Variations in injury risk with different forms of forward facing child restraint system misuse

Lucas, E.[1], Brown J.[1], Bilston L.E[1].
[1]Prince of Wales Medical Research Institute, University of New South Wales
email: j.brown@powmri.edu.au; l.bilston@powmri.edu.au

Introduction

The misuse of forward facing child restraints (FFCRs) is common, and an association between FFCR misuse and serious injury has often been reported, e.g. [1]. However there are many ways in which a FFCR can be used incorrectly. Lalande et al [2] demonstrated that different forms of misuse can have different effects on the protection provided by an incorrectly used restraint. Although they studied only a few types of misuse, this work indicated that some forms of misuse are much more serious than other forms. A recent observation study of child restraint use in NSW has quantified and described the types of misuse occurring among children using FFCRs across NSW (Brown & Bilston, unpublished data). There is a need to identify those forms of FFCR misuse that deserve highest priority in countermeasure development among those forms of misuse occurring most commonly in Australia.

This paper presents the results of a study examining injury risk variations in a sample of 15 common forms of FFCR misuse compared to a correctly used restraint, when subjected to simulated oblique impact. The implications, in terms of countermeasure development, are also discussed.

Methods

Thirty-two simulated impacts using the CRABI 6 month dummy restrained by a common FFCRS on a standard test seat were conducted. 15 different misuse modes representing 8 common usage and 7 common installation problems were compared to correct use (see Table 1). Duplicate tests of each condition were performed. Tests were conducted on a rebound sled at an approximate severity of 32 km/h and 16g. Head accelerations were measured in the dummy. High speed video was used to capture dummy and restraint motion. Variations in head injury potential were assessed using dummy responses and dummy and restraint motion.

Descriptor	Type	Description
NM	Correct	No misuse
H1	Usage	One arm out of harness
H2	Usage	Both arms out of harness
H3	Usage	Harness positioned too high
H4	Usage	Harness positioned too low
H5	Usage	Harness slack (50mm)
H6	Usage	Harness slack (75mm)
H7	Usage	Harness twisted
H8	Usage	Baby insert still in place
I1	Installation	Seat belt slack
I2	Installation	Top tether slack
I3	Installation	Seat belt & top tether slack
I4	Installation	No tether
I5	Installation	No seat belt
I6	Installation	Incorrect seat belt routing
I7	Installation	Seat belt not buckled

Table 1: Forms of misuse

Results and discussion

Variations in head injury potential were assessed by comparing Head Injury Criteria (HIC) values and dummy head excursion. Figure 1 illustrates the HIC values associated with each restraint configuration compared to correct use (black bar Figure 1). The majority of misuse forms resulted in higher HIC values than when the restraint was used correctly, indicating generally an increase in head injury potential. The highest HIC values were obtained when the tether was not used (I4) and the tether was loosely attached (I2). These conditions resulted in HIC values that were 82% and 70% respectively higher than in the correctly used restraint.

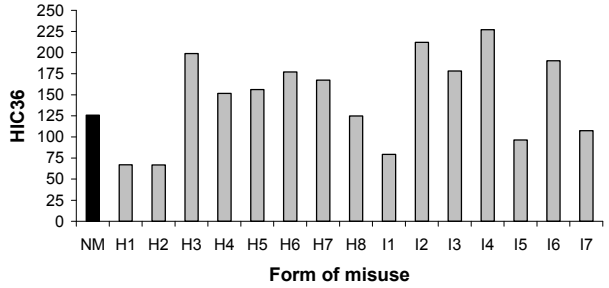

Figure 1: HIC values associated with different forms of FFCRS misuse. The black bar denotes correct use. Definitions of misuse descriptors are given in Table 1.

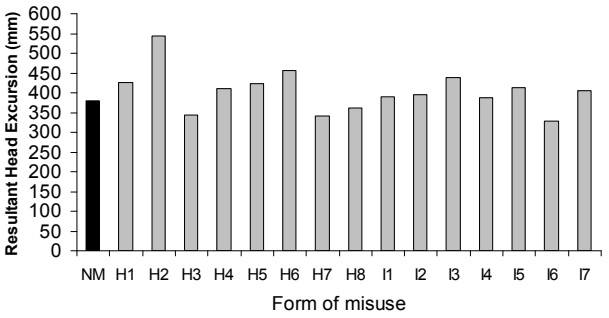

Figure 2: Resultant head excursion associated with different forms of FFCRS misuse. The black bar denotes correct use. Definitions of misuse descriptors are given in Table 1.

It should be remembered however that HIC is primarily designed to describe head injury risk associated with head impact. This test setup includes few of the vehicle interior components that pose a risk for head strike. The use of HIC as the main indicator of head injury risk is therefore questionable. Furthermore, some forms of incorrect use (H1, H2, I1, I5, I7) were associated with a reduction in HIC yet these restraint configurations were among those that resulted in the greatest forward excursion of the dummy. The relatively lower HIC values alone are not associated with a reduction in injury risk. The greater the forward movement of the dummy the greater the risk of the dummy (or a child in the real world) striking an intruding structure or some part of the vehicle interior. As shown in Figure 2, 11 of the 15 forms of misuse tested resulted in dummy head excursion that was greater than when the restraint is used correctly.
Head excursion was increased in all forms of misuse that allowed greater motion of the dummy and/or the restraint. The only forms of misuse tested that did not have this effect were the conditions when the harness was positioned above the dummy's shoulders; the harness was twisted; the baby insert was left in place; and, the seat belt was routed incorrectly. The worst restraint configurations in terms of head excursion were when both arms were not within the harness and there was 75mm of slack left in the harness.

From Figures 1 and 2 it appears that incorrect installation problems such as the lack of top tether use, a slack top tether and incorrect seat belt routing had the most deleterious effect on the HIC values, and usage problems such as failing to use the harness or allowing the harness to be used with 75mm or more of slack had the most deleterious effect on head excursion. These modes of misuse should be given the highest priority in terms of countermeasure development.

It is important to note that in most cases the effects of harness misuse were equal to or worse than the effects of incorrect installation. Existing FFCR misuse countermeasures, such as LATCH and ISOfix anchorages, restraint fitting station networks and/or other hands-on child restraint fitting guidance programs, often focus on incorrect installation. The results of this test program demonstrate the need for education and restraint based programs for reducing the misuse of the internal harness system of FFCRs. Specifically child restraint manufacturers should be encouraged to design harness systems that are easy to use and adjust correctly. The Australian child restraint evaluation program (CREP) [3] provides for the award of bonus points for child restraints that have some means of alerting parents and carers that a child is not using the internal harness system. While such a warning system is technically feasible, no restraint currently includes such a feature. There is also scope for more specific warning labels on the child restraint reminding parents and carers of the importance of correctly using the internal harness system. This issue is currently being contemplated for inclusion in the upcoming revision of AS/NZ1754, the

mandatory standard covering the design of child restraints sold in Australia (CS-085 committee, personal communication).
The misuse modes tested here represent those modes most commonly observed in a recent observation study of children travelling in cars in NSW (Brown & Bilston, unpublished data). It is likely that with current strategies to increase the number of children using FFCR, the frequency of these forms of misuse will increase linearly with any increase in FFCR use. This also means that strategies such as the recent change in child restraint legislation will not be as effective in reducing casualty numbers among child occupants as they might be, unless specific strategies to combat these forms of misuse are also introduced.

Conclusions
The highest priority for countermeasure development to reduce the rates of misuse among forward facing child restraint users should be given to those measures aimed at reducing the incorrect use of the internal harness system. Measures to reduce installation errors associated with the top tether and the correct use of the seat belt as part of the restraint's anchorage system are also important.

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