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Age-based selection of child restraints

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Abstract

Background. Advice to parents about child restraints is sometimes based on the child's weight, and can be complicated and confusing. Children tend to want to progress to the next restraint earlier rather than later, and the lack of clarity in advice to parents means that parents are more likely to move children up into the next type of restraint prematurely. Moreover, many parents do not know the weight of their child. This paper explores what might be the consequences of very simple advice, such as advising parents to change the type of restraint when children reach 6 months of age, 4 years, and 8 years. **Method**. The distribution of children's weights at different ages is used, along with the range of weights for which each restraint is appropriate, to work out the number of children who would be in an inappropriate restraint if progression were at particular ages. **Results.** If 6 months is the age of transition from an infant capsule to a forward-facing child restraint, the number of children misclassified is approximately two one-month cohorts. If 48 months is the age of transition from a forward-facing child restraint to a booster seat, the number of children misclassified is again approximately two one-month cohorts. **Conclusion**. These numbers of misclassifications are low (relative to what has been reported in surveys when weight-based advice was the norm). It has not been proven that there would indeed be good compliance with sharp ages of transition, but the simplicity and salience of age make it attractive as a criterion.

Keywords

Advice to parents, Age-based advice, Anthropometry of children, Child restraints, Weight-based advice

Introduction

Published surveys of in-vehicle child restraint use demonstrate that many children are in an inappropriate type of restraint [1-18]. In particular, children progress from a forward-facing child restraint to a booster seat at too small a size, and from a booster seat to an adult belt at too small a size. It seems likely that child restraints have been designed to be suitable for children within a certain weight range, not an age range, and until recently the standards were written that way. Thus it might seem natural for advice to parents to emphasise the child's weight as the criterion for selecting a type of restraint, but unfortunately there is a tendency for this to lead to advice becoming complicated and confusing. National child restraint laws that give greater prominence to age than to weight or height were introduced in Australia in 2010, and advice easily available to parents now reflects this. (The authors hope that the advice is perceived as being insistent that age is almost always a sufficient guide to the appropriate restraint, but at present it is not known if that is the case.)

In the United States, the American Academy of Pediatrics has a webpage that emphasises age [19], but the formal policy [20] is complicated and, for the broad age range 2 to 8 years, relies on weight and height. Since March 2011, National Highway Traffic Safety Administration (NHTSA) advice is age-focused, with an aim of preventing too-early progression [21]. Children tend to progress to the next restraint earlier rather than later, and the fact that this happens so frequently may be because of lack of clarity. Moreover, many parents do not know the weight of their child. This has also been found in child restraint surveys and in other contexts [3, 22, 23]. Very likely, there are some places where parents do know the heights and weights of their children, e.g., Japan, where there is thrice-yearly measurement by school nurses [24].

In Australia, the main types of in-vehicle child restraint are

- Infant capsule (rearward-facing infant restraint), known as type A1
- Forward-facing child restraint (FFCR), which has an integral harness - type B
- Booster seat (or booster cushion), which positions the child so that an adult seatbelt can be used safely. (Some booster seats have a back.) This is known as type E.

The 2004 edition of Australian Standard 1754 specified that these must respectively be suitable for children weighing 0-9 kg, 8-18 kg, and 14-26 kg. The 2010 edition [25] refers to 'the occupant of supine length up to 70 cm, and approximately 6 months of age', 'suitable for children approximately 6 months to 4 years of age', and 'suitable for children approximately 4 to 8 years of age whose height is less than 128cm'. Shoulder height markers [26, 27] are incorporated in the restraints and are intended to be directive as to their use and unsuitability, taking precedence over a child's age.

Elsewhere in the world, standards have been written differently, and not necessarily in ways that are easily comparable to Australian practice. (However, roughly speaking, the European Union employs weight ranges of 0-10 kg, 9-18 kg, and 15-25 kg, and the US employs weight ranges of 5-22 lb, 20-40 lb, and 40+ lb.) Historically, standards for child restraints have not been well coordinated with standards for adult seatbelts. It is tacitly assumed that children will graduate to an adult belt at 7 or 8 years; however, at this age, children are appreciably smaller than a 5th percentile adult female, which is the smallest size for which adult belts have to be satisfactory. The 2010 Australian Standard makes provision for a larger booster seat - type F - suitable for children up to 10 years. In practice, adult belts are used for many children as young as 4 years.

This paper explores what might be the consequences of very simple advice, such as 'change the type of restraint at 6 months, 4 years, and 8 years'. Obviously, children differ in size but design can, in principle, ensure that the restraint is suitable both for a small-for-age child at the youngest age and a large-for-age child at the oldest age. Given the distribution of children's weights at different ages and the range of weights for which each restraint is appropriate, the number of children who would be in an inappropriate restraint if progression were at particular ages is derived. For details of some aspects, see [28-30].

Method

Formulation of the key question

If children changed from one restraint to another at a specific age, how many would be in the wrong restraint?

Notice this question refers to a sharp transition age, with no mention of an age range or a weight range. Once this question is formulated, the information needed becomes clear: how many of the children younger than the transition age are too big for the first restraint? how many of the children older than the transition age are too small for the second restraint?

It is assumed that a particular type of restraint, such as an FFCR, is suitable for a particular range of weights of children, and unsuitable for other weights. It is also assumed that the distribution of children's weights at different ages is known. Specifically, the data from the Centers for Disease Control and Prevention in the United States [31] will be used. In this dataset, children are disaggregated by sex and one-month cohorts of age.

Notation concerning the restraint. A child changes from restraint A to a larger restraint B at age y. Restraint A is satisfactory for children whose weight u is a or less. Restraint B is satisfactory for a child whose weight u is b or greater.

Notation concerning the child. In the ith month of life, the child is in one-month cohort i. For this cohort, the proportion of children whose weight is less than u is $F_i(u)$. Change from restraint A to B occurs at the end of month y.

The function F. For fixed i and regarded as a function of u, F describes the variability of children at a given age; statisticians would call it the cumulative distribution function of weight. For fixed u, F decreases as a function of i: it reflects the growth of children with age by describing the falling proportion who are smaller than a given weight u.

Obtaining the answer

First, consider children younger than y. These are in restraint A. The proportion of cohort i who are too big for restraint A is $1\text{-}F_i(a)$. The relevant one-month cohorts are those up to and including y. The total number of children (in units of the number in a single month cohort) is $\sum_1 [1\text{-}F_i(a)]$, where $\sum_1$ denotes summation from $i = 1$ (or the previous transition) up to $i = y$.

Second, consider children older than y. These are in restraint B. The proportion of cohort i who are too small for restraint B is $F_i(b)$. The total number of children is $\sum_2 F_i(b)$, where $\sum_2$ denotes summation from $i = y+1$ up to the next transition.

The total number of children who are either younger than y but too big for A, or older than y but too small for B, is the sum of these, $\sum_1 [1\text{-}F_i(a)] + \sum_2 F_i(b)$. This total is a function of y, a, and b. Given these, and knowing the function $F_i(u)$ from [31] or some other source, the total may easily be worked out.

Choice of transition age

The quantities a and b are characteristic of the restraints available. Restraints can be redesigned, thus changing a and b. But the easier issue to tackle is what the age y should be.

As y increases, the number of children in restraint A who are actually too big for it increases, and the number in restraint B but actually too small for it decreases. Thus, there is a trade-off. It is possible to identify an age at which the sum is minimised.

Results

Transition from infant capsule to FFCR

The first step is to consider one particular choice of transition age. For the transition from infant capsule to FFCR, we took a to be 9 kg and b to be 8 kg (as in the 2004 version of Australian Standard 1754). Suppose that the transition age is $y = 6$ months.

- Boys, cohorts 1 to 4. Very few of these are too big for an infant capsule (i.e., exceed 9 kg).
- Boys, cohort 5. Some 2% of these exceed 9 kg.
- Boys, cohort 6. Some 8% of these exceed 9 kg.
- Boys, cohort 7. Some 43% are too small for an FFCR (i.e., are less than 8 kg).
- Boys, cohort 8. Some 25% are less than 8 kg.
- Boys, cohort 9. Some 13% are less than 8 kg.
- Boys, cohort 10. Some 6% are less than 8 kg.

And so on. Total misclassification is 103% of a one-month cohort of boys, made up of 10% who were too big for the infant capsule in the month or two before the transition, and 93% who were too small for the FFCR in the months after transitioning. Thus the total misclassification is around 9% of boys in their first year of life. A similar calculation can be made for girls.

The second step is to repeat the calculations for different choices of the transition age y (5 months, 7 months, 8 months, and so on).

There are two forms of visual presentation of the results that are quite helpful:

- Having calculated the total number of children (in units of one-month cohorts) who are too large for restraint A and the total number who are too small for restraint B, these numbers can be plotted one against the other, the different data points corresponding to different ages of transition, y. As y increases, so the first of these numbers increases and the second decreases: there is a trade-off between them. One wants to select the point on the graph that is closest to the origin, i.e., where the sum of these proportions is minimised. (If it is considered plausible that one type of misclassification is more serious than the other, one could consider a generalized sum is which one misclassification is given more importance than the other.)
- The sum can be plotted against transition age y. Naturally, this presupposes that one is comfortable with the idea that the two types of misclassification are equally important.

It turns out that the sum is minimised at 7 months for boys and 9 months for girls. The improvement from 6 months is not great enough to suggest changing from this, however (see Table 1).

Table 1. Numbers of children misclassified (in units of a one-month cohort), for various choices of the transition age from an infant capsule to an FFCR

Age of transition,	**Number of children misclassified**		
y (months)	Too big for the first restraint	Too small for the second restraint	Total
6	0.06	1.53	1.59
9	0.80	0.31	1.11
12	2.74	0.04	2.78

Table 2. Numbers of children misclassified (in units of a one-month cohort), for various choices of the transition age from FFCR to booster seat

Age of transition	Number of children misclassified		
y (months)	Too big for the first restraint	Too small for the second restraint	Total
36	0.11	4.09	4.20
48	1.22	0.70	1.92
60	5.45	0.04	5.49

Transition from FFCR to booster seat

The method of calculation for the transition from a forward-facing child restraint to a booster seat is similar to that described in the previous section. The authors took a to be 18 kg and b to be 14 kg (as in the 2004 version of AS 1754). Some results are in Table 2.

Transition from booster seat to adult belt

As mentioned earlier, there has been something of a disconnect between standards for child restraints and standards for adult seatbelts. This has become of concern to an increasing number of people in recent years, with it being suggested that an adult belt is only suitable once a child has reached 145 cm in height. Possible solutions include ensuring that adult belts are suitable for smaller people than the 5th percentile adult female (e.g., the average 7 year old), developing booster seats suitable for bigger children (e.g., the average 12 year old), or a compromise between these strategies.

To proceed with an analysis similar to those for earlier transitions, it would need to be known how unsatisfactory a standard booster seat is as a function of weight (over the range 26-40 kg, say), and also how unsatisfactory an adult belt is as a function of height (over the range 120-145 cm, say). However, this probably goes beyond what can be confidently supported.

Discussion

Effect of change to standards

The calculations above take a and b as known, and examine what effect y has. A complementary analysis would suppose that y has been fixed at some memorable and convenient age (such as 4 years) and determine how a and b affect the proportion of children misclassified. Comparison could be made of the present Australian, European, and US standards. Also, the effect of a change to a and/or b in the Australian context could be examined. See [29] for more on this.

If a exceeds b, there is overlap in the weight ranges for successive restraints. This is the case for some standards but not for others. Overlap will mean that a sharp age transition will lead to fewer misclassifications by weight. Thus having an FFCR suitable for up to 40 lb and a booster seat suitable only from 40 lb upward, as in the United States, is not well-suited to a sharp age transition. (However, this is a simplification of what the US system is, and may be exaggerating the unsuitability.)

Children vary more when they are older and bigger than when they are younger and smaller. Consequently, a given amount of overlap (e.g., 1 kg) is more useful at a younger age and smaller size. For the FFCR-to-booster transition in Australia, a is 18 kg and b is 14 kg. If $y = 48$ months were chosen as the transition age, the number of children misclassified would be about two one-month cohorts (Table 2). Keeping y the same, if a were 19 kg and b were 13 kg, the number of children misclassified would be reduced to about 0.8 one-month cohorts.

Once the calculation has been programmed, it is easy to compute the result for a grid of values of a and b. Then the results can be presented as, for example, a contour plot. The effect of specifying different a and b in the standard can then easily be seen.

Overview of different methods of illustration

It may be useful to list a number of ways of illustrating the calculations and their results that have been mentioned in preceding sections of this report, either implicitly or explictly [26-28].

- There is variability in the size of children at any given age. This is described by F, regarded as a function of u for fixed i.
- Children grow. This is described by F, regarded as a function of i for fixed u.
- As different transition ages are considered, so the proportions of children too big for restraint A and too small for restraint B vary in opposite directions. They can be plotted one against the other to demonstrate the trade-off.
- The two proportions of misclassifications can be added together and plotted against transition age.
- Greater overlap in the weight ranges for successive restraints (i.e., b exceeding a to a greater extent) will mean fewer misclassifications. This can be shown by, for example, a contour plot, the axes being a and b.

Alternative analyses

Earlier in this report, any type of restraint was said to be either unsuitable or suitable for a particular weight of child. The analysis could be generalised by devising and utilising a 'suitability function'. However, it is unlikely that anyone knows how the unsuitability of being (say) 2 kg too heavy for one restraint compares with the unsuitability of being 1 kg too light for another. Thus it has simply been assumed that if a restraint satisfies a standard, it is suitable for the weight range mentioned in the standard and unsuitable for other weights. (In effect, the analysis assumes that suitability is 1 for some range of weights, and 0 for other weights.)

Child weight has been assumed to be the important variable. Instead, the analysis could be adapted to height, or sitting height, or shoulder width, provided data on these measurements were available.

It might be said that the sizes of boys are different from those of girls, or that children from different ethnic backgrounds differ in size. However, differences are not sufficient for it to be worthwhile destroying the simplicity of advice in order to tailor it to a particular sex or ethnicity.

Concluding remarks

The implication of the way the central question was worded at the start is that advice to parents can be very simple and directive. For example, the advice might be simply to switch the child from one restraint to the next at the ages of 6 months, 4 years and 8 years – with no mention of weights, no mention of ranges and no mention of big-for-age or small-for-age. (It would be appropriate to include information about where to find expert assistance if the child is very unusually sized or shaped, or if there are closely-spaced children in the family.)

The standards describing successive restraints would need to have overlapping weight ranges. Responsibility for exercising expertise - accommodating the range of different sizes and shapes of children - is thus being placed with the designer and manufacturer of the restraint, not with the parent. That seems entirely appropriate.

Two possible weaknesses in the argument here need to be addressed. First, there might be concern that designers and manufacturers would find it very difficult if standards prescribed an overlap of weights. This concern can be confidently dismissed. There are small overlaps in the Australian and European standards at present, and informal discussions indicate the overlaps could be made a little greater without difficulty. Indeed, the dummy specified in the Australian standard for dynamic testing of the FFCR weighs 22 kg, even though the specification otherwise requires suitability for an 18 kg child. Second, the calculations assume compliance with the directions to graduate the child from one restraint to the next at a particular age. It could be said that it is not fair to compare results from a theory that assumes compliance with results observed in the real world where many parents and children are not complying with the advice available. A complete answer to this cannot be given, in the sense of proving that there would be compliance with firm directives. But it is plainly common sense that clear advice is easier to understand than complicated advice, that advice in terms of something that parents know (child's age) is better than advice in terms of something parents often do not know (child's weight), and that similar factors apply in respect of children's wishes and demands.

Should advice to parents be simplified and based on a child's age? The calculations have, at least, not demolished this strategy. Using weight as the criterion seems reasonable when the restraint itself is in one's mind. But if the problem lies with parents' and children's knowledge and their utilisation of that knowledge, the simplicity and salience of age increase its attraction as a criterion.

A strategy has been suggested here that puts the child's age - well known to adults and highly salient to children- at centre-stage. What has been done is

- demonstrate by reference to surveys that there is a problem at present
- formulate a question concerning what might happen if there were sharp ages of transition
- answer that question, finding that the proportion of misclassified children would be low with the present Australian Standards, and could be even lower if there were greater overlap in the weight ranges of different types of restraint
- informally check with experts on restraint design and manufacture that greater overlap is practicable.

What has not been done is to prove that there would indeed be good compliance with sharp ages of transition. Perhaps experts on the promotion of health advice to the general public are able to comment on the merits or otherwise of simple directives based on child age.

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Prevalence of mobile phone vs. child-related driver distraction in a sample of families with young children

by CM Rudin-Brown, S Koppel, B Clark and J Charlton

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Abstract

Motor vehicle crashes are the leading cause of accidental death in Australia, with substantial societal costs. Unlike crash test dummies, child vehicle passengers rarely sit still and their behaviour can often be unpredictable. Analysis of naturalistic driving video data from journeys undertaken by 12 families with young children revealed that children accounted for 12% of all potentially distracting activities, with drivers in this study interacting with rear seat child occupants 12 times as often as they did with mobile phones. Educational interventions to reduce driver distraction are discussed and the use of the naturalistic driving methodology is proposed to investigate the