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# Establishment Procedure of Child Restraint Systems Reference List for ASEAN NCAP

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**Abstract** – *Babies and children below the age of 12 are the most vulnerable road users compared to older children (i.e., 12 years and above) and adults. To reduce the risk of severe injuries in the case of crashes or emergency braking, it is important that these groups of children are transported properly using age- or size-appropriate Child Restraint Systems (CRS) for as long as possible. As part of the ASEAN NCAP protocol, a so-called "CRS Reference List" that contains a sample of widely available, well-performing child seats in the ASEAN market was established to assess the vehicle's ability to safely and correctly accommodate child seats. The reference list should be reviewed every two years following a systematic revision process and published in ASEAN NCAP's website. In this paper, some shortlisted CRS identified in previous work would be assessed following ASEAN NCAP Child Occupant Protection (COP) protocol where the CRS performance is evaluated. The technical assessment is explained in detail in this paper, where several measurements taken during vehicle impact tests using several shortlisted CRS are shown. The final "CRS Reference List" would then be established by ASEAN NCAP following the systematic assessment process based on the findings and recommendations from this work for the future ASEAN NCAP COP assessment.*

**Keywords:** Child Restraint System (CRS), CRS reference list, ASEAN NCAP, Child Occupant Protection (COP), child safety, technical assessment


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## 1.0 INTRODUCTION

The New Car Assessment Program for Southeast Asian Countries (ASEAN NCAP) has conducted child occupant safety assessment since its very first test. The ASEAN NCAP Child Occupant Protection (COP) protocol uses a selection of popular Child Restraint Systems (CRS) represented in the CRS Reference List to evaluate the child protection level in a particular vehicle (ASEAN NCAP, 2018). Meanwhile, Original Equipment Manufacturers (OEM) for CRS have strived to ensure their products are capable of meeting the NCAP strict requirements by making several improvements that are optimized to the latest COP protocol (Bendjellal et al., 2017). To keep up with the changes, the CRS Reference List shall be reviewed every two years and published in ASEAN NCAP's website.

Abu Husain et al. (2018b) outlined the revision process undertaken to establish the new CRS Reference List for ASEAN NCAP, which started by exploring available CRS in Malaysia, Thailand and Indonesia via online shopping platforms (e.g., Amazon, Lazada, etc.). Three types of CRS were studied for selection, i.e., the universal belted CRS, ISOFIX CRS, and the combination of belted and ISOFIX CRS. The information collected was summarized into a CRS database. Then, specifications for each CRS in the database were evaluated based on several predetermined evaluation criteria – availability in ASEAN country, regulation approved, group combination, prize, size and direction of installation. Top-performing CRS were chosen for shortlisting as tabulated in Table 1. ASEAN NCAP proceeded to obtain each of the shortlisted CRS for further technical assessment before the CRS Reference List could be finalised. The whole revision process is illustrated in Figure 1, while a detail explanation could be found in Abu Husain et al. (2018b).

In this paper, the technical assessment procedure for the shortlisted CRS presented in Abu Husain et al. (2018b) is explained in detail. The focus was on utilizing the shortlisted CRS in frontal impact tests to measure their performance for the COP. The assessment procedure could then be a standard process for ASEAN NCAP in the future.


**Figure 1:** Overview of process for establishing CRS Reference List for ASEAN NCAP (Abu Husain et al., 2018a)

**Table 1:** Shortlisted CRS according to type (Abu Husain et al., 2018b)

| Type | Brand | Group | | | | Direction | Interface |
|---|---|---|---|---|---|---|---|
| | | 0/0+ | I | II | III | | |
| Universal Belted | Sweet Heart Paris CS375 | √ | | | | Rearward | B _ _ _ |
| | Cosatto Hold 0+ | √ | | | | Rearward | B _ _ S |
| | Peg-Perego-Primo Viaggio Tri-Fix | √ | | | | Rearward | B _ _ _ |
| | Welldon Smart Sport II BS02-T | √ | √ | √ | | Convertible | B _ _ _ |
| | Joie - Stages | √ | √ | √ | | Convertible | B _ _ _ |
| | Mothercare Madrid | √ | √ | | | Convertible | B _ _ S |
| | Cybex Pallas | | √ | √ | √ | Forward | B _ _ _ |
| | Cosatto Zoomi | | √ | √ | √ | Forward | B _ _ _ |
| | Safety 1st Continuum 3-in-1 | √ | √ | √ | √ | Convertible | B _ _ S |
| | Safety 1st Guide 65 | √ | √ | √ | | Convertible | B _ _ S |
| | Sweet Heart Paris CS286 | √ | √ | √ | | Convertible | B _ _ _ |
| ISOFIX CRS | Chicco KeyFit 30 | √ | | | | Rearward | _ I _ S |
| | Peg-Perego-Primo Viaggio ISOFIX | √ | | | | Rearward | _ I L _ |
| | Joie - Stages ISOFIX | √ | √ | √ | | Convertible | _ I L _ |
| | Meinkind - Sonata | | √ | √ | √ | Convertible | _ I _ S |
| | Joie - Every Stage FX | √ | √ | √ | √ | Convertible | _ I _ S |
| Universal Belted & ISOFIX CRS | Chicco - Autofix | √ | | | | Rearward | B I L S |
| | Maxi-Cosi - Cabriofix | √ | | | | Rearward | B I _ S |
| | Britax Romer - Evolva 123 Plus | | √ | √ | √ | Convertible | B I _ S |
| | Cybex Pallas S Fix | | √ | √ | √ | Forward | B _ _ S |
| | KIDDY Guardian Pro 2 | | √ | √ | √ | Forward | B I _ _ |
| | Safety 1ST Grow'N'Go | √ | √ | √ | √ | Convertible | B I _ S |

## 2.0 ASSESSMENT METHOD

CRS Technical Assessment is outlined as follows:


**Figure 2:** CRS technical assessment

## 2.1 Pre-Test

### *2.1.1 Visual Assessment of CRS*

Shortlisted CRS's that have been obtained by ASEAN NCAP need to go through a thorough visual assessment to check on the quality and authenticity of the child seat. Safety label is checked to ensure that the identified CRS have obtained regulatory approval of at least the United Nation Economic Commission for Europe (UN ECE) R44 regulation. It is also important to confirm that the car seats are brand new.

### *2.1.2 Test Set-up*

CRS that have passed the visual assessment would then be installed in a car with two different Q-Series dummies representing 18-month-old (Q1.5) and 3-year-old (Q3) children. Both dummies are instrumented with transducers as listed in Table 1 according to procedures laid out in SAE J211/1 (SAE International, 2014a) and SAE J211/2 (SAE International, 2014b) for Photographic Instrumentation. The test vehicle is set up with the standard vehicle instrumentation (ASEAN NCAP, 2017b), with an additional accelerometer installed under the rear seat floor (Figure 3) to measure actual acceleration acting on the CRS (ASEAN NCAP, 2017a). An on-board data acquisition unit is also included.

**Table 2:** Q1.5 and Q3 dummies instrumentation (ASEAN NCAP, 2017b)

**Q3**

| Location | Parameter | | Minimum Amplitude | No of Channels |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | | 150g | 3 |
| Neck | Forces | $F_x$ $F_y$ | 3kN | 2 |
| | | $F_z$ | 6kN | 1 |
| | Moments, $M_x$ $M_y$ $M_z$ | | 290Nm | 3 |
| Chest | Accelerations, $A_x$ $A_y$ $A_z$ | | 150g | 3 |
| | Deflection Frontal | | 50mm | 1 |
| | Total Channels per Dummy | | | 13 |

**Q1.5**

| Location | Parameter | | Minimum Amplitude | No of Channels |
|---|---|---|---|---|
| Head | Accelerations, $A_x$ $A_y$ $A_z$ | | 150g | 3 |
| Neck | Forces | $F_x$ $F_y$ | 3kN | 2 |
| | | $F_z$ | 6kN | 1 |
| | Moments, $M_x$ $M_y$ $M_z$ | | 290Nm | 3 |
| Chest | Accelerations, $A_x$ $A_y$ $A_z$ | | 150g | 3 |
| | Deflection Frontal | | 50mm | 1 |
| | Total Channels per Dummy | | | 13 |


**Figure 3:** Tri-axial accelerometer placement under the rear seat floor (ASEAN NCAP, 2017a)

## 2.2 Vehicle Frontal Impact Test

Frontal impact test was conducted at MIROS's Provisional CRASE Crash Centre Laboratory (or the PC3 Laboratory – Figure 4) located in Melaka following ASEAN NCAP Testing Protocol – Frontal Impact (ASEAN NCAP, 2017b). The car was subjected to an offset deformable barrier test at 64 km/h ± 1 km/h. Dynamic response data was recorded; specific for the Child Occupant Protection assessment, the dynamic measurement for the CRS performance was focused on the acceleration data under the rear seat floor and measurements on the dummies' head and chest following the ASEAN NCAP's COP protocol (ASEAN NCAP, 2018).

**Figure 4:** MIROS PC3 Laboratory at Melaka (MIROS, 2018)

### 2.3 Post-test

Post-test assessment is conducted following Subsection 4.1 in ASEAN NCAP Child Occupant Protection Assessment (ASEAN NCAP, 2018).

*2.3.1 Inspection on Dummies Condition*

The child dummies should be inspected after the crash test to see whether they are ejected or partially ejected from the CRS during impact. Ejection of any dummies from its child seat would cause the CRS to be eliminated from the CRS shortlist.

*2.3.2 Inspection on CRS Condition*

If the CRS is partially or wholly unrestrained due to the CRS failure during impact, that particular CRS would not be considered in the final CRS Reference List.

*2.3.3 Data Analysis*

Acceleration data recorded on the dummies' head and chest in frontal impact are examined based on the guidelines provided by ASEAN NCAP (Table 3) (ASEAN NCAP, 2018):

**Table 3:** Head and chest resultant acceleration

| **Head Resultant Acceleration** | | |
|---|---|---|
| **Q1.5** | 4 points ≤ 72g; | 0 points ≥ 88g |
| **Q3** | 4 points ≤ 87g; | 0 points ≥ 100g |
| **Chest Resultant Acceleration** | | |
| **Q1.5** | 2 points ≤ 41g; | 0 points ≥ 55g |
| **Q3** | 2 points ≤ 50g; | 0 points ≥ 66g |

## 3.0 RESULTS AND DISCUSSION

This section shall the results, i.e. the pre-test, frontal impact test, and post-test.

### 3.1 Pre-test

*3.1.1 Visual Assessment of CRS*

Shortlisted CRS as presented in Table 1 were obtained by ASEAN NCAP and assessed visually to check on the quality and authenticity of the child seat. A few of the CRS were found to be below standard and have to be removed from further consideration. However, the authors would not list those removed CRS in this paper to avoid future implications.

*3.1.2 Test Set-up*

The impact tests were performed in three separate occasions at MIROS PC3 using a combination of forward and rear-facing CRS that have passed the visual assessment. The crash test was witnessed by the authors and CRS suppliers.

### 3.2 Vehicle Frontal Impact Test

Figures 5 and 6 illustrate the sequence of impact towards CRS and child dummies Q1.5 and Q3 respectively. It is important to analyse the impact recording to see the child dummies and CRS conditions during impact. It was observed that both dummies and CRS were intact and secured during impact. A similar observation was found when using different CRS.

**Figure 5:** CRS and Q1.5 dummy condition during impact (Ahmad, 2018)

**Figure 6:** CRS and Q3 dummy condition during impact (Ahmad, 2018)

### 3.3 Post-test

*3.3.1 Inspection on Dummies Condition*

The condition of child dummies was inspected after the crash test. It was found that both Q1.5 and Q3 dummies were fully secured in their CRS. A similar observation was found when using different CRS.

### *3.3.2 Inspection on CRS Condition*

The condition of both forward and rear-facing CRS was inspected after the crash test. It was found that all tested CRS were fully restraint to the vehicle's restraint system during and after the crash.

### *3.3.3 Data Analysis*

Acceleration data collected on the rear seat floor is recorded and presented in Figure 7. The measured acceleration on the rear seat floor exceeded the new limit curves developed by ASEAN NCAP (2017b), which demonstrates a high acceleration impact to the rear passenger (i.e., in this work is the children in CRS). This finding highlighted the importance of using the CRS when travelling with children.

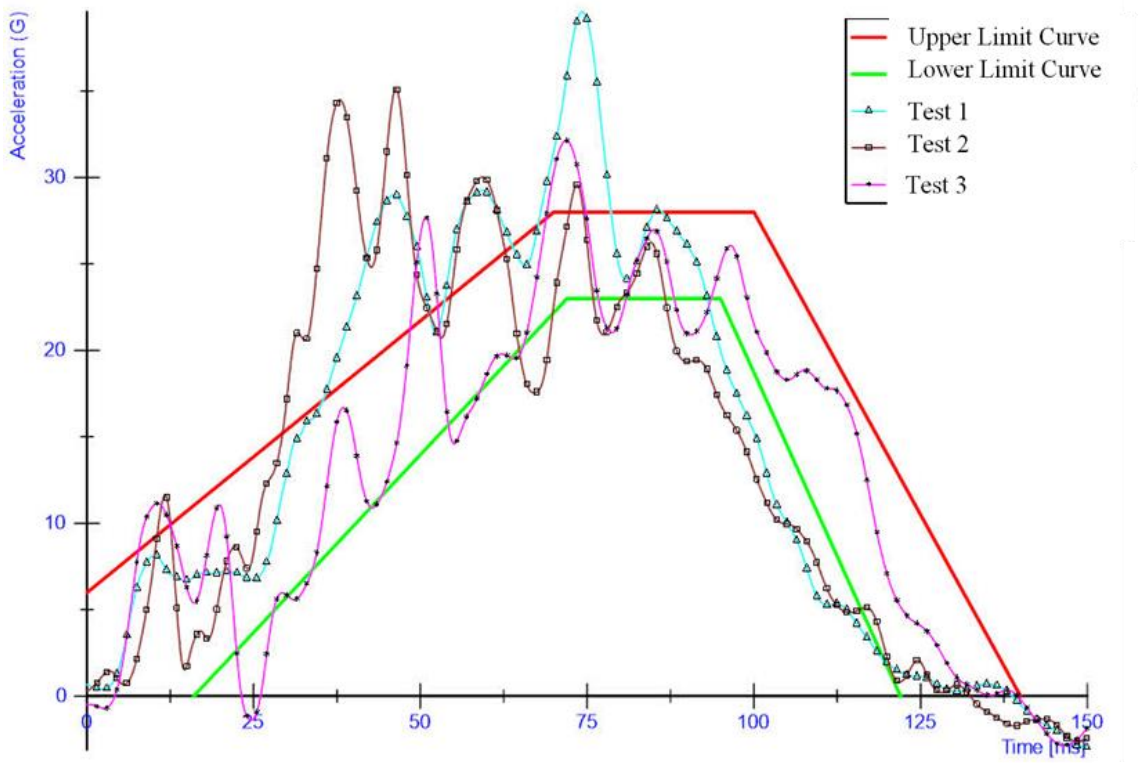


**Figure 7:** Acceleration data at rear seat floor (Ahmad, 2018)

Figure 8 depicts head resultant acceleration measured on the Q1.5 (top) and Q3 (bottom) dummies using six different CRS. From Figure 8 (top), it can be observed that the peak resultant data is way below the guideline provided by ASEAN NCAP of 88g, while acceleration data on Q3 shows similar findings (i.e., below peak limit of 100g). Multiple peaks indicate rebounds due to impact.

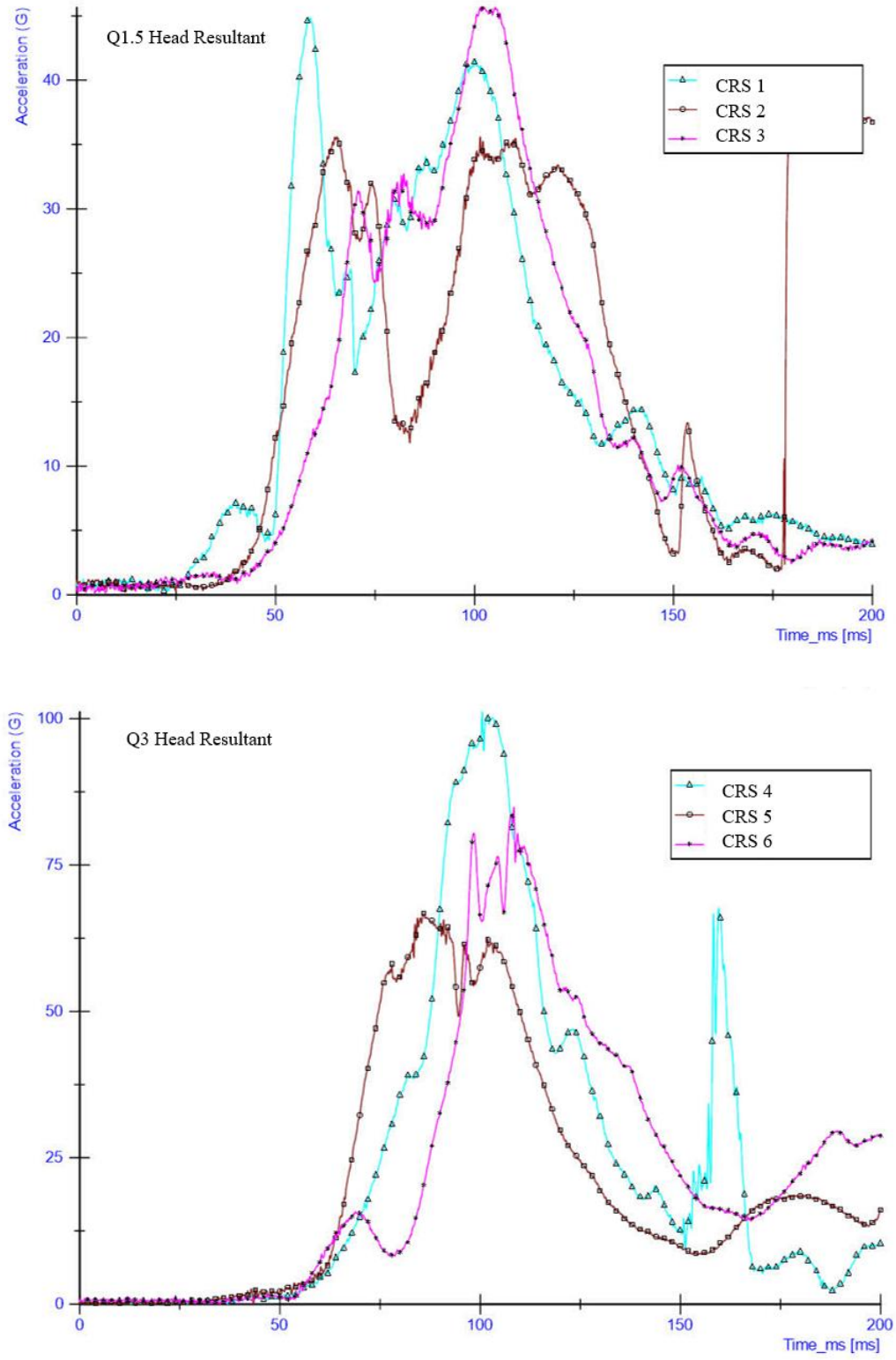


**Figure 8:** (Top) Head resultant acceleration on Q1.5 dummy; (Bottom) Head resultant acceleration on Q3 dummy (Ahmad, 2018)

Figure 9 illustrates chest resultant acceleration measured on the Q1.5 (top) and Q3 (bottom) dummies using six different CRS. From Figure 9 (top), it can be observed that the peak resultant data is below the guideline provided by ASEAN NCAP of 55g, while acceleration data on Q3 shows similar findings (i.e., below peak limit of 66g). Figures 8 and 9 demonstrate that all selected CRS are suitable for the CRS Reference List. A number of shortlisted CRS would be assessed similarly to complete the final CRS Reference List.

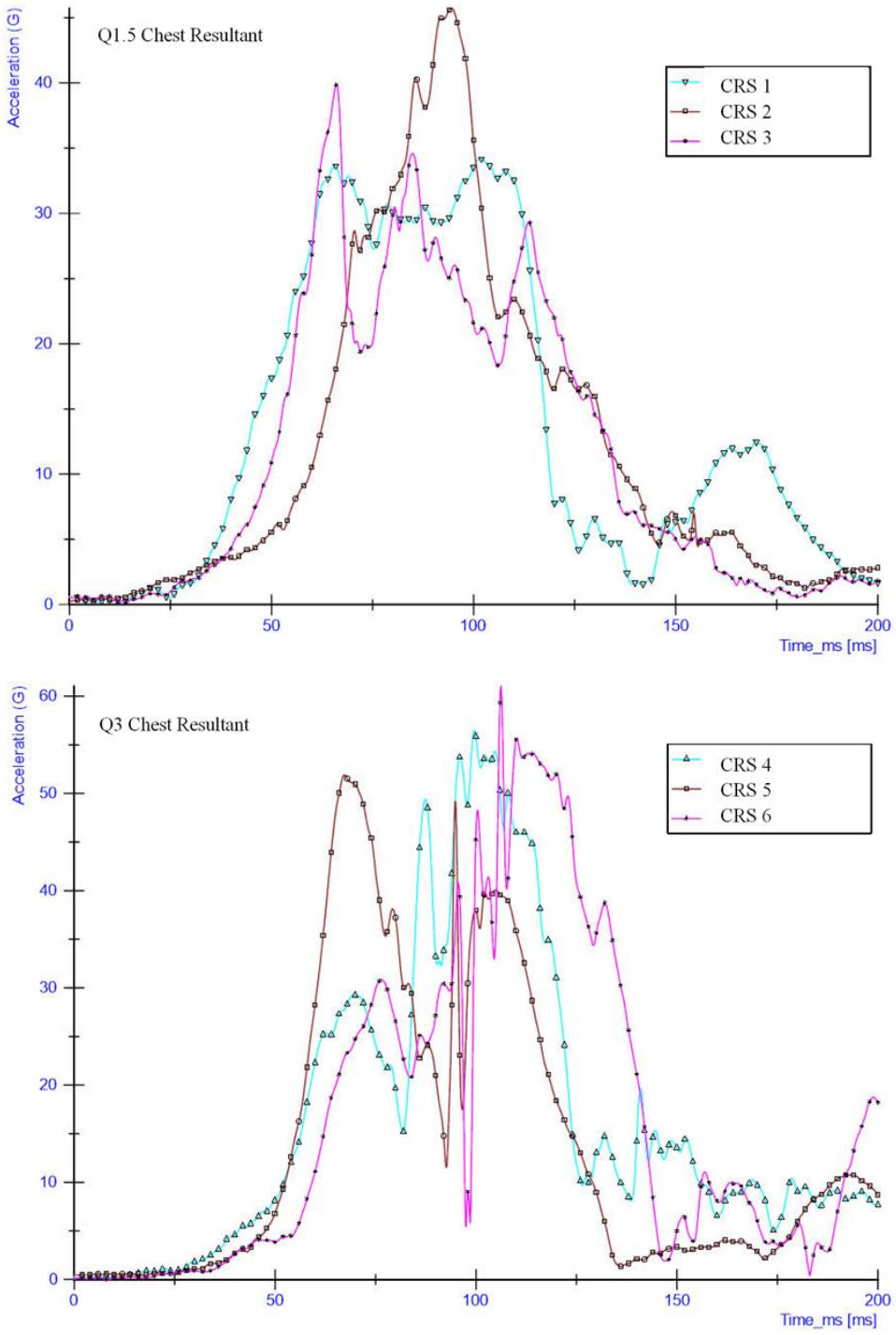


**Figure 9:** (Top) Chest resultant acceleration on Q1.5 dummy; (Bottom) Chest resultant acceleration on Q3 dummy (Ahmad, 2018)

## 4.0 CONCLUSION

This paper presents the technical assessment procedure to establish the updated CRS Reference List used in the ASEAN NCAP Child Occupant Protection protocol. The assessment process includes the pre-test, vehicle impact test and post-test evaluation. During the pre-test assessment, a few CRS were ruled out from the shortlist. The remaining CRS were tested accordingly and their performances were reported in this paper. It is recommended for ASEAN NCAP to follow the systematic revision process for its future modification of the CRS Reference List.

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