≥30 weeks pregnant ($n = 12$) sat in the left side of the rear seat of a typical mid-size passenger sedan and fastened the seatbelt. Seating posture was investigated by measuring the coordinates of the anthropometric data points of the pregnant women (head, shoulder, hip joint, and knee joint). The belt path was analyzed by measuring the clearance between the belt and the sternum or navel.

Results: Among the 12 pregnant women at 33.9 week ± 3.3 week gestation, the shoulder belt deviated to the right side and subsequently contacted to the neck in four pregnant women (Contact group). The height of the Contact group was significantly shorter than that of Non-contact group (152.3 cm ± 3.0 cm vs. 159.0 cm ± 3.3 cm, $p = 0.008$). Regarding the relative position of the seatbelt to the subject's body, the distances from the top of the sternum to the center of the shoulder belt were significantly shorter in Contact group (3.9 cm ± 3.5 cm) than that in the Non-contact group (8.0 cm ± 1.6 cm, $p = 0.03$). However, no significant difference was found for the distance from the umbilicus to the center of the lap belt.

Conclusion: Our findings show that because of short height and late term of pregnancy with protrusion of the abdomen, the shoulder belt deviates to the right or left, avoiding the protruded uterus, and subsequently makes contact with the neck. Seatbelt systems for rear seats need to be developed to improve passenger safety, especially for pregnant women.

Introduction

With 13 million deaths worldwide, motor vehicle collisions (MVCs) are a leading cause of death, and the largest cause of accidental death and disability among pregnant women.[1] A recent study performed at Sapporo City in Japan revealed that 2.9% of women with 35–37 weeks pregnant had experienced MVC as an occupant during their pregnancy.[2] According to previous reports about traffic injuries among pregnant women and fetal or neonatal outcomes, severe maternal injury was associated with a higher risk of fetal loss.[3] Therefore, to improve safety for both mothers and fetuses, it is important to prevent or reduce the severity of injuries from vehicle collisions. Seatbelts are widely recognized as an effective preventive tool and seatbelt use is legally required in many developed countries. Because seatbelt use reduces the risks of fatal injuries for pregnant women and their fetuses in vehicle collisions, seatbelt use by pregnant drivers and front seat passengers is legally required in Japan.[4] Since 2008 in Japan, seatbelt use has become legally mandatory for all rear seat passengers. After this traffic law revision in Japan, although the rate of seatbelt use among rear seat passengers increased, only 36.0% and 71.8% of rear seat passengers wore seatbelts on normal roads and highways, respectively, in 2016.[5]

Real-world accident data analysis from the United States shows that properly restrained pregnant occupants involved in motor vehicle crashes had a significantly reduced risk of MVC-related adverse fetal outcomes, including pregnancy loss, compared with unrestrained pregnant occupants.[6] Therefore, the American College of Obstetricians and Gynecologists recommends seatbelt use to

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improve maternal and fetal survival after MVCs for pregnant women seated in rear seats.

Despite the legal requirements, some pregnant women tend not to fasten seatbelt when sitting in the rear seat of a vehicle because of discomfort caused by the seatbelt making contact with the neck. Seatbelt–neck contact might also lead to adverse events during a MVC. Therefore, to confirm that seatbelt–neck contact in rear seats affects the safety of pregnant women and their fetuses, we carried out an anthropometric study on Japanese pregnant women. According to the results of this study, we propose measures to improve and develop seatbelt systems for rear seats passenger safety, especially for pregnant women.

Subjects and methods

The protrusion of a pregnant woman's abdomen increases according to the week of gestation; therefore, we opted to measure women who were in later terms of pregnancy. An open call for volunteers was issued, and 12 pregnant women, all of whom were 30 or more weeks pregnant were chosen as participants. Prior to the study, a physician gave the participants full verbal and written explanations of the purpose and method of the study. The participants then provided written consent. The Ethics Committee of the Dokkyo Medical University School of Medicine approved this study. The participants sat in the left side of rear seat of a typical mid-size passenger sedan (2008 Honda Accord Inspire). Next, the pregnant women fastened their seatbelts, and then, measurements were taken with water levels and flexible rulers. During the course of measurements, the following items were assessed.

Basic information

Age, height (cm), weight (kg), gestational age, and abdomen circumference and width (cm) were measured.

Seating posture

The position of the head, shoulders, knees, and pelvis were measured relative to the reference points in the vehicle. The door switcher and the upper face of the side sill were both used as the vehicle's X-coordinate reference point and Z-coordinate reference surface, respectively (Fig. 1). The measurement points on the head, shoulder, pelvis, and knee were as follows: the center of the external acoustic opening, center of the shoulder joint (the midpoint of the greater and lesser tubercles of the humerus), greater trochanter, and center of the knee joint (the tip of the lateral femoral condyle), respectively. To compare the seating posture among individuals and groups, the positions of each body part, relative to the X- (longitudinal axis, mm) and Z-coordinates (vertical axis, mm) of the vehicle, were measured and plotted as a schematic representation of the seating posture.

We also measured the horizontal length between the most protruded position of the abdomen and the X-coordinate reference points, as well as the width of the hip of the pregnant women.

Relative position of the seatbelt to the subject's body

The position of the seatbelt was measured after being fastened. The following parameters were measured: (1) the distance from the top of the sternum to the center of the shoulder belt (cm); (2) the distance from the center of the shoulder belt to the umbilicus (cm); and (3) the distance from the umbilicus to the center of the lap belt (cm).

Statistical analysis

A Mann–Whitney test was used to examine the differences in the values between the two groups. Differences with a p-value less than 0.05 were considered statistically significant.

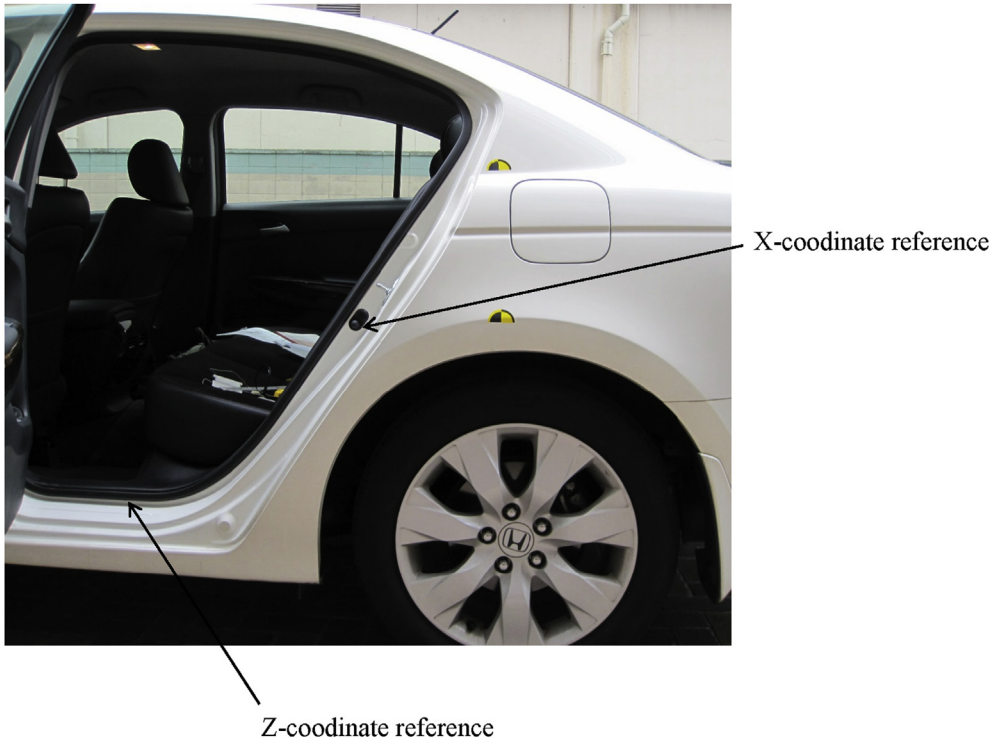

Fig. 1. Interior of the vehicle used in the measurement. The door switcher and upper face of the side sill were used as the vehicle's X-coordinate reference point and Z-coordinate reference surface, respectively.

Results

Subject characteristics

The gestational weeks of the 12 women ranged from 30 to 38 weeks with a mean of 33.9 weeks ± 3.3 weeks. The mean ± standard deviation for the pregnant women were age, 32.5 years ± 2.3 years (29–36 years); height, 156.8 cm ± 4.5 cm (148–165 cm); weight, 61.9 kg ± 14.0 kg (42.0–77.6 kg); abdominal circumference, 87.1 cm ± 4.5 cm (87–124 cm).

When observing the belt path, the shoulder belt deviated to the right side and subsequently came to rest on the neck in four pregnant women (Contact group). In the remaining eight pregnant women, the shoulder belt pathed on the adequate position and did not make contact with the neck (Non-contact group). Comparing the above characteristics between these two groups, the height of the Contact group was significantly shorter than that of the Non-contact group (152.3 cm ± 3.0 cm, vs. 159.0 cm ± 3.3 cm, $p = 0.008$). However, no significant differences were found between the Contact and Non-contact groups in other items, such as age, gestational weeks, and weight, (33.0 years ± 2.2 years, vs. 32.0 years ± 2.4 years; 33.5 weeks ± 3.1 weeks, vs. 34.1 weeks ± 3.6 weeks; 61.0 kg ± 22.3 kg, vs. 62.4 kg ± 9.6 kg, respectively; $p > 0.05$).

Anthropometric values

Seating posture

The shape of the plotted lines in the graph represents a simplified form of the posture of the torso for each subject. The shape of each line shows the right side view of the woman sitting on the seat. A graph representing the positions of the head, shoulders, pelvis, and knees of the subjects, relative to the vertical and horizontal coordinates, is shown in Fig. 2. There is less variation, by a small amount, among the pregnant women. The figure shows no marked different patterns between the Contact and Non-contact groups. In addition, the horizontal length between the most protruded position of the abdomen and the X-coordinate reference points, and the widths of the hips of the pregnant women when sitting on the seat were compared between the two groups. No significant differences were found between the Contact and Non-contact groups (45.9 cm ± 8.5 cm, vs. 46.3 cm ± 3.4 cm; 37.5 cm ± 6.3 cm, vs. 37.0 cm ± 2.8 cm, respectively; $p > 0.05$).

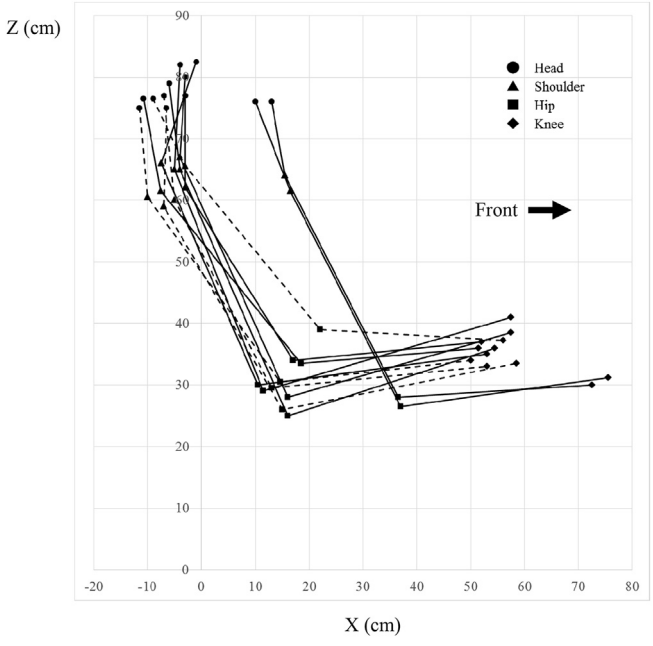

Fig. 2. The shape of each line shows the right side view of the woman sitting on the seat. Seating postures represented by the head, shoulder, hip and the knee coordinates (dotted line: Contact-group, straight line: Non-contact group).

Relative position of the seatbelt to the subject's body

The mean distance from the top of the sternum to the center of the shoulder belt in all pregnant women was 6.6 cm ± 3.0 cm, that from the center of the shoulder belt to the umbilicus was 27.0 cm ± 4.2 cm, and that from the umbilicus to the center of the lap belt was 9.2 cm ± 2.0 cm. The distance from the top of the sternum to the center of the shoulder belt was significantly shorter in Contact group (3.9 cm ± 3.5 cm) than that in the Non-contact group (8.0 cm ± 1.6 cm; $p = 0.03$). However, for other two items, the differences were not found to be statistically significant (28.7 cm ± 6.7 cm, vs. 26.0 cm ± 1.8 cm; 8.7 cm ± 3.0 cm, vs. 9.4 cm ± 1.6 cm, respectively; $p > 0.05$).

Discussion

In studies of suburban areas in Japan, more than 90% of female drivers continued driving after pregnancy.[7] However, among female vehicle passengers, seat preference changed after becoming pregnant. From the recent analysis in Japan, the rate of women who reported preferring the rear seat increased significantly from 16.7% to 23.8% after the establishment of pregnancy.[2] However, the prevalence of pregnant women who always fastened their seatbelt among those preferring the rear seat was 78.4%, which was significantly lower than that among those preferring the front seat, 89.2%.[2]

For the safety of rear seat passengers, increased promotion of seatbelt use is required. In Japan, the MVC fatality or severe injury rate in restrained rear seat passengers was 0.17%, which was smaller than that in non-restrained rear seat passengers (0.58%).[8] Among rear seat occupants, seatbelt use can reduce the risk of death by 60%.[9] Furthermore, in frontal crashes, the risk of death or severe injury among front seat passengers increased when rear seat occupants were unrestrained.[10,11] According to a study on teenage passengers in the US, more than three quarters of rear-seated teenagers who died were unbelted.[12] Therefore, the benefit of using a seatbelt in the rear seat was scientifically confirmed. Some reports discussed that the reasons that passengers do not use seatbelts include forgetfulness, perceived low injury risk, and uncomfortable belts.[13,14] Therefore, the feeling of comfort with adequate belt path leads to good protection.

In this study, we confirmed that the shoulder belt made contact with the neck of the pregnant women at the third trimester of pregnancy sitting on the rear seat of a sedan vehicle. Drivers and front seat passengers can adjust the position of seatbelt shoulder anchorage to adequately fit the belt path. For front seat passengers, the permissible field of the seatbelt anchorage points is defined by legal specifications, such as the Federal Motor Vehicle Safety Standard 210 and European Community Directive.[15] In nearly every car, the upper anchorage point is adjustable in the vertical direction. However, in rear seats, as the equipment of shoulder height adjuster is not legally restricted, it is fixed without height adjusters in most vehicles; subsequently, not all rear seat passengers fit the seatbelt-appropriate position if correctly used. When the seatbelt is not in a good geometrical position in relation to the chest, effective protection at collision is not observed.

According to the results of this study, seatbelt–neck contact occurred in pregnant women of lower height. Small stature can become a risk of poor seatbelt fit. Typically, seatbelts alone do not

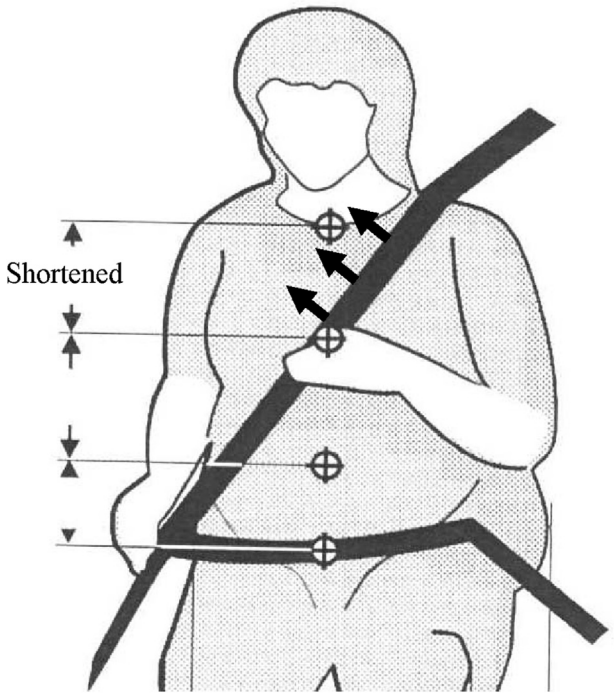

Fig. 3. Illustration of shoulder belt making contact with the neck of a late term pregnant women. The shoulder belt deviated to the right to avoid crossing the enlarged uterus.

fit children well until they are between ages of 8 and 12. By raising children up, booster seats help with the position of the shoulder belts crossing the center of the chest to provide maximum protection in a crash. Studies have found an overall injury reduction associated with booster seats ranging from 14% to 45%.[16,17] Therefore, recently in the US, most states have strengthened their child restraint laws to require older children to be restrained in rear-facing child restraints or belt-positioning booster seats. Because booster seat laws were associated with an increase in booster seat use, children who were covered by booster seat laws were less likely to be hospitalized for motor vehicle injuries than children who were not covered.[18–20]

In this study, the mean height of the women in the Contact group was 152.3 cm, which is commonly seen in adult females in Japan. Furthermore, for women in the late term of pregnancy, as the abdomen protruded, the shoulder belt deviated to the right side to avoid crossing the enlarged uterus (Fig. 3). Also, if the woman sits in the right side of the rear seat, the shoulder belt may deviate to the left side. Therefore, the shoulder belt came to rest on the neck. Subsequently, discomfort and compression of the neck led rear seat passengers to avoid seatbelt use.

This study had some limitations. First, the sample size was small. Although this study was performed in the ward of a medical university hospital, there were some concerns as participants were women in the late term of pregnancy. Therefore, in accordance with the advice of the Ethics Committee, the study was performed using as small a number of pregnant women as possible. In future, more pregnant women at various gestational weeks should be examined. Second, we used only one type of sedan. Because the seatbelt systems for rear passengers are similar in most sedan cars, we used one sedan car. However, a few differences may be found regarding the stiffness of the seat or belt fit among different types of cars. Therefore, further studies using other types of vehicles (e.g. one-box or light truck) are needed.

Nonetheless, seatbelt tension during a collision may cause neck compression among pregnant women sitting in the rear seat. Subsequently, adverse result may occur for both pregnant woman and their fetuses at the collision. Some traffic injuries of pregnant women caused by improperly positioned seatbelts may not be visible and, therefore, may be underreported. According to the results of this study, we propose that the seatbelt anchorage point be made adjustable in the vertical direction to fit the seatbelt appropriate position for rear seat passengers. Improvement and development of seatbelt systems for rear seats are important for passenger safety, especially for pregnant women.

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