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Experimental Study of the Safety Levels of Car Seat Belt-Positioners for Children

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Abstract: Safety belts should be worn by children at all times, particularly on the express way. However, it has been reported that the safety belt-wearing rate of children is only 30% on the express way, despite the need to have belts on constantly. It has also been reported that children aged 5~6 years old could be thrown out of the car if it were hit by an object at a speed of >50 km h^{-1}. Therefore, some testing experiments were performed in accordance with code 2009~No. 0977 of the Products Safety Managing Act. Namely, 3-year-old dummies were used in the test. It was found that commercially purchased products are not made in compliance with requirements.

INTRODUCTION

The Child Restraint System (CRS) is a child safety product certified by the Special Law on the Safety of Children's Products. It refers to a product that is attached to the seat of an automobile to protect the child from injuries or to reduce injuries in the event of a car accident using a seat belt attached to the vehicle to sit or lay the child and to fix their position and apply restraint. Article 50 (Compliance with Specific Driver) of the Road Traffic Act and Article 30 (Infant Protective Equipment) of the Act's enforcement regulation requires infant protective gear to be worn. However, on 10 August 2015, Lee Chan-Yeol, a member of the new Political and Democratic Union Party and of the National Land and Transportation Committee of the National Assembly, stated that the rate of car seat use had only been 30% the previous year, based on data from the National Transportation Safety Authority. This rate had been the lowest over the preceding 5 years with 35.9% in 2010, 37.4% in 2011, 39.4% in 2012 and 33.6% in 2013.

According to statistics from the National Police Agency, there were 223,552 traffic accidents in 2002, 4,762 deaths from traffic accidents and 337,497 injuries, which represented an increase of 3.8% (8,198) for traffic fatalities and 2.7% (8,786) for traffic accident injuries. Meanwhile, in 2002, the number of deaths per 10,000 vehicles was 2.0 persons (2.4 persons in 2012) and the number of deaths per 100,000 people was 9.4 persons (10.8 persons in 2012), showing a decline. In comparison with major developed countries, the number of traffic accidents per 10,000 cars in Korea is very high (Table 1).

Car protection devices for children have been reported to reduce children injuries by up to 90%. According to this report, children who are not properly restrained will be forced forward by 30-60 times their body weight in a collision at a speed of 30 km h^{-1}. Children who are not properly restrained are more likely to break through the window and are likely to face serious risks of injury when other passengers collide with them.

Table 1: Traffic accident statistics

	Years				
Types	2010	2011	2012	2013	2014
Accidents	226.878	221.711	223.656	215.354	223.552
Fatalities	5.505	5.229	5.392	5.092	4.762
Injuries	352.458	341.391	344.565	328.711	337.497
Accidents per 10.000 vehicles	2.600	2.400	2.400	2.200	2.000

In the event of a vehicle collision, the probability of a child bouncing out of the car is 49% in children who are not fixed at all, 35% in children inadequately fixed with an age-appropriate car safety device, 10% in children properly fixed with an age-inappropriate car child protection device and only 3% in children properly fixed with an age-appropriate car child protection device.

If a frontal impact crash occurs when driving at 50 km h^{-1} without a seat belt strapped on, children aged 5 to 6 may break through the window and suffer serious injury. However, even when a seat belt is worn, there is still a risk that the child may suffer severe internal organ damage from the pressure of the seat belt as the latter are designed for adults[1, 2].

The most common problem with the use of child protection devices in automobiles is that when a child protection device that does not fit the height of the child is used in some cases the child may not be properly secured by the device. Although, children must be properly secured with child safety devices in vehicles, products such as safety belt positioning devices have recently been marketed instead of proper child safety devices for automobiles. These products are selling better than child protection devices as they are cheap, ease to use and advertised as safe. However, most of these seat belt adjusters for children are pulling both the shoulder and waist belts and they generally pull the waist belt over the child's abdomen. A seat belt that passes over a child's abdomen can cause a seat belt injury.

When a collision accident occurs, a seat belt worn on a child's abdomen presses the abdomen strongly, causing a seat belt injury. In this study, four types of car seat belt positioners for children (samples #1, #2, #3 and #4) were selected and car collision accidents were simulated using a dummy with a human body structure similar to a child's, experiments were performed to determine how secure the belt positioners were. During the collision, the dummy was checked for an abnormal posture or a discharge of the derby that would compress the abdomen or waist, causing a seat belt injury[3].

We measured the acceleration value of the chest and the acceleration of the chest perpendicular to the head from the abdomen to the head to consider what kinds of risks children are actually exposed to when using a child seat belt positioner as a substitute for a child safety device in automobiles.

(a) (b)

Fig. 1(a, b): Test equipment

Table 2: Colliding test conditions

Crash direction	Speed (km h^{-1})	Test pulse	Stopping distance (mm)
Forward collision	50+0, - 2	1	650±50

MATERIALS AND METHODS

Test conditions

Samples: Four types of manufactured vehicle seat belt adjusters (samples #1, #2, #3 and #4) were bought online.

Test equipment and setup: To confirm the safety of vehicle seat belt positioners, it is generally assumed that they are used by children aged 3 years or older, rather than newborns who cannot sit in the vehicle. Among the dummies presented in the "Regulation No 44 of the Economic Commission for Europe of the United Nations (UN/ECE)-Uniform provisions concerning the approval of restraining devices for child occupants of power driven vehicles ('child restraint systems')", dummies for 3-year-old children (TNO P3, 3-year-old dummy (nominal mass of 15 kg) for homologation testing of group I and II child restraint systems) were used and the composite acceleration as measured with an accelerometer attached to the chest center in three axial directions was measured (Fig. 1 and Table 2).

The collision test used to measure the acceleration value of the dummy chest portion and the acceleration value of the vertical component of the chest toward the head from the abdomen to the head was performed in accordance with the forward collision test conditions and safety standards prescribed in the Regulation No 44 of the Economic Commission for Europe of the United Nations (UN/ECE) and the results were compared with the safety requirement standards to confirm the safety. To check whether the dummy was released from the seat belt or whether an abnormal posture occurred during the collision, the movement of the dummy was photographed at a speed of 1/2000 frame using a high-speed camera to check the changes in position[4].

RESULTS AND DISCUSSION

Chest impact acceleration and impact acceleration value of the chest vertical component from the abdomen to the head: Table 3 shows the impact acceleration values applied to the chest area of the dummy during the collision test. The impact acceleration value obtained from the test was expressed by converting the gravity acceleration G value obtained through the experiment into 1G = 9.8 m sec^{-2}.

The results of the measurement of the impact acceleration on the dummy's chest were as follows. The collision test results for the vehicle seat belt positioners showed that the chest impact acceleration value was higher than the safety standards for 2 products (samples #2 and #4). For the other samples (#1 and #3), the acceleration values for the vertical components of the chest from the abdomen to the head did not exceed the safety requirements but were close to their acceptable limits (Fig. 2-9).

Table 3: Colliding test results

Test results	Sample #1 (m sec^{-2})	Sample #2 (m sec^{-2})	Sample #3 (m sec^{-2})	Sample #4 (m sec^{-2})	Safety standards (m sec^{-2})
Chest impact acceleration value	445.1	669.0	493.3	561.6	539 (55 G)
Acceleration value of the vertical component of the chest from the abdomen to the head	291.8	270.3	265.0	280.3	295 (30 G)

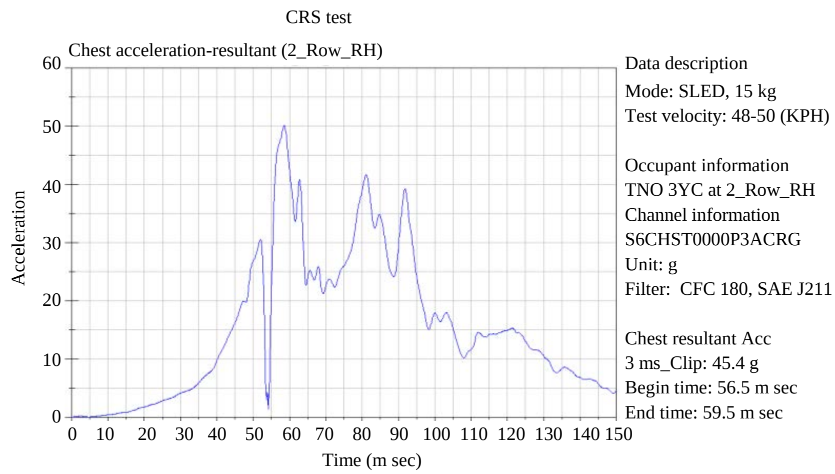

Fig. 2: Sample #1 chest impact acceleration

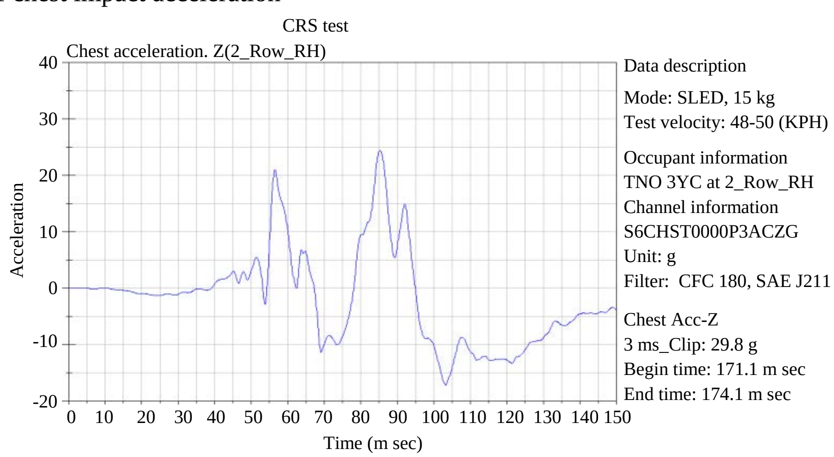

Fig. 3: Sample #1 breast-to-head abdomen perpendicular acceleration

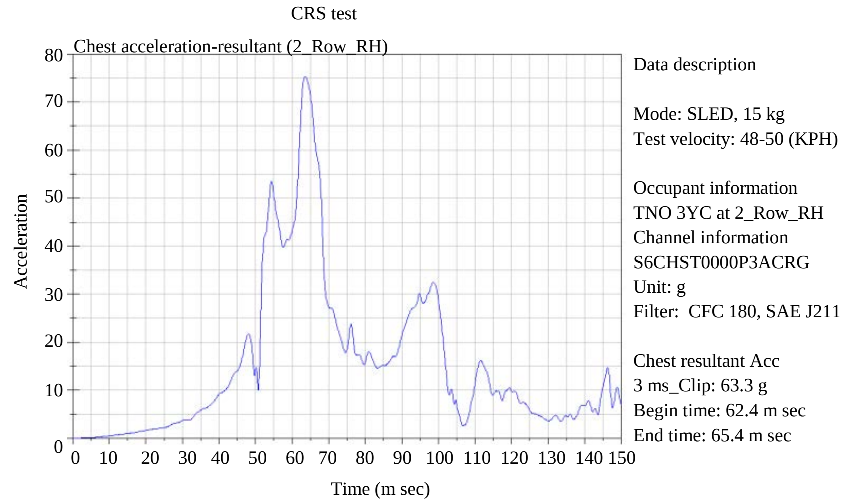

Fig. 4: Sample #2 Chest impact acceleration

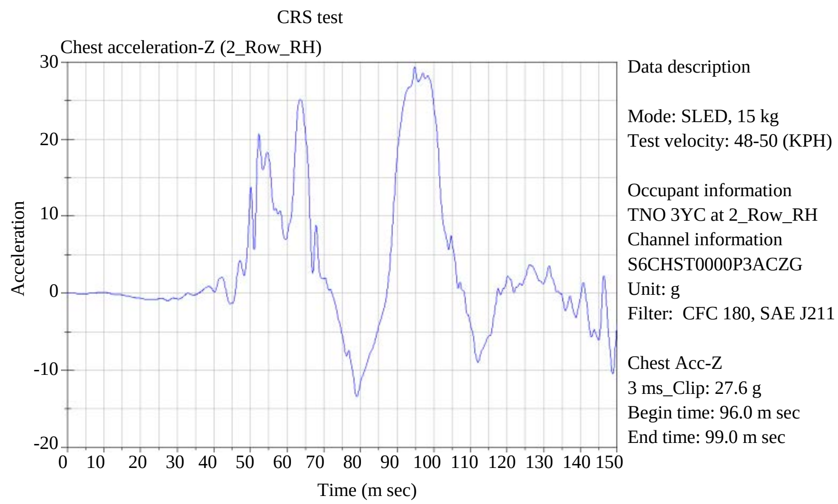

Fig. 5: Sample #2 breast-to-head abdomen perpendicular acceleration

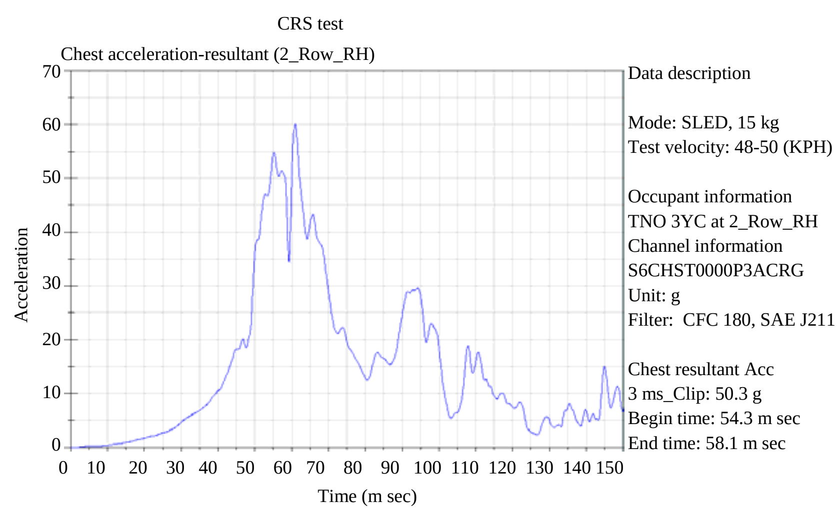

Fig. 6: Sample #3 chest impact acceleration

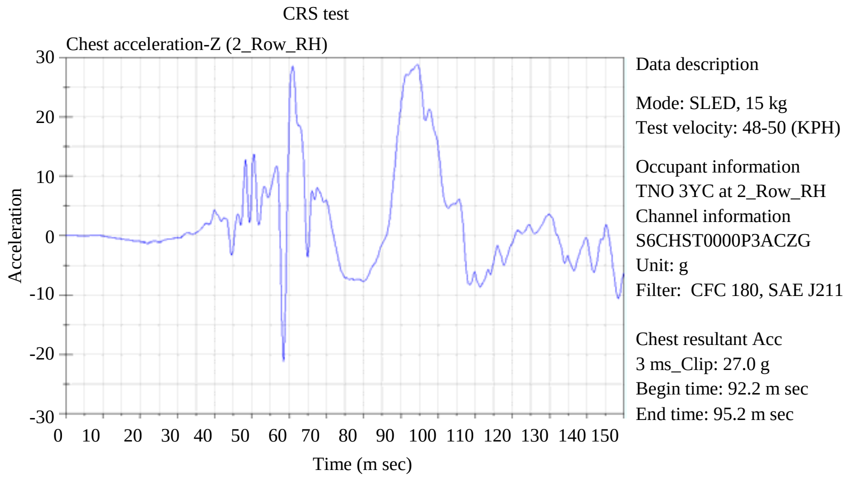

Fig. 7: Sample #3 breast-to-head abdomen perpendicular acceleration

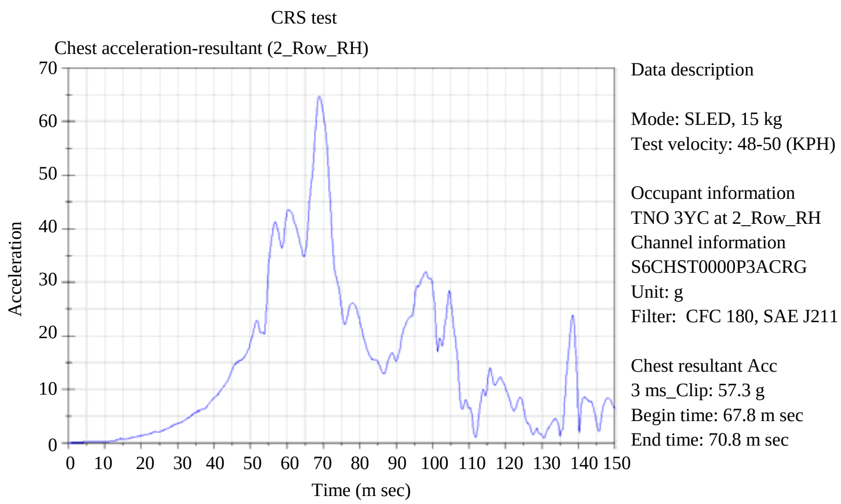

Fig. 8: Sample #4 chest impact acceleration

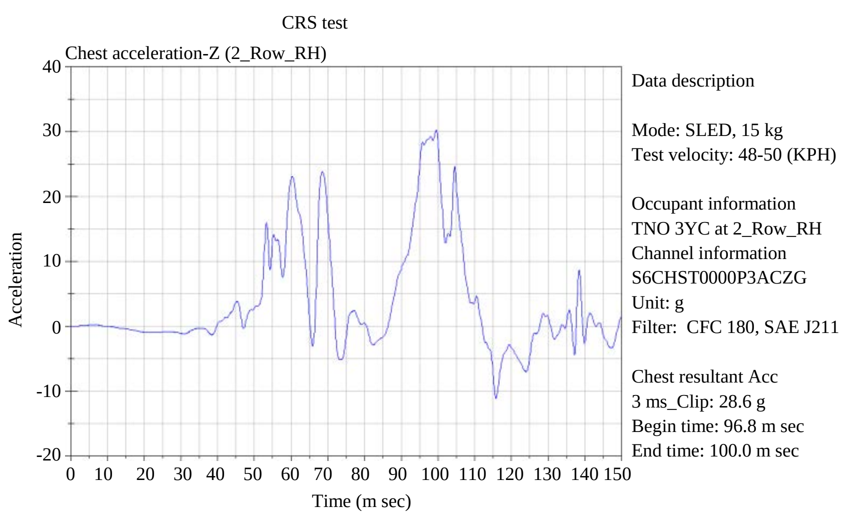

Fig. 9: Sample #4 breast-to-head abdomen perpendicular acceleration

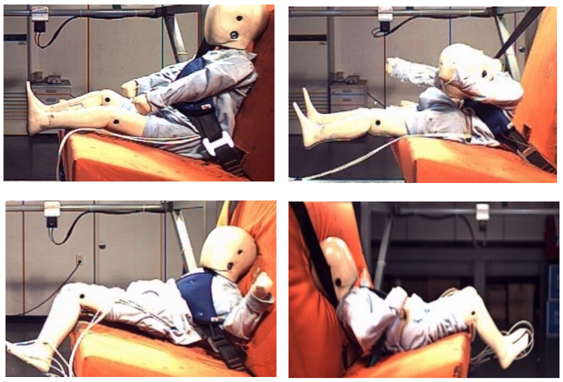

Fig. 10: Sample #1 dummy posture and movement

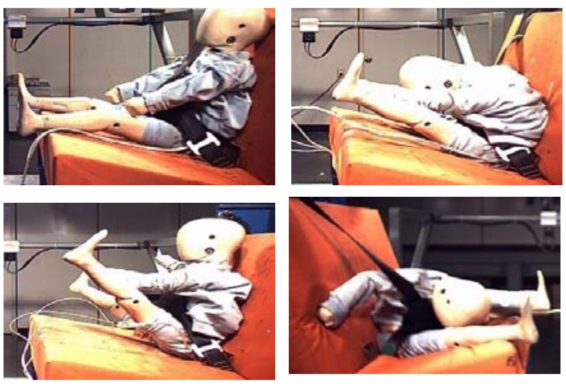

Fig. 11: Sample #2 dummy posture and movement

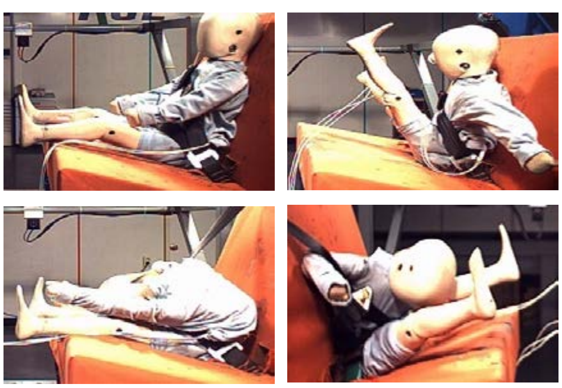

Fig. 12: Sample #3 dummy posture and movement

Dummy posture behavior in the colliding tests: The examination of the dummy's posture behavior during the collision test using a high-speed camera confirmed that the seat belt slipped into the abdomen of the derby and penetrated into the dummy by pressing its abdomen in the tests for all four samples. The shoulder strap was found to have displaced the dummy into an abnormal posture or to have compressed its neck. Figure 10 for sample #1 shows that the abdominal seat belt penetrated into the dummy by

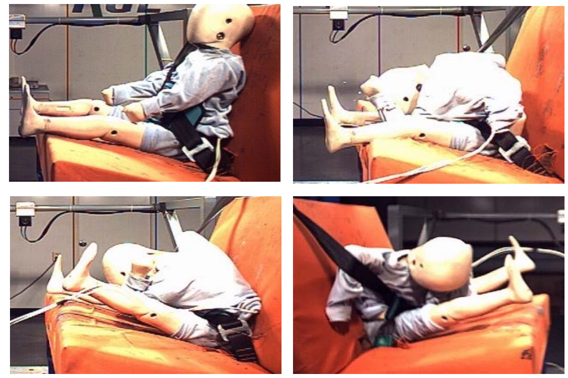

Fig. 13: Sample #4 dummy posture and movement

squeezing the abdomen of the derby and the shoulder belt compressed the neck of the dummy. In Fig. 11-13 for samples #2, #3 and #4, respectively, the seat belts penetrated inside the abdomen of the derby during the collision test and the appearance of an abnormal posture was confirmed. The abnormal posture and deviation are very likely to cause seat belt injuries leading to internal organ damage and lumbar damage, as the seat belt compresses the chest, abdomen and neck of children during collisions[5].

CONCLUSION

To examine the safety of car seat belt positioners for children, collision tests were carried out to confirm the acceleration of the chest impact and the acceleration of the chest vertical component toward the head. From checking the postural behavior of the dummy during the collision test with high-speed shooting, the following conclusions were obtained.

Vehicle seat belt positioners which can be purchased by customers easily through the internet or in shopping malls, exceeded or approximated the safety requirements prescribed by safety standard for the acceleration of the chest impact and the acceleration of the vertical component of the chest toward the head. This implies that car collisions can cause fatal injuries to the chest area of children when using these devices.

In the collision tests for all samples, the dummy posture behaviors were confirmed to have deviated into abnormal postures and the waist belt and shoulder belt parts of the seat belt were found to press the dummy's neck and abdomen. This suggests that there is a high risk of seat belt injuries leading to internal organ damage being caused by a seat belt pressing on the chest and abdomen of a child in the event of a collision.

Through this study, it was found that child seat belt positioners are unlikely to guarantee children's safety and cannot properly restrain children during an accident. Parents using these products should pay special attention to the use of child seat belt positioner products and it is desirable to use appropriate restraint devices to ensure the safety of children in passenger cars[6].

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