USING CHILD AGE OR WEIGHT IN SELECTING TYPE OF IN-VEHICLE RESTRAINT: IMPLICATIONS FOR PROMOTION AND DESIGN

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ABSTRACT

A survey of motor vehicle child restraint use found around 28% of children under the age of six using weight-inappropriate restraints. Many parents did not know when a child was likely to outgrow a booster seat nor the weight of their child, but they did know the child’s age. Anthropometric data show that, if advice on restraint transition, given solely in terms of age (6 months, 4 years, 8 years) were followed in Australia, incorrect restraint selection would occur in 5% of children under the age of six. Further analysis suggests how rewriting the Standard could reduce this number.

We present an argument for placing age-based transitions at the heart of the strategy to improve child restraint compliance. This may be superior to one based on the child’s weight or other anthropometric measurement. Our argument may be summarized as follows:

1 Age-based rules for selecting child restraints are simple, require less information to be retained, and might be more natural criteria for parents. They might have a greater chance of being adopted as norms, and of encouraging good peer cues. Anthropometric rules, on the other hand, assume that parents know the current dimensions of their children and have the tools at their disposal to measure these dimensions.

2 The consequences of age-based promotion for the proportion of children in a restraint suitable for their weight can be estimated for alternative regulatory frameworks. We will report such Calculations below and show that this rate can potentially be very high.
The rate would be even higher if child restraint design standards were drafted with age-based transitions in mind. Age-based transitions imply restraint specifications (weight and height limits) that can be determined from anthropometric survey data.

Such standards would necessarily imply overlapping anthropometric ranges for the different types of restraint. However, we emphasize that these overlaps would exist to facilitate age-based transitions, not to feature in publicity advising on the correct selection of child restraints.

Under such a regime, promotion is driven by what information is readily usable by parents, and ceases being consequential to the standards-setting process.

In support of this argument we shall report a survey of restraint use among parents of pre-school and school aged children, and an analysis of the weights (or other dimensions) of children that provides a technique for estimating how well age-based transition could work. The remainder of this paper is divided into sections covering the survey and the anthropometric study. These are synthesized in a discussion of their implications for restraint promotions and standards setting.

SURVEY OF CHILD RESTRAINT SELECTION IN ADELAIDE, SOUTH AUSTRALIA

The aim of the survey was to estimate rates of child restraint use in the metropolitan area (population about one million) of Adelaide, South Australia. We also examined drivers’ knowledge of and attitudes to the use of child restraints. For more details than those noted below, see Edwards et al. (2006) and Anderson et al. (2006)

SURVEY POPULATION AND DATA COLLECTION – Thirty-one randomly selected sites (16 pre-schools or child parent centers, and 15 junior primary or primary schools) were visited in August 2004. We approached 427 drivers who were arriving to drop off a child or children. We selected vehicles that were carrying at least one child who we judged to be ten years of age or less. In total, 357 interviews were conducted, a response rate of 84%, covering the transportation of 586 children in the target age range.

The observations and interviews were undertaken on school days. Data were only collected during pupil-arrival (not departure) times, to minimize any situation in which drivers could alter their behavior as a consequence of being observed.

The survey covered driver knowledge about appropriate transitions from one restraint type to another. Photographs of restraint types were used to avoid any confusion about the types of restraint being referred to. The driver was asked about demographic and restraint details for themselves and all children being transported, the weight and height of the children, whether they were members of their own household, and
whether they normally transported them to school. Drivers were also asked questions related to their attitudes toward restraint use. Neither weight nor height was measured by the surveyors.

Restraint use of the children and the seatbelt use of the driver were noted as the vehicle approached, and the interview followed. If it was impossible to observe actual restraint use due to height of the vehicle or tinted windows, we relied on responses by the participants. Whether occupied or unoccupied, child restraints were directly observed in the vehicles. Drivers who declined participation were noted. Of the 586 children, the restraint type available to the child and its actual use was observed in 74% of cases, were reported in 16% of cases, and in the remaining 10% of cases, restraint type was noted but use of the restraint was reported (as the child had already removed it before the observation).

Approval for this study was granted by the University of Adelaide’s Human Research Ethics Committee, the Department of Education and Children’s Services (DECS) and the Catholic Education Office.

RESTRAINT USES BY AGE – We present the rates of restraint use according to the ages of the children. Observed restraint use by age and type of restraint is given in Table 1. Notable among these proportions is the majority of children over 5 years of age (6th year of life and beyond), who were using an adult belt for restraint.

Direct disaggregation of restraint use by weight was not possible: experience with conducting the survey, and subsequent examination of the data, led us to conclude that the responses from drivers about the weight and height of their children were too inaccurate to be of use. For 29% of the children being transported, drivers were unable to offer an estimate of their weight. Survey staff reported that many responses appeared to be ‘educated guesses’ rather than specific knowledge. Further, more reported weights than expected (around 20%) were outside the reference 5th and 95th percentile growth charts.

Does Table 1 imply that there is widespread early progression to unsuitable restraints, or is the spread of restraint types among age groups a reflection of the variation in children’s sizes at each age? To answer this, we made use of U.S. growth data from the Centers for Disease Control and Prevention (CDC) (Ogden et al., 2002) to estimate the proportions of a population (for whom the CDC data might apply) that fall within the weight ranges specified by the Australian Standard for child restraints (AS1754:2004). These weight ranges are 0-9 kg (infant restraint), 8-18 kg (forward facing child restraint), 14-26 kg (booster seat), and over 26 kg (too heavy for a child restraint). Figure 1 shows the results of our calculations.
Table 1 – Percentages of children in the survey within each age group using each method of restraint (N=586).

<table>
<thead>
<tr>
<th>Year of life</th>
<th>Infant capsule</th>
<th>Child seat</th>
<th>Booster seat</th>
<th>Adult belt</th>
<th>None</th>
<th>Count</th>
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<tr>
<td>1/2 of 1st</td>
<td>82</td>
<td>18</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>2/2 of 1st</td>
<td>0</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>2nd</td>
<td>0</td>
<td>84</td>
<td>5</td>
<td>11</td>
<td>0</td>
<td>19</td>
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<tr>
<td>3rd</td>
<td>0</td>
<td>68</td>
<td>29</td>
<td>3</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>4th</td>
<td>0</td>
<td>38</td>
<td>43</td>
<td>17</td>
<td>2</td>
<td>42</td>
</tr>
<tr>
<td>5th</td>
<td>0</td>
<td>9</td>
<td>54</td>
<td>35</td>
<td>2</td>
<td>162</td>
</tr>
<tr>
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<td>0</td>
<td>2</td>
<td>32</td>
<td>65</td>
<td>1</td>
<td>91</td>
</tr>
<tr>
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<td>2</td>
<td>20</td>
<td>75</td>
<td>3</td>
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<tr>
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<td>91</td>
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<td>304</td>
<td>10</td>
<td>586</td>
</tr>
</tbody>
</table>

Figure 1 – The percentages of children in each year of life who are within the weight specifications of each kind of child restraint. Based on pooled CDC growth tables (Ogden et al., 2002) and restraint specifications in AS1754:2004.
To construct Figure 1, we pooled month data from the CDC growth tables to calculate proportions within restraint specifications for six-month and twelve-month age groups, males and females combined. The figure shows that, in a population for whom the CDC growth tables apply, the weights of 84 percent of children in their second six months of life fall within the specifications of a forward facing child restraint. This rises to 99 and 100 percent in the second and third year of life, as the smallest children in the population of one- and two-year-olds grow heavier than 8 kg. Twelve percent of three-year-olds (i.e. in their fourth year of life) are too heavy for the forward facing child restraint, and the number remaining within the weight specification of the restraint steadily declines in the following years of life. After the fourth birthday, a greater proportion is within the weight specification of a booster seat. The other lines in Figure 1 may be read in a similar fashion.

Figure 1 suggests that a sizeable proportion of children become too large for a booster seat only in the seventh year of life. Yet, in our survey, sizeable proportions using an adult belt were noted for children in their fourth year of life and older. The observed proportions of children in their sixth and seventh years of life using an adult belt (65 and 75 percent) far exceed the proportions that had probably outgrown a booster (around 13 and 37 percent from Figure 1). Similar early progression can be inferred between FFCR and booster seats from Table 1 and Figure 1.

Elsewhere, we estimated the rates of weight-inappropriate restraint use at different ages in this sample without resorting to the reported weights of the children (Edwards et al., 2006; Anderson et al., 2006). To do this, assumptions were made about how weight may or may not affect choice of restraint at a given age; however the result was surprisingly insensitive to what was assumed. And we also needed to assume the CDC data applies to Australian children and our sample in particular. Given these assumptions, we estimated that among children in their 5th, 6th, 7th, 8th years of life, the percentage in a weight-inappropriate restraint was about 55%.

Thus it is clear from Table 1 that premature progression occurred in nearly every age group, and was most prevalent amongst children of late pre-school age and early primary school age.

KNOWLEDGE REGARDING BOOSTER-TO-ADULT BELT TRANSITION – We asked drivers at what age they thought it would be appropriate to cease the use of the different restraint types. Many drivers stated that size should be used, but very few of these drivers included reference to the specific dimensions, and often the specifics were irrelevant (e.g. when the child can see out of the window), although many know that height and/or weight might be important. Two-thirds of respondents indicated an age at which the adult belt might be suitable. The modal age-response was five years of age, and the average age-
response was about six years of age. About one-sixth of all respondents thought that children might outgrow a booster at seven or eight years of age. Thus the majority of respondents appeared not to realise that a booster seat might be suitable for many children beyond the age of five or six.

The responses of participants to questions relating to weight and height gave us pause: how suitable is a regime of advice based on anthropometric measurements given that many parents do not appear to have contemporary knowledge of the size of their children, and do not know when a child is likely to reach a size where a change in restraint type might be appropriate? Furthermore, Figure 1 suggests that the overlaps contained in AS1754:2004 might allow simpler advice based on age: a large majority of children would be accommodated in a suitable restraint if transitions were made between an infant carrier and a FFCR at six months of age, and to the booster at four year of age. Further, the booster would be suitable for a large majority until at least the seventh birthday. Age advice might be memorable to parents, and uses knowledge about the child that parents possess.

The following Section explores this concept and shows how both the transition ages and the specification of seats might be optimised to allow age-based guidelines to be used.

**CONSEQUENCES OF AGE-BASED RESTRAINT TRANSITIONS**

The survey reported above, and others (Apsler et al., 2003; Decina and Knoebel, 1997; Ebel et al., 2003; Ramsey et al., 2000; Charlton et al., 2006) show both that many children use a restraint that is less than ideal for them, and that drivers often do not know the weights of the children they are transporting. Many drivers assume that the booster is no longer useful by age five or six.

A contributing factor to this may be that a lot of information, some of it conflicting, is presented to parents. The South Australian leaflet, for example, deals with five types of restraint, and refers to some combination of lower and upper weight and a lower and upper ages for each of these, and mentions 16 numbers in all. The ages mentioned do not relate very well to restraint specifications. For example, it mentions the use of a booster seat until “about […] 6 years” (DTEI, 2000) despite very few children at 6 being too large for a booster. It is probably unreasonable to expect parents to remember all elements of such advice, and the volume of information may also obscure the essentials that would be worth remembering. As a result it is possible that it is the age guideline that is recalled, being something that is simple for parents to relate to their child.

There have been suggestions for consistent messages to promote correct restraint use (e.g. Winston and Durbin, 1999) but these have mostly relied on weight (probably the best method given the US child
restraint standards), and little attention has been given to whether age might be successfully used, and what the consequences of age-based promotion might be.

We wish to explore the possibility of advising parents in very simple terms, to present a form of advice that might lead to better compliance. For example: move your baby from a capsule to an FFCR at six months, move your child from an FFCR to a booster seat at four years, cease use of booster seat at eight years. Such an approach is not new (in fact it was the probable motivation for the overlapping weight ranges in the Australian Standard in the first place), but it has fallen from favour in an attempt at greater precision. However, to our knowledge, the consequences of promoting age-based transitions have not been evaluated previously. Notice that such advice would refer to sharp, definite, ages – not an age range. The fact that children vary in size will be accommodated, so we envisage, by the restraints being designed to be suitable for a child small for their age at the youngest age, and by a child large for their age at the oldest age. It might seem natural to quote an age range, or allow for some fuzziness about the age for commencing use of a restraint of a particular type, but we think this would be misguided – children being what they are, if there is any apparent ambiguity or flexibility, they are likely to demand to be graduated from one restraint to the next at too young an age.

The consequences of such a strategy will be discussed in two parts. Firstly, we will use anthropometric data to determine how many children would be in an unsuitable restraint if there were good compliance with a sharp age transition. In summary, the result will be that this number is small in the case of the present Australian Standard, which has overlaps in the weight ranges for successive types of restraint. Secondly, we will consider how the Standards for restraints could be modified in order to further reduce the number of children in an unsuitable restraint when sharp age transitions are used.

**WEIGHT-INAPPROPRIATE RESTRAINT USE CONSEQUENT ON AGE-BASED TRANSITIONS** – The starting point is the CDC dataset giving the distribution of weight amongst the population of male and female children at each month of life. For each potential age of transition, the number of children that would be in the wrong restraint (misclassified) according to their weight may be calculated. This will be made up from those under the transition age but too large for the pre-transition restraint, and those over the transition age but too small for the post-transition restraint. Any choice of a transition age will entail a trade-off between the two forms of misclassification, but an age can be chosen that minimises their sum. Consider the following:

A child progresses from one restraint (device A) to a larger restraint (device B) at age $y$.

The relevant design standard is written to ensure that A is satisfactory for children who have a dimensional value (e.g. weight) $u$
that is \( a \) or less.

Similarly, \( B \) is satisfactory for a child with a dimensional value \( u \) that is \( b \) or greater.

Note that \( b \) may be less than \( a \), providing some transitional overlap. However, the overlap may be non-existent \( (a = b) \) or possibly even negative \( (a < b) \).

The proportion of children with a dimensional value less than \( u \) within the age cohort \( i \) is \( F_i(u) \). A child in their \( i \)th month of life is in the one-month cohort \( i \). The transition between restraint types occurs at the end of month \( y \). (For example, a transition at 6 months of age occurs at the end of a child’s 6th month of life.)

If all children progress from the first restraint to the second at age \( y \), the number of children in an “incorrect” restraint, \( P \), is given by

\[
P = \sum_{i=0}^{y} 1 - F_i(a) + \sum_{i=y+1}^{\infty} F_i(b)
\]

The total number of children misclassified (in units of the number of children in a month cohort) is the sum of children that are aged less than \( y \) that are too large for \( A \), and those that are aged more than \( y \) that are too small for \( B \). Hence, \( P \) in Equation 1 describes the total misclassification, while the two sums refer to the number of children using \( A \) who are too large and the number of children using \( B \) who are too small. Incidentally, it is not necessary that the functions of \( a \) and \( b \) describe the distributions of the same dimension: one may describe weight, and the other seated height, for example. All that is required is knowledge of the distribution of the dimension at different ages.

It is possible to determine \( P \) and its two components for different choices of the transition age \( y \). The relative size of the two sums represents the trade-off that must be made if restraint transition is to be made at one exact age. Plotting one sum against the other shows how the trade-off is affected by the choice of transition age and indicates the age at which the total, \( P \), is minimised. The trade-off lines for two restraint transitions under the Australian Standard AS1754:2004 are shown in Figure 2. The optimum ages, where \( P \) is minimised, are 8 months (for infant restraint to FFCR) and 46 months (for FFCR to booster seat).

Commonly nominated transition ages are 6 months and 4 years (e.g. VicRoads, 2006). Figure 2 shows that the consequence of a transition at 6 months is 1.5 month cohorts in weight-inappropriate restraints, and the consequence of the transition at four years is 1.9 month cohorts in weight-inappropriate restraints; a total of 3.4 month cohorts, or about 5% of children under the age of six (=3.4/72).
Figure 2 – Trade-off graph. Lower line refers to the first transition (infant restraint to FFCR), and upper line to the second (FFCR to booster seat). Data labels refer to transition age in months. The total misclassification $P$ is noted for 6 month and 4th birthday transitions.

Figure 3 shows how the proportion in weight-inappropriate restraints varies with age: it is greatest around the transition ages. It should be noted that a large proportion of children misclassified are nearly within the weight range of the restraint type. For example, about three quarters of children too large for an FFCR (> 18 kg) in their 48th month of life weigh between 18 kg and 20 kg.

Figure 3 – The proportion of children misclassified to weight-inappropriate restraints by age under AS1754:2004, when transitions are at 6 months, 4 years, 8 years.

Of children past their sixth birthday, an increasing proportion is greater than 26 kg and hence heavier than the specified upper weight limit of the booster seat (26 kg is the 50th percentile weight of an eight year old child). The 26 kg limit is probably too low to accommodate many children of ages seven and eight.

STANDARD SETTING WITH AGE-BASED TRANSITIONS IN MIND – Above, we examined $P$ as a function of $y$ for values of $a$ and
from the Australian Standard, AS1754:2004. We now consider this from another perspective: given \( y \) (the transition age), how does \( P \) vary with \( a \) and \( b \)? In other words, if a transition age has been decided upon because it is memorable and convenient for parents, what effect does the Standard itself have? To examine this we can calculate \( P \) over a grid of potential values of \( a \) and \( b \). For a transition age of 48 months, Figure 4 shows contours of \( P \) as a function of \( a \) and \( b \). It can be seen that if, for example, the aim were to keep \( P \) to less than a single month cohort, then an overlap of weights of \( a = 20, b = 14 \) would accomplish this (or better still, \( a = 19, b = 13 \)). This can be compared with the current overlap in AS1754:2004 of \( a = 18, b = 14 \), for which \( P \) is approximately 2 one-month cohorts.

![Figure 4 – Contour plot of \( P \) (in units of one-month cohorts) as a function of \( a \) and \( b \) for a transition age of 48 months.](image)

We do not know exactly how difficult manufacturers would find it to comply with \( a \) being 19 or 20, rather than 18, but we have been advised that a small change such as this is feasible, as dynamic testing of forward facing child restraints is performed in Australia with a TNO P6 dummy weighing 22 kg (AS 1754:2004).

This brief illustration demonstrates that it is possible to begin the process of standards-setting with an transition age in mind, and that seat specifications can be worked out using this transition age and relevant anthropometric data.
DISCUSSION

Norms surrounding the use of child restraints are different from norms surrounding adult-belt use: Australia has a high rate of belt use, particularly in metropolitan areas. In this survey, only 1% of drivers were unrestrained (Edwards et al., 2006). Yet inappropriate child restraint selection was much higher.

If society publicises anthropometry-based rules for restraint selection, it is asking parents to make decisions that are more complex than the one that they must make for themselves, the latter being to simply use the restraint that is hanging at their side. Drivers are not asked to select and install their own restraints according to their weight and height. Yet we do expect a high level of knowledge when it comes to parents selecting restraints for their children. Our data suggested that some parents were inaccurate when asked to state the weights of their children, and more still were unable to provide an estimate. This has been observed before in child restraint surveys (Apsler et al., 2003) and also in pediatric emergency care (Leffler and Hayes, 1997; Harris et al., 1999). Furthermore, the ages reported in our survey regarding appropriate use of an adult belt were premature. Poor knowledge regarding the correct criteria for restraint selection has been noted before, even amongst health care professionals (Rothenstein et al., 2004).

The use of children’s age to mark their development is natural, and it is knowledge that parents have about their children at all times. It can be made suitable as a basis for selecting restraints too. It may be the most memorable form of advice on restraint use in any case. Yet, the recent trend in restraint promotion is to emphasise the child’s dimensions over the ages for which restraints are suited, even though, in Australia at least, we possess a design Standard that allows age to be used as a reliable guide to restraint selection (as we have shown above).

We have examined the feasibility of returning to a system of sound age-based guidelines where the responsibility for appropriate anthropometric fit lies with the relevant design standard, not with parents. The use of age-based advice was suggested by Apsler et al., (2003) although they expressed concern about the crudity of the approximation. However, in Australia, the consequences of using age to guide restraint selection would be that only about 5% of children under the age of six would be in a weight-inappropriate restraint, assuming good compliance with age guidelines. This proportion could be reduced by altering the design Standard. For example, amending the overlap of weights of FFCRs and booster seats from 14-18 kg to either 14-20 kg or 13-19 kg would halve the number of children misclassified by weight when making the transition from FFCR to booster on their fourth birthday. In the US, where no transitional weight range exists between restraint types, the use of age would not be as effective: the recommendation to make a transition between FFCR and booster at 40
pounds (18 kg) suggests an age transition at five years, but the resulting misclassification would be 10 one-month cohorts of children (Anderson and Hutchinson, 2007). In the light of the considerations discussed in the present paper, we feel that the authorities in the US who are responsible for writing Standards should examine whether an overlap should be introduced to allow age to be used to guide restraint selection.

A limitation on the results of our analysis is that we assume that Australian children are represented by the CDC data. Note though that CDC data is used in Australia to describe normal growth patterns and the application of the CDC data is recommended for all racial and ethnic groups (Department of Human Services, State Government of Victoria, 2006).

The argument of the present paper has been as follows.
1. There is a problem with child restraint use. It is mostly one of too early progressions to the next type of restraint. The evidence that there is a problem is threefold: observations of children in unsuitable restraints; parents lacking knowledge of their child’s weight; parents lacking knowledge about when transitions should occur.
2. Parents do know the child’s age. Thus this could potentially be used as the basis for restraint selection. It was at previous times the centre of promotional strategy.
3. Promote on the basis of an exact age, not a range. Parents easily comprehend this. It might be more acceptable to children. And it permits consequences for size-appropriate restraint use to be calculated, as we have shown.
4. The proportion of children misassigned by weight when assignment is by age can be calculated from $y, a, b$.
5. How bad is this strategy in the short term? Given $a$ and $b$, work out $P$ as a function of $y$.
6. Choose $y$ so as to minimise $P$.
7. For the longer term, given $y$, consider $P$ as a function of $a$ and $b$. Consider alternative Standards that reduce $P$ at the cost of greater overlap of $a$ and $b$. This approach is summarised schematically in Figure 5.

We have shown that the consequences of graduating children to their next child restraint on the basis of their age could reduce premature progression, and increase appropriate selection. However, the situation for the transition from booster seat to adult belt is not clear-cut. AS1754:2004 is not coordinated with any Australian Design Rule for seat belts (ADRs are the Australian vehicle safety standards), and there seem to be analogous problems in other jurisdictions. From age six, an increasing number of children are heavier than 26 kg; half of all children are heavier than 26 kg by their eighth birthday. As to the adult belt, some have suggested a minimum height of 145 cm (Klinich et al., 1994). As 145 cm corresponds roughly to eleven years of age, the consequence
would be that no restraint can be specified for a significant number of children between the ages of seven and twelve. The question then arises of whether 144 cm (say) really is too short for an adult belt to be satisfactory. If so, either a larger booster seat and/or amendments to seat belt regulations to ensure passengers of smaller dimensions can be accommodated are needed.

Figure 5 – Schematic representation of the argument for using age to guide restraint selection and the setting of design standards.

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