A Comparison between ISOFIX and Seatbelt Installation Methods for Child Restraint System on Child Occupant Performance

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ABSTRACT

Seat belt is a proven intervention to reduce the risk of fatalities in road accidents involving adults. Nevertheless, for children, there is another prominent safety system known as child restraint system (CRS) to protect them. However CRS does not come as a standard part of the car. It needs to be installed to the car by users. Two different installation methods i.e. ISOFIX with Top Tether, and traditional three-point seatbelt were utilized in this study to compare the effectiveness of the system to reduce the injury of the child occupants. The New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP) has incorporated rating assessment for Child Occupant Protection (COP) to ensure that the safety of children traveling in cars is properly highlighted. The study has made used the data from the ASEAN NCAP assessment test. Two child dummies representing 18 months and 3 years old seated in separate CRSs were subjected to offset frontal crash test at 64 km/h, as per ASEAN NCAP protocol. The accelerometers were installed at the head and chest to record the injury level of the dummies. The test parameters and same models were utilized for the comparison purpose in two crash test. Overall results, found that the combination of ISOFIX and Top Tether offered better safety performance in reducing the child occupant injuries as compared to the three-point seatbelt. ISOFIX system has improved the CRS performance for both three years old and 18 months old dummies. Head and chest resultant injuries were improved by 24% and 14% respectively for the three years old dummy. However, there is no improvement offered for vertical chest measurement. Head resultant improvement for both dummies is similar with

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24% for P3 dummy and 22% for P1.5 dummy. The system is offering better chest injuries protection for the 18 months old dummy. Chest resultant is improved by 41% while chest vertical by 38%.

Keywords: *ASEAN NCAP, Child Restraint System, Installation Method, ISOFIX, Top Tether.*

Introduction

Road traffic injuries are a major public health problem in Malaysia. Approximately, more than 6000 people are killed each year on the road in Malaysia. Children are also part of the statistics and there is no exception for them. In 2014, there were 141 children aged less than 10 years old killed on the road [1].

This is an alarming problem for children in Malaysia. According to Norlen et al. [2], children transported in private vehicles are the first and second leading groups of causalities among children aged 1-4 years old (43.8%) and 5-9 years old (30.2%) respectively. Thus, the statistics and findings highlight the needs to implement measures to reduce traffic fatalities among children.

Correctly installed CRS may help to reduce the risk of death by 71% for infants and by 54% for children aged 1 to 4 years old and reducing the need for hospitalization by 69% for children aged 4 years old and below [3]. Seat belt is a proven intervention to reduce the risk of fatalities during road accidents for adults. However, it is not design to protect a child. Therefore, special child restraint systems are necessary to protect children from road crashes.

As an alternative to seat belts, CRS was introduced. Children aged 2 to 5 years old who are restrained in adults' safety belts are three and half time more likely to suffer serious injury, and more than four times more likely to suffer a serious head injury than children of the same age who are restraint in CRS [3].

There are many methods for CRS installation inside the car. It can be installed using an adult three-point seatbelt or specially design system to install CRS in the car such as ISOFIX and tether strap. All of the installation methods are allowed in regulation and ASEAN NCAP however, it is most significant to use the method that can help the tested vehicle to score good results in the dynamic category in order to achieve higher star rating.

ISOFIX system can help to decrease the mistakes during installation of CRS inside the vehicle. With upper tether straps, it can provide a substantial reduction of child's head excursion during impact [4]. The sled test showed that ISOFIX installation reduces the forward movement and the pitching was small during the test [5]. There are others method to reduce the head and chest acceleration such as introduction of the load limiter [6].

Thus, this paper aims to assess the effectiveness of the installation method towards head and chest injuries for both forward and rearward facing in full scale crash test. This study will use the crash test from ASEAN NCAP. In ASEAN NCAP test protocol, CRS used in each test vehicle were installed by using an ISOFIX system (either with a top tether or base with support leg) or a three-point seatbelt.

Methodology

The performance comparison of the installation methods were based on the frontal offset deformable barrier (ODB) crash test. Two tests were conducted according to ASEAN NCAP crash test protocol. In order to ensure the same crash performance, both tests using the same make and model of the car. The first car was installed using seat belt and the second car using ISOFIX system for the attachment.

The injury data were compared based on the accelerometer installed in the child dummies. Two dummies were used in this comparison. P3 dummy represent 3 years old child and P1.5 dummy represent 18 months child. The same type of CRS using for both cases and the only different is the installation method. Britax Baby Safe (18 months) and Britax Duo Plus (3 years old) were used for this study. These CRSs are capable of using both installation methods.

Frontal ODB Crash Test

One of the ASEAN NCAP crash test assessment is frontal ODB crash test. The test was conducted by propelling the car towards stationary barrier. The barrier is construct using aluminium in shape of honeycomb. The impact speed of the test is 64km/h and it shall cover 40% of the front face in the driver side. An illustration of the crash test configuration is shown in Figure 1.

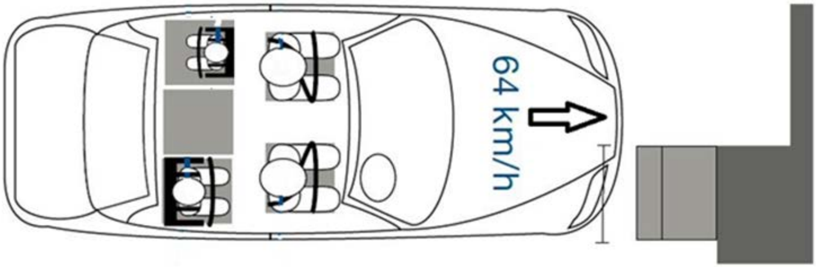

Figure 1: ASEAN NCAP crash test configuration

In the front seats of the car, there are two instrumented Hybrid III 50th percentile dummies. Seated in the rear child restraints are P 1.5 (representing 18 months old) and P3 dummy (representing 3 years old). P1.5 dummy was placed behind the passenger with rearward facing arrangement. P3 dummy was placed behind the driver in the forward facing arrangement. Both child dummies data were used to compare the child safety occupant for both types of installation.

CRS Installation Method

The aim of the study is to compare the performance of different type of the installation. All other the parameters were fixed accept the installation methods. Two crash tests were conducted using the same vehicle model for both cases. The installation configuration is shown in Table 1.

Table 1: Attachment configurations for P3 and P1.5

Dummy	Vehicle A	Vehicle B
P3 (3 years old)	ISOFIX & top tether	Three-point belts
P1.5 (18 months old)	ISOFIX with base	Three-point belts

Two set of dummies were used for both tests. Which are P3 dummy and P1.5 dummy represented 3 years old and 18 months children. The first vehicle (A) was installed using ISOFIX and top tether or based system. The second vehicle (B) was installed using three point belts system.

ISOFIX & Top Tether (Vehicle A)

Three Point Seat Belts Vehicle (B)

Figure 2: P3 Dummies Installation for Vehicle A and B

P3 dummies for both cases were installed in forward facing direction using the same CRS Britax Duo Plus as shown in figure 2. Vehicle A was installed using ISOFIX and top tether, where based of CRS fixed using ISOFIX system and top of the CRS fixed using top tether. Vehicle B was installed using three -point seatbelt by slotting in the structure of the CRS.

ISOFIX with base (Vehicle A)

Three Point Seat Belts Vehicle (B)

Figure 3: P1.5 Dummies Installation for Vehicle A and B

Figure 3 shows the installation of P1.5 dummies for both cases. The dummies were installed using Britax Baby safe CRS in rearward facing. ISOFIX with base where the ISOFIX bracket was fixed to vehicle seat structure and the support leg was placed on the floor of the vehicle. Seat was routing around the CRS in case of vehicle B.

Child occupant performance was compared from the data and videos collected from the crash test. Then child performance comparisons were conducted separately between P1.5 and P3 dummies. Both dummies were compared in term of kinematic performance and injury criteria.

Results

Vehicle crash pulses were compared to confirm that both vehicles were subject to the same energy level i.e. the same vehicle structure was used. The crash energy level was compared using a crash pulse of the vehicle. The crash pulse was recorded by using accelerometer attached at the B-pillar. The energy levels of both vehicles are similar as shown in Figure 4.

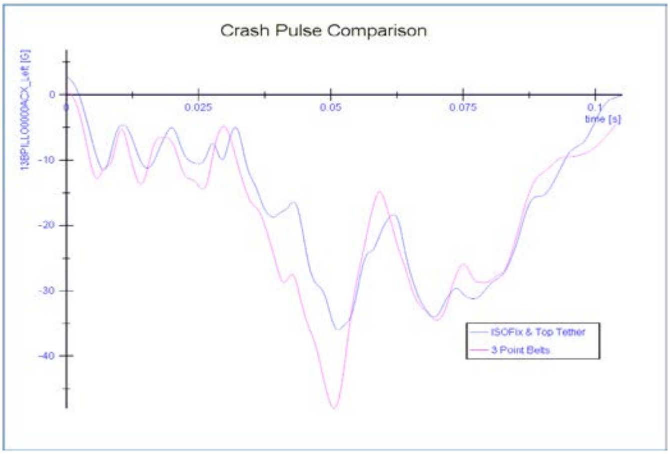

Figure 4: Crash comparison between vehicles

Injury Comparison

Child occupant injuries were recorded through the accelerometer installed inside the dummies. The head and chest performances were compared for both dummies. Table 2 shows injuries result for P3.

Table 2: 3 ms acceleration head and chest injuries result for P3 dummy

Body region	ISOFIX + top tether (g)	Three-point belt (g)
Head resultant	69.80	91.36
Chest resultant	46.74	54.64
Chest vertical	33.87	33.32

Vehicle A was tested using ISOFIX and top tether as shown in Figure 5. All injuries were calculated using 3 ms criterion. Head resultant with 3 ms criterion is 69.80 g. Chest resultant and vertical chest acceleration were recorded at 46.74 g and 33.87 g respectively.

Figure 5: P3 dummy installed inside the car using ISOFIX and top tether

P3 dummy for Vehicle B was placed using three-point seatbelt as shown in Figure 6. The 3 ms head acceleration is 91.36 g. Chest resultant and vertical chest acceleration were recorded at 54.64 g and 33.32 g respectively.

Figure 6: P3 dummy installed using three-point seatbelt

P1.5 dummy or 18 months old baby dummy was placed rearward facing in the car. This is according to the regulation requirement that requires newborn baby up to 13 kg to be seated rearward facing. Table 3 shows injuries result for P1.5 dummy.

Table 3: 3 ms acceleration head and chest injuries result for P1.5 dummy

Body region	**ISOFIX + top tether (g)**	**Three-point belt (g)**
Head resultant	37.69	48.22
Chest resultant	30.70	51.87
Chest vertical	16.54	26.61

P1.5 dummy was placed inside Vehicle A using ISOFIX with base. It integrates support leg for the anti-rotation feature. Figure 7 shows the installation of the child in Vehicle A. The 3 ms head resultant acceleration for this case is 37.69 g. Chest resultant acceleration is 30.70 g, and vertical chest acceleration are 16.54 g.

Figure 7: P1.5 dummy placed inside vehicle using ISOFIX with base support

In Vehicle B, the P1.5 dummy was placed using a three-point seatbelt as shown in Figure 8. The 3 ms head acceleration result for this case is 48.22 g. Chest resultant and vertical acceleration are respectively at 51.87 g and 26.61 g.

Figure 8: P1.5 dummy installed inside the tested vehicle using a three-point belt

Discussion

The study was conducted based on one vehicle model only due to the cost of the full scale vehicle crash test. This was limiting the case study to only one model of CRS for each type of dummies.

The percentages of the acceleration reduce by the using ISOFIX system installation when compared to seatbelt performance is presented in Table 4.

Table 4: Percentage performance improvements by ISOFIX system

Body region	P3 dummy (%)	P1.5 dummy (%)
Head resultant	-24%	-22%
Chest resultant	-14%	-41%
Chest vertical	+2%	-38%

In case of P3 the head resultant acceleration were reduced by 24% and chest resultant acceleration were reduce by 14%. This is the result of the rigid connection between the vehicle and the CRS offered by the ISOFIX system. Previous study based on sled test (non-destructive test) has founded that the slack is smaller in ISOFIX CRS top tether compared to the seat belt installation. It resulted the difference speed of the dummy where dummy movement is higher in the seat belt installation case causing the higher head acceleration [5]. This is also applicable to the P1.5 dummy where head resultant acceleration and chest resultant acceleration were reduced by 21% and 41% respectively.

However in case of the chest vertical acceleration is increased by 2% in case of P3 dummy while reduce significantly by 38% in case of P1.5 dummy. This is due to the different kinematic movement of both dummies. P3 was installed in forward facing where dummy movement restraint by the five-point seatbelt where it held the vertical movement of the dummy. It contradicted with P1.5 dummy where the dummy installed in rearward facing CRS. In rearward facing CRS is moving and rotating together with the dummy. It also explain in previous study, that head acceleration were more sensitive to the vehicle crash pulse which cause the movement of CRS while chest acceleration were more dependent on the CRS internal restraint system [7].

Conclusion

The most important note that this study is not stated that the seat belt installation is not good to be used in the car. The results show the value of the injuries is below than the regulation requirements. In UNECE R44, it requires that chest resultant acceleration shall not exceed 55 g and the vertical component of the acceleration from the abdomen towards the head shall not exceed 30 g. However, it does not mention about head acceleration [8].

However, there is always room of improvement to reduce the level of the injuries. For example, in ASEAN NCAP, these requirements from the regulation are used as the minimum limit to obtain star rating and anything more than this will score 0 point. Head requirements are stated in the ASEAN NCAP requirement, in which it will only be counted if there is any contact with the CRS. Otherwise, it will score full points [9].

In this study, both sets of dummies passed the requirements for the regulation and minimum level of ASEAN NCAP. Nevertheless, only chest vertical for P3 dummy failed to meet the requirement of 30 g for both cases. Significant improvement offer by the ISOFIX system compared to the seatbelt attachment system.

It can be concluded that the ISOFIX system installation method provides higher child occupant protection based on ASEAN NCAP frontal offset crash test configuration for child occupant assessment. By using the system, it improves the dynamic score and COP star rating for the tested vehicle.

References

[1] PDRM, *Statistik kemalangan trafik 2013-2014*, (2015).

[2] Norlen, M., S.V. Wong, Hizal Hanis, H. and Ilhamah, O., *An Overview of Road Traffic Injuries Among Children in Malaysia and Its Implication on Road Traffic Injury Prevention Strategy*, MRR 03/2011, (Malaysian Institute of Road Safety Research, Kuala Lumpur, 2011).

[3] C. Parenteau and D. Viano, “Field data analysis of rear occupant injuries part II: Children, toddlers and infants,” *SAE Technical Paper 2003-01-0154*, doi:10.4271/2003-01-0154, (2003).

[4] M. Lumley, “Child restraint tether straps - A simple method of increasing safety for children,” *SAE Technical Paper 973305*, doi: 10.427/973305, 123-135, (1997).

[5] Tanaka Y.,Yonezawa H.,Hosokawa N., “Responses of Hybrid III 3YO and Q3 Dummies in Various CRSs Tested Using ECE R44 Impact Conditions,”*Proceedings of the 21st (esv) international technical conference on the enhanced safety of vehicles, held june 2009, Stuttgart, Germany*, 09-0242 (2009)

[6] Hu J., Mizuno K., “The Kinematic Behaviour and responses of Hybrid III 3YO dummy and child human FE model in ISOFIX CRS in Frontal impact.,” *International Journal of Crashworthiness Vol 14,* doi: 4.082009, 391-404 (2009)

[7] Hu J., Wang D.,Mellor M., “Safety performances comparisons of

different types of child seats in high speed impact test," *Proceedings of the 22nd (esv) international technical conference on the enhanced safety of vehicles, held june 2011, Washington, USA*,11-0053(2011)

[8] United Nations, *UN ECE R44 Child Restraint System,* (2005).

[9] ASEAN NCAP, *Testing Protocol - Frontal Impact, Version 1.2*, New Car Assessment Program for Southeast Asian Countries, Malaysia, Retrieved from http://www.aseancap.org/wp-content/uploads/2013/08/ASEAN-NCAP-Frontal-Impact-Testing-Protocol-Version-1.2.pdf, (2016).