IS COMFORT IMPORTANT FOR OPTIMAL USE OF CHILD RESTRAINTS?

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ABSTRACT

Suboptimal restraint use, particularly the incorrect use of restraints, is a significant and widespread problem among child vehicle occupants, and increases the risk of injury. Previous research has identified comfort as a potential factor influencing suboptimal restraint use.

Both the real comfort experienced by the child and the parent’s perception of the child’s comfort are reported to influence the optimal use of restraints. Problems with real comfort may lead the child to misuse the restraint in their attempt to achieve better comfort whilst parent-perceived discomfort has been reported as a driver for premature graduation and inappropriate restraint choice. However, this work has largely been qualitative. There has been no research that objectively studies either the association between real and parental perceived comfort, or any association between comfort and suboptimal restraint use. One barrier to such studies is the absence of validated tools for quantifying real comfort in children.

We aimed to develop methods to examine both real and parent-perceived comfort and examine their effects on suboptimal restraint use.

We conducted online parent surveys (n=470) to explore what drives parental perceptions of their child’s comfort in restraint systems (study 1) and used data from field observation studies (n=497) to examine parent-perceived comfort and its relationship with observed restraint use (study 2). We developed methods to measure comfort in children in a laboratory setting (n=14) using video analysis to estimate a Discomfort Avoidance Behaviour (DAB) score, pressure mapping and adapted survey tools to differentiate between comfortable and induced discomfort conditions (study 3).

Preliminary analysis of our recent online survey of Australian parents (study 1) indicates that 23% of parents report comfort as a consideration when making a decision to change restraints. Logistic regression modelling of data collected during the field observation study (study 2) revealed that parent-perceived discomfort was not significantly associated with premature graduation. Contrary to expectation, children of parents who reported that their child was comfortable were almost twice as likely to have been incorrectly restrained (p<0.01, 95% CI 1.24 - 2.77).

In the laboratory study (study 3) we found our adapted survey tools did not provide a reliable measurement of real comfort among children. However our DAB score was able to differentiate between comfortable and induced discomfort conditions and correlated well with pressure mapping.

Our results suggest that while some parents report concern about their child’s comfort, parent-reported comfort levels were not associated with restraint choice. If comfort is important for optimal restraint use, it is likely to be the real comfort of the child rather than that reported by the parent. The method we have developed for studying real comfort can be used in naturalistic studies involving child occupants to further understand this relationship.

This work will be of interest to vehicle and child restraint manufacturers interested in improving restraint design for young occupants as well as researchers and other stakeholders interested in reducing the incidence of restraint misuse among children.
INTRODUCTION

One of the leading causes of death among children in Australia is traffic crashes. On average 70 children are killed per year (10 year average, 2002-2011, (BITRE 2012)), and 3000 are seriously injured as vehicle passengers (Brown and Bilston 2012) despite greater than 99% child restraint system (CRS) use (Brown et al. 2010). These statistics have not changed greatly over the last two decades (Brown and Bilston 2012).

Incorrect and inappropriate CRS use or suboptimal CRS use is a widespread problem that reduces the protection offered by a child restraint and increases the risk of injury (Brown and Bilston 2007; Bull et al. 1988; Jakobsson et al. 2005). Incorrect restraint use includes both the errors in installation as well as incorrect adjustment and securing of the child into the restraint. Inappropriate restraint use is the use of a restraint that does not match the age and size of the child, this usually manifests in using a restraint designed for an older/larger child. Incorrect restraint use is as common as inappropriate restraint choice (Brown et al. 2010) and carries a higher risk of injury than inappropriate choice (Brown and Bilston 2007; Du et al. 2008).

There have been some indications that child comfort and/or the parental perception of child comfort plays a role in the choice of CRS and/or the correctness of use of a child restraint (Bilston et al. 2011; Pettersson and Osvalder 2005; Simpson et al. 2002). Studies have suggested that children prefer restraints that are comfortable for them (Bohman et al. 2007; Osvalder et al. 2013; Pettersson and Osvalder 2005). While Bingham et al. (2006) reported that parental perception of increased comfort motivated parents to use boosters for their children rather than adult seat belts, other studies report perceived discomfort in a booster seat as a reason for parents to prematurely move their child to an adult seat belt (Charlton et al. 2006; Simpson et al. 2002).

Discomfort has also been associated with incorrect child restraint use (Klinich et al. 1994; Osvalder et al. 2013). Bohman et al. (2007) suggested that poor restraint fit caused discomfort in children, and the avoidance of discomfort resulted in severe misuse of restraints.

The lack of validated methods for studying seating comfort in children is a barrier to the study of comfort among children in child restraints. While there are accepted methods such as the use of self-report survey tools (Chae et al. 2011; Donnelly et al. 2009; Gyi and Porter 1999; Smith et al. 2006) and pressure distribution mapping (Chae et al. 2011; Gyi and Porter 1999; Kyung and Nussbaum 2008; Kyung et al. 2008; Paul, Daniell, et al. 2012; Paul, Pendlebury, et al. 2012; Porter et al. 2003) for studying the comfort of adults in vehicles there has been almost no use of these methods for child occupants. The exception is a recent study by Osvalder et al. (2013) who used a self-report survey tool to capture comfort of children in a naturalistic study of children in booster seats. However, the validity of this self-report tool is untested. Earlier studies examined the comfort and usability of different CRS through the observation of parental handling and interaction with the CRS, parental surveys and observations of the child in the CRS during a drive (Pettersson and Osvalder 2005). This study did not interview the child, noting that incoherent answers are often provided by children under the age of 10. Nilsson and Wolstedt (2007) combined anthropometric data, ergonomic modelling and child opinions to develop an ergonomic booster seat however they did not describe the process in detail.

Over the last three years, we have undertaken a number of studies in an attempt to study comfort and its association with sub-optimal restraint use. This paper presents an overview of the work conducted to date.

METHODS

The work presented here relates to preliminary findings from three independent studies conducted as part of a large program of work aimed at providing a wider understanding of the factors underpinning optimal restraint use and the role that comfort might play. All studies have been approved by the UNSW Human Research Ethics Committee.

Online Parent Survey

This study used data collected during an online survey of a cohort of Australian parents and carers, designed to examine and evaluate barriers to appropriate and correct restraint use. Data was collected between May and
July, 2014. Participants had to be over the age of 18, own their own vehicle, have a child between the ages of 0 and 7 years who they transport at least once a week, and regularly use some sort of child restraint. Three questions related to comfort were extracted for this analysis.

One question asked parents to report which of the following factors they would take into account when making a decision to move their child into a different type of restraint: “My child is too big for the restraint; The new restraint is more convenient than my current restraint; The restraint is easier to use than my current restraint; My child is not comfortable in the current restraint; My child is too old for the restraint; My child does not want to use the current restraint any longer; I need the restraint for a younger child”. This data was used to examine how often parents take comfort into account when making transition decisions.

The second question asked whether parents thought that the child restraint their child was using looked comfortable using a five level Likert scale.

The third question asked parents directly if their child was comfortable in the restraint and if so they were asked to provide reasons why. This was an open ended question. The reasons provided by parents were qualitatively explored. This involved reading through the responses and identifying commonly reported reasons why parents thought the child was comfortable using content analysis techniques.

Field Observation Study

This analysis used data collected during a 2008 cross-sectional population representative observational study of child restraint practices among children aged 0-12 years across NSW (see Brown et al. (2010) for more details). Children aged 0-12 arriving in vehicles were observed at randomly selected early childhood health clinics, day care centres, pre-schools and primary schools within randomly selected local government areas across NSW. Trained researchers made in situ observations of the child within the restraint, conducted a detailed examination of the restraint installation, and conducted a structured interview with the driver. Only one child per vehicle was selected for observation.

Variables related to parent perceived comfort issues and other known risk factors of inappropriate and incorrect use, together with the observed appropriate and correct use of restraints was extracted for this analysis and this has been reported elsewhere (Fong et al, manuscript under review). In summary, logistic regression modelling was used to examine 1. the relationship between age appropriate restraint use and parent reported comfort issues while controlling for parent education levels, language spoken at home, parent income and the restraint type (seat belt vs child restraint), and 2. The relationship between correct restraint use and parent reported comfort issues while controlling for parent education levels, language spoken at home, parent income and the restraint type (convertible restraint, yes/no).

All analysis was performed using SAS Version 9.4 (SAS Institute, 2013). The SURVEYLOGISTIC procedure was used to account for the complex sample design.

Laboratory Comfort Measuring Study

This study compared anthropometrically comfortable seating positions to induced discomfort seating positions using a specially designed seating rig that allowed for the adjustment of cushion length and seat belt height. Children aged 4- 8yrs were recruited through social media and advertisements on public noticeboards. Prior to the sitting trial, stature, weight and buttock-to-popliteal length (BPL) were measured.

The comfortable (Fit) position of the seat was determined for each child using (i) a seat cushion length that corresponded to the BPL, and (ii) adjusting the seatbelt D-ring so that the sash belt was placed in the optimum position running midway across the shoulder, crossing the centre of the chest without contacting the neck. The seat back angle remained at a constant 10 degree recline.

Children were then asked to sit sequentially in the four conditions listed in Table 1. The order of these conditions was randomised. Each child was required to sit, correctly restrained, in each condition for 10
minutes. At the end of the 10 minutes, while the child was still restrained, the self-report survey tool was administered. There was a 10 minute break between each trial.

For the majority of the trials, the child watched children’s TV shows throughout the 10 minute trial interval. In four participants, this was removed to provide the ‘no stimulus’ (NS) condition.

Each trial was video recorded for later analysis.

<table>
<thead>
<tr>
<th>Condition</th>
<th>n</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fit</td>
<td>14</td>
<td>Anthropometric fit based of stature and buttocks to popliteal length (comfortable)</td>
</tr>
<tr>
<td>Fit+Footrest</td>
<td>14</td>
<td>As above with the introduction of a footrest (comfortable)</td>
</tr>
<tr>
<td>Cushion Long</td>
<td>14</td>
<td>As above but with the cushion length 10cm too long (uncomfortable)</td>
</tr>
<tr>
<td>Seat Belt High</td>
<td>14</td>
<td>As Fit+Footrest but with the seatbelt height adjusted to create sash belt contact with neck (uncomfortable)</td>
</tr>
<tr>
<td>No Stimulus</td>
<td>4</td>
<td>As Fit but without video stimulus</td>
</tr>
</tbody>
</table>

Three different methods of measuring comfort were compared in order to find a method that can reliably differentiate between comfortable and uncomfortable seating positions among children. This is also presented in more detail elsewhere (Fong et al, manuscript in preparation). In summary, the methods used to measure comfort were (i) a self-report questionnaire, (ii) pressure distribution mapping, and (iii) a newly developed analysis method.

For the self-report survey tool, we looked at established and validated pain research protocols (Bieri et al. 1990; Hicks et al. 2001; Wong and Baker 1988) and guidelines for constructing surveys for children (Borgers et al. 2000, 2004) as well as some tools used to study comfort in adults (Gyi and Porter 1999). Taking all these into account we modified the body discomfort chart (Gyi and Porter 1999) and paired it with a modified form of the Wong-Baker FACES Pain (Wong and Baker 1988) in an effort to create a survey instrument that can be used with children.

Two different survey tools were used. Survey Tool 1 included the FACES Pain Scale with one mid-range face removed (7 point scale modified to 6 point scale) and the full 20 point Body Part Discomfort Chart, with the scale reduced from 1-7 to 0-5. The mid-range face was removed as it did not appear to provide much discrimination between the two adjacent faces, and the Body part Discomfort Chart scale was reduced in line with Borgers et al. (2000, 2004)’s guidelines. Survey Tool 2 used the same components of the FACES Pain Scale with the 20 Body Part Discomfort Chart summarised to six body regions. See Figure 1.
Pressure distribution data were collected using a CONFORMat (Tekscan, Inc South Boston MA, USA) which consists of two pressure mats, one for the seat base and one for the seat back. Recordings from the CONFORMat system was analysed in three ways; change in centre of force (ΔCOF - distance), contact area (CA - area) and peak pressure (PP - force).

Video footage was recorded using a 720p camcorder placed at a 45 degree angle to the left of the testing rig to record wide angle front left quarter view. Still images were also captured using a 12MP digital camera for reference. A video analysis protocol was developed to calculate the rate of Discomfort Avoidance Behaviours (DAB) observed. Video footage was analysed using Kinovea (Kinovea 0.8.15, Kinovea.org 2012) video analysis software. DAB was defined as any shift in seating position, playing with the seat belt, and child stretching. To score the footage, each clip was watched and any instance of these behaviours was marked with a reference frame in the software. These behaviours were then tallied for each condition before being divided by the video clip duration to calculate the average number of discomfort avoidance behaviours per minute (the DAB score or DAB rate).

The reliability of the DAB rate was measured by having a second researcher repeat the scoring. Differences between the two researcher scores were examined using the intraclass correlation coefficient (ICC).

The overall analysis involved paired samples T-tests to examine differences between seating conditions for the DAB, pressure and survey protocols. Correlation between the three measures of comfort was examined using Pearson’s r. Normal distribution of data was also tested.

**RESULTS**

**Online Survey**

Data was collected from 470 parents or carers across Australia. Figure 2 provides the responses obtained to the question about what factors parents consider in making restraint transitions.
Figure 2: Relative importance of reasons provided by parents for considering a new restraint or moving their child into a seat belt (multiple responses were allowed)

Almost one quarter of parents (23%) reported that they would consider transitioning their child if they thought their child was not comfortable in their current restraint.

Most parents (86.4%) agreed that the restraint their child was using looked comfortable (39.4% strongly agree, and a further 47% agree).

Three quarters (75%) of parents also indicated they perceived their child was comfortable in the restraint. The most common reasons given related to a lack of complaint from the child (26% of those reporting the child was comfortable), the ability of the child to sleep in the restraint (22% of those reporting the child was comfortable) and the presence of padding and support in the restraints (22% of those reporting the child was comfortable).

Field Observation Study

Results from the logistic regression modelling are presented in Table 2 and Table 3.

As shown in Table 2 there was a significant increase in the odds of child restraint misuse when there were no comfort problems reported by the parent (OR 1.85, 95% CI 1.24-2.77). There was also an increased odds of restraint misuse when a convertible restraint (rearward facing/forward facing or forward facing/booster) was used, irrespective of a reported comfort problem (OR 13.47, 95% CI 5.66-32.03).
Table 2
Logistic regression results for incorrect use vs correct use (** = significant)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Unweighted Frequency</th>
<th>Weighted %</th>
<th>Unweighted OR</th>
<th>CI 95%</th>
<th>Weighted OR</th>
<th>CI 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComfortProblem**</td>
<td>Yes</td>
<td>60</td>
<td>61.7%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>374</td>
<td>58.3%</td>
<td>0.87</td>
<td>0.57 - 1.32</td>
<td>1.85</td>
<td>1.24 - 2.77</td>
</tr>
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<td>Education</td>
<td>Tertiary Education</td>
<td>288</td>
<td>56.9%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Secondary or Lower</td>
<td>155</td>
<td>61.9%</td>
<td>1.24</td>
<td>0.81 - 1.91</td>
<td>0.98</td>
<td>0.46 - 2.10</td>
</tr>
<tr>
<td>LanguageAtHome</td>
<td>Other</td>
<td>20</td>
<td>60.0%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>English</td>
<td>444</td>
<td>58.6%</td>
<td>1.24</td>
<td>0.35 - 4.36</td>
<td>2.15</td>
<td>0.69 - 6.67</td>
</tr>
<tr>
<td>Income</td>
<td>Over $100,000</td>
<td>112</td>
<td>60.7%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$50,000-$100,000</td>
<td>191</td>
<td>56.5%</td>
<td>0.91</td>
<td>0.52 - 1.60</td>
<td>0.99</td>
<td>0.36 - 2.71</td>
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<tr>
<td></td>
<td>Less than $50,000</td>
<td>132</td>
<td>59.8%</td>
<td>1.13</td>
<td>0.71 - 1.78</td>
<td>1.45</td>
<td>0.42 - 4.99</td>
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<tr>
<td>Convertible**</td>
<td>No</td>
<td>350</td>
<td>46.0%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>147</td>
<td>90.5%</td>
<td>11.88</td>
<td>6.73 - 20.97</td>
<td>13.47</td>
<td>5.66 - 32.03</td>
</tr>
</tbody>
</table>

As shown in Table 3 there was no significant association between parent reported comfort problems and the use of age appropriate child restraints. However, there was a significant decrease in the odds of using a non-age appropriate restraint when the parents education level was higher, irrespective of a parent reported comfort problem (OR 0.33, 95% CI 0.21-.53). Furthermore, the likelihood that an age appropriate restraint was used was increased when a child restraint was used as opposed to a seatbelt, irrespective of a parent reported comfort problem (OR 2.75, 95% CI 1.29-5.12).

Table 3
Logistic regression results showing age appropriate restraint use versus inappropriate use (** = significant)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Unweighted Frequency</th>
<th>Weighted %</th>
<th>Unweighted OR</th>
<th>CI 95%</th>
<th>Weighted OR</th>
<th>CI 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComfortProblem</td>
<td>Yes</td>
<td>60</td>
<td>73.3%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>374</td>
<td>80.7%</td>
<td>1.42</td>
<td>0.80 - 2.54</td>
<td>1.11</td>
<td>0.34 - 3.59</td>
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<td>Education**</td>
<td>Tertiary Education</td>
<td>288</td>
<td>80.2%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
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<tr>
<td></td>
<td>Secondary or Lower</td>
<td>155</td>
<td>76.1%</td>
<td>0.78</td>
<td>0.59 - 1.03</td>
<td>0.33</td>
<td>0.21 - 0.53</td>
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<tr>
<td>LanguageAtHome</td>
<td>Other</td>
<td>20</td>
<td>60.0%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>English</td>
<td>444</td>
<td>80.2%</td>
<td>1.75</td>
<td>0.51 - 6.03</td>
<td>1.90</td>
<td>0.88 - 4.12</td>
</tr>
<tr>
<td>Income</td>
<td>Over $100,000</td>
<td>112</td>
<td>83.0%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$50,000-$100,000</td>
<td>191</td>
<td>78.0%</td>
<td>0.80</td>
<td>0.50 - 1.28</td>
<td>0.81</td>
<td>0.31 - 2.15</td>
</tr>
<tr>
<td></td>
<td>Less than $50,000</td>
<td>132</td>
<td>78.8%</td>
<td>0.88</td>
<td>0.49 - 1.61</td>
<td>1.03</td>
<td>0.40 - 2.67</td>
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<tr>
<td>RestraintType**</td>
<td>Seatbelt</td>
<td>196</td>
<td>63.8%</td>
<td>Reference</td>
<td></td>
<td>Reference</td>
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<tr>
<td></td>
<td>Restraint</td>
<td>301</td>
<td>89.7%</td>
<td>3.99</td>
<td>2.40 - 6.64</td>
<td>2.57</td>
<td>1.29 - 5.12</td>
</tr>
</tbody>
</table>

Laboratory Comfort Study

Data was collected from 14 participants aged 4-8yrs (M=5.4yrs, SD=1.5yrs), 3 males and 11 females.

We found our adapted survey tools did not provide a reliable measurement of real comfort among the children within our sample. There were no significant differences in survey scores between seating conditions with the
children reporting comfort even in induced discomfort seating conditions. Survey Tool 1 was used with the first 10 participants but we found it was impractical with the young children that we were working with because they appeared to lose concentration due to the number of items in the tool. Survey Tool 2 was used with the remaining 4 participants but did not seem to be any more useful than Survey Tool 1 because the children did not provide answers that could be used to discriminate between seating conditions.

The seat base and the seat back pressure distributions were analysed separately. There was a significant increase in the ΔCOF between Fit and Fit+Footrest conditions for the seat base (p=0.033, n=13) and a non-significant trend towards an increase ΔCOF for the seat base between Fit and No Stimulus (p=0.056, n=4). For the seat back there was a non-significant trend toward an increase in ΔCOF between Fit and No Stimulus (p=0.058, n=4).

There was a significantly higher average seat base contact area for the Fit condition compared to the Fit+Footrest condition (p=0.007, n=14) and a significantly lower average seat base contact area for the Fit condition compared to the Cushion Long condition (p=0.000, n=14). For the seat back there was a significantly higher contact area for the F condition compared to the CL condition (p=0.023, n=14).

There were no significant differences for either the seat back or seat base for peak pressure.

Analysis of the video footage for discomfort avoidance behaviours allowed us to calculate a DAB rate. We observed a significant increase in the DAB rate for the Seat Belt High condition over the baseline F condition (p<0.01, n=13). No other significant differences were observed between any conditions (Figure 4). However the difference in the DAB rate between Fit and the No Stimulus condition could be significant if there was a larger sample (p=0.087, n=4).

Significant correlations between DAB rate and ΔCOF were observed for the seat base (r(10)=0.763, p<0.01) and seat back (r(11)=0.584, p<0.05) in the Cushion Long condition and in the seat base (r(11)=0.679, p<0.05) of the Fit condition.

![Figure 3: Comparison of ΔCOF for the seat base between conditions (No Stimulus, n=4, for all other conditions n=14). A statistically significant difference was observed between the Fit and Fit+Footrest conditions (p<0.05).](image-url)
The DAB scoring method also proved to be repeatable with average intra class correlation coefficient (ICC) was 0.98 (95% CI 0.954-0.991, F(31,31)=61.425, p<0.001) which indicates a high degree of agreement between the two raters used to assess the DAB rate, indicating the repeatability of this measurement.

DISCUSSION

Our key results from the online survey were that parents continue to report comfort as a factor in their transition decisions but most parents feel that their child is comfortable in their current restraint. In the field observation study we saw that parent perceived comfort is not a predictor of age appropriate restraint use, but contrary to expectation the lack of reported comfort problems increased the odds of restraint misuse. The laboratory comfort study demonstrated that the most useful tool for studying comfort of children in child restraints is likely to be the DAB score.

Parent perception of child comfort in restraints

From the combined field observation study and parental survey we observed an overall low rate of parent reported comfort problems, suggesting that most parents do not believe that their child is experiencing issues with comfort in their CRS. Despite this, comfort was the third most common factor reported as a consideration when making decisions about restraint transitions. This suggests some disconnect in how parents perceive the comfort of their children ‘now’ i.e. the restraint they are using now looks comfortable, and they are comfortable in the restraint they are using now, compared to how parents think they might act in the future e.g. if the child becomes uncomfortable in the future they would change restraints. Yet in the logistic regression models, there was no significant association between parent reported comfort and appropriate/inappropriate restraint status of the child, indicating this ‘future’ concern is not actually driving inappropriate restraint choices. Future analysis could explore this in more detail to examine any possible difference in parent reported comfort for children at transition margins compared to other children.

In our open-ended questions asking why parents thought their child was comfortable; the most common reasons were a lack of complaint from the child, and the child’s ability to sleep in the restraint. While these would appear to be indicators of the child’s actual comfort in the restraint, there is no available data linking child behaviour to comfort. Therefore while this provides some understanding of how the parent perception of child comfort is built, it still does not tell us anything concrete about the actual comfort of the child.
Our finding that child restraint misuse is almost twice as more likely in children where parents do not report comfort problems is contrary to expectations. Considering the above discussion it suggests that when children are not complaining, or are sleeping, or are otherwise indicating to their parents that they are not uncomfortable there is an increased risk of misuse. This anomaly requires further study. It may be that children have incorrectly positioned themselves to achieve a level of comfort or that there is some problem with the factors parents use in making decisions about their child’s level of comfort. Either way it highlights the need to educate parents to be alert for errors in use. Furthermore, this indicates that as suggested by other researchers (Bilston et al. 2011; Pettersson and Osvalder 2005; Simpson et al. 2002), there may be a relationship between the actual comfort of children and incorrect use. While there have been few studies examining comfort experienced by children in child restraint systems and the influence this might have on misuse this remains untested. One study which examined the subjective comfort experienced by a small sample of children using different types of boosters suggested a potential interaction between comfort and the seated posture adopted by a child (Osvalder et al. 2013). There may also be a link between the posture adopted by the child and incorrect use, and this also requires further study.

**Measuring the actual comfort of the child**

A major barrier to the study of the actual comfort of the child is the lack of available validated measures of comfort in children in child restraint systems. Comfort in general is difficult to study, and young children offer a particular challenge. While there have been a number of studies examining comfort in adults, including in vehicles (Chae et al. 2011; Kyung and Nussbaum 2008; Kyung et al. 2008; Paul, Pendlebury, et al. 2012), there are few validated methods for assessing comfort that could easily be adapted for use with young children. Self-report surveys, questionnaires and pressure distribution mapping (Chae et al. 2011; Gyi and Porter 1999; Porter et al. 2003; Smith et al. 2006) appear to be the most common methods employed. Notable examples of survey instruments include the Automotive Seating Discomfort Questionnaire (ASDQ) (Smith et al. 2006) and the body discomfort chart used by Gyi and Porter (1999). However as noted by other researchers (Pettersson and Osvalder 2005), survey and interview measures may not be reliable in children as unreliable answers are often provided by children under age 10. To counter this, we attempted to combine a method commonly used to capture self-reported pain data in young children, with survey and interview methods. However, as reported here, we found this to be an unsuccessful approach. Interestingly, Osvalder et al. (2013) reported the successful use of a survey tool developed using a combination of faces paired with questions in their battery of survey tools to collect information about comfort from children in vehicles. It may be that the difference in child age range between our study and their study might explain this discrepancy. In our study the majority of our participants were less than the age of 6, while in the (Osvalder et al. 2013) study they studied children aged 7-9 years. However it is important to note that our laboratory study aimed to validate the responses of the children with anthropometrically predicted comfortable and uncomfortable seating positions while no validation data for the survey used by other researchers has been presented.

In our laboratory comfort study we attempted to provide each participant with a personalised baseline anthropometric fit using our adjustable testing rig which was constructed from the rear seat of a car as a baseline “comfort” seating condition. This rig was constructed to allow the adjustment of cushion length and height of the D-ring for the seat belt. The angle of the seat back was fixed. For children it has been suggested that a seat base length of 80-95% of the buttocks to popliteal length is required for good fit (Parcells et al. 1999). Our rig allowed us to achieve this seat base length. We have assumed that this will equate to a comfortable seating situation as providing sufficient cushion length would avoid discomfort caused by uneven pressure distribution due to increased flexion of the hips and knees as seen by Le et al. (2014) in taller people; and discouraging a slouched posture since the knees can bend over the front edge of the seat (Parcells et al. 1999). We have also assumed that having an appropriate sash belt fit that does contact the neck and passes over the mid line of the shoulder would also equate to a comfortable condition. However, to date there is no data to support or refute this assumption. Our DAB results do however indicate that children were more likely to fidget in seating conditions where the seatbelt D-ring was high indicating that our assumption about sash belt fit comfort may be correct.
Pressure distribution mapping is another method commonly used to study comfort of adults in vehicle seats. Pressure data has been reported to be strongly associated with comfort (Kolich and Taboun 2004; Kyung and Nussbaum 2008) and static pressure distribution measurements have been shown to be repeatable and sensitive to different seating characteristics (Kolich and Taboun 2004). However, at least two studies have reported no clear relationship between interface pressure and comfort (Chae et al. 2011; Gyi and Porter 1999; Porter et al. 2003). Furthermore, Porter et al. (2003) reported pressure measurements lacked enough sensitivity to distinguish between four different seats. Despite the contentiousness of this issue, pressure mapping continues to be a reasonable objective measure of comfort/discomfort and pressure variables are still commonly used for this purpose in ergonomic seat design. Chae et al. (2011) and Kyung and Nussbaum (2008; 2008) argue that pressure data such as the total contact area, average pressure ratio and peak pressure still provide useful data for seat. In our laboratory study we did observe some significant variations between change in centre of force and average contact area between different seating conditions, indicating some sensitivity of this method to postural changes at least, when used with child occupants. However the relationship between changes in pressure distribution and the association between anthropometrically predicted fit and comfort remains unclear.

We also saw significant correlations between pressure distribution measurements and our newly developed DAB score. The DAB rate proved to be the most sensitive measure of discomfort between the three different methods that we tested. Furthermore, this is a relatively easy method to implement and may prove a useful tool in naturalistic studies.

Osvalder et al. (2013) used video analysis in their naturalistic study to monitor the child’s behaviour and body language. Our work takes this further and employs video recordings and subsequent analysis to quantify the child behaviours in a repeatable form, the DAB rate. Forman et al. (2011) extracted frames from video recordings to evaluate seat belt fit and posture, whilst this is a good compromise for seat belt fit analysis we felt that we would lose too much data and we were using much shorter video recordings which made a full video analysis much more manageable.

**Limitations**

It should be noted that each of the three studies has its own limitations. Firstly, the online parental survey was distributed primarily through social media with the aid of a motoring services company, NRMA, and targeted parents who were currently using a child restraint. This delivery method leads to a sample bias towards those parents who are interested or concerned about child restraints and currently using a child restraint and consequently likely to be better informed about child restraints. It also targets parents with existing links to the motoring services organization. While the data extracted from the observation study came from a study that originally had a robust population referenced sample, the comfort variable used in this analysis had a lot of missing data (24.7%). Therefore weightings used may not accurately reflect the population, so results cannot be generalised to the wider population. Finally, the laboratory study was conducted as a pilot study to develop methods for later work. The sample size, particularly for some aspects of the analysis, was very small. Non-significant results may reflect low power, particularly those related to trials involving the ‘NFS’ condition. Further, the sample size was also biased towards younger children, and it may be fruitful to repeat this work with a larger sample and greater age range of children.

**Conclusion**

Our results suggest that whilst some parents report that child comfort is a contributor to their restraint transition decisions, in reality parent reported comfort is not associated with appropriate or inappropriate restraint use by their children. If comfort is important for optimal restraint, it is likely to be the real comfort of the child rather than that reported by the parent. The method we have developed for studying real comfort can be used to further understand this relationship.
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